University of Arkansas Cotton Breeding Program 2010 Progress Report

F.M. Bourland[1]

RESEARCH PROBLEM

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

BACKGROUND INFORMATION

Cotton breeding programs have existed at the University of Arkansas since the 1920s (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines, that are highly adapted to Arkansas environments and possess good host-plant resistance traits. Bourland (2010) provided the most recent update of the current program. The breeding program has primarily focused on conventional genotypes. The recent advent of glyphosate-resistant pigweed has renewed some interest in conventional cotton cultivars, but no highly adapted conventional cultivars have been available.

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

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

RESULTS

Breeding Lines

Each of the 30 sets of crosses made in 2010 was between conventional cotton lines. The primary focus of these crosses was to combine lines having specific morphological traits, enhanced yield components and improved fiber characteristics. In addition, crosses were made with lines that are resistant to imazamox. The 2010 breeding line effort also included 24 F_2 populations, 14 F_3 populations, 20 F_4 populations, 600 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 (661) were selected from the F_4 populations. After discarding individual plants for fiber traits, 552 progeny from the individual plant selections will be evaluated in 2011. Also, 192 superior F_5 progeny were advanced, and 72 F_6 advanced progeny were promoted to strain status.

Strain Evaluation

In 2010, 108 conventional and 18 transgenic strains (preliminary, new and advanced) were evaluated at multiple locations. Screening for host-plant resistance included evaluation for resistance to seed deterioration, bacterial blight, verticillium wilt, tarnished plant bug, and root knot nematode (in greenhouse). Work to improve yield stability by focusing on yield components and to improve fiber quality by reducing bract trichomes continued.

Two approaches for improving cotton yield stability are being used. The first approach focuses on yield components. Increased lint index and fiber density are being used as selection criteria to improve yield stability (Groves and Bourland, 2010). The second approach focuses on host-plant resistance, with specific emphasis on improving heat tolerance and resistance to tarnished plant bug. A method for evaluating heat tolerance is still being refined. Response of all entries in the Arkansas Cotton Variety Test, three Regional Strain Tests, and three Arkansas Strain Tests to tarnished plant bug was evaluated. Consistent response over years has been found.

Germplasm Releases

Germplasm releases are a major function of public breeding programs. The Arkansas Agricultural Experiment Station released six cotton germplasm lines in 2010. These lines included Arkot 0008, Arkot 0009, Arkot 0012, Arkot 0015a, Arkot 0015b, and Arkot 0016. Variation with respect to yield, adaptation, yield components, fiber properties, and specific morphological and host-plant resistance traits are represented in these lines. The lines provide new genetic material to public and private cotton breeders with documented adaptation to the Mid-south cotton region. In addition, one conventional variety, 'UA48' was released in 2010. UA48 exhibits an unparalleled combination of early maturity, high yielding ability and very high fiber quality.

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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Effects of Cultural Practices and Two Soilborne Pathogens on Root Morphology of Cotton in the Field

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RESEARCH PROBLEM

In many Arkansas cotton fields, factors such as inefficient tillage operations, extremely dry weather and traffic pressure may result in a compacted soil layer or hardpan. Soil compaction dramatically increases soil strength and can restrict cotton root penetration, leading to suppressed cotton height and lint yield (Taylor and Earl Burnett, 1963). This problem may be exacerbated by soilborne pathogens such as the root-knot nematode (*Meloidogyne incognita*) and the black root rot fungal pathogen (*Thielaviopsis basicola*). Studies relating the effects of cultural practices and these two soilborne pathogens on cotton root morphology especially in the field have not been reported.

BACKGROUND INFORMATION

Soil compaction tends to increase the soil bulk density (dry soil weight divided by soil volume) and soil penetration resistance. Under compacted soil conditions, aeration was inadequate, soil pore size was reduced and soil bulk density was increased (Veihmeyer and Hendrickson, 1948). Cotton (*Gossypium hirsutum* L.) plants grow poorly in soils with high strength (Taylor et al., 1964). Reduced plant height and yield associated with increased bulk density and penetration resistance limited root volume, resulting in insufficient water and nutrient supplies to the plant (Lowry et al., 1970). Root infection by the root-knot nematode leads to the formation of root galls which also reduces water and mineral absorption and transmission capability (Kirkpatrick, et al., 1995). Similarly, *T. basicola* infection causes cotton seedling disease by disturbing the cortical portion of root, resulting in necrosis and loss of seedling roots (Rothrock, 1992). An interaction between these two pathogens has also been reported on cotton (Walker et al., 1998). Appropriate cultural practices such as subsoiling could improve the soil physical condition and affect the distribution and survival of both root-knot nematodes

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and *T. basicola*. Recent advances in root topological methodology now enables us to investigate the quantitative aspect of root systems associated with cultural practice and soilborne pathogens under controlled environments and in the field.

RESEARCH DESCRIPTION

Field studies were conducted in a commercial cotton field at Leachville, Mississippi County, northeast Arkansas in 2009 and 2010. The predominant soil type is sandy loam (85-90% sand). Before planting, this field was selectively subsoiled using a paratill tillage implement at a depth about 12-15 inches in field-length strips. A portion of these strips along with an identical area adjacent to each strip that was not subsoiled were fumigated with Telone II (Dow AgroSciences LLC, Indianapolis, Ind.) using a Yetter Avenger to eliminate nematodes effects. Ninety-six plant samples were taken from four different areas in each treatment strip at about 40 and 145 days after planting and at harvest, respectively. Plant growth parameters including height, number of nodes, leaf area, and biomass as well as soil penetration resistance were measured in both growing seasons. Cotton growth mapping and seed cotton yield were collected in each treatment immediately prior to harvest. Cotton root systems were scanned and analyzed using WinRHIZO software (Regent Instruments Inc., Quebec, Canada) to 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]. SAS version 9.2 (SAS, Inc., Cary, N.C.) was utilized to analyze plant growth and root morphology and topology data. Means separation was conducted using Fisher's protected least significant difference (LSD) at $P \leq 0.05$. When interactions were significant ($P \leq 0.05$), mean values and LSD were calculated

RESULTS AND DISCUSSION

Telone II application increased root architecture parameters such as magnitude, altitude, exterior pathlength, and also increased root growth, resulting in larger surface areas, root volumes and longer root lengths (Fig. 1). Soil fumigation with Telone II also significantly reduced galling of *M. incognita* (Fig. 2). In most cases, subsoiling numerically increased root architecture parameters (magnitude, altitude, exterior pathlength) but response was not as great as with Telone II. The effects of Telone II and subsoiling were more evident during the early growing season (data not shown). In order to better understand the effects of cultural practices and these soilborne pathogens on cotton root systems, microplot studies are also currently underway.

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

PRACTICAL APPLICATION

A better understanding of the relationship between cultural practices and soil-borne pathogens could provide some practical disease management strategies in the field where soil compaction is found.

ACKNOWLEDGMENTS

Special thanks to Mr. Greg Lyerly who provided the research fields.

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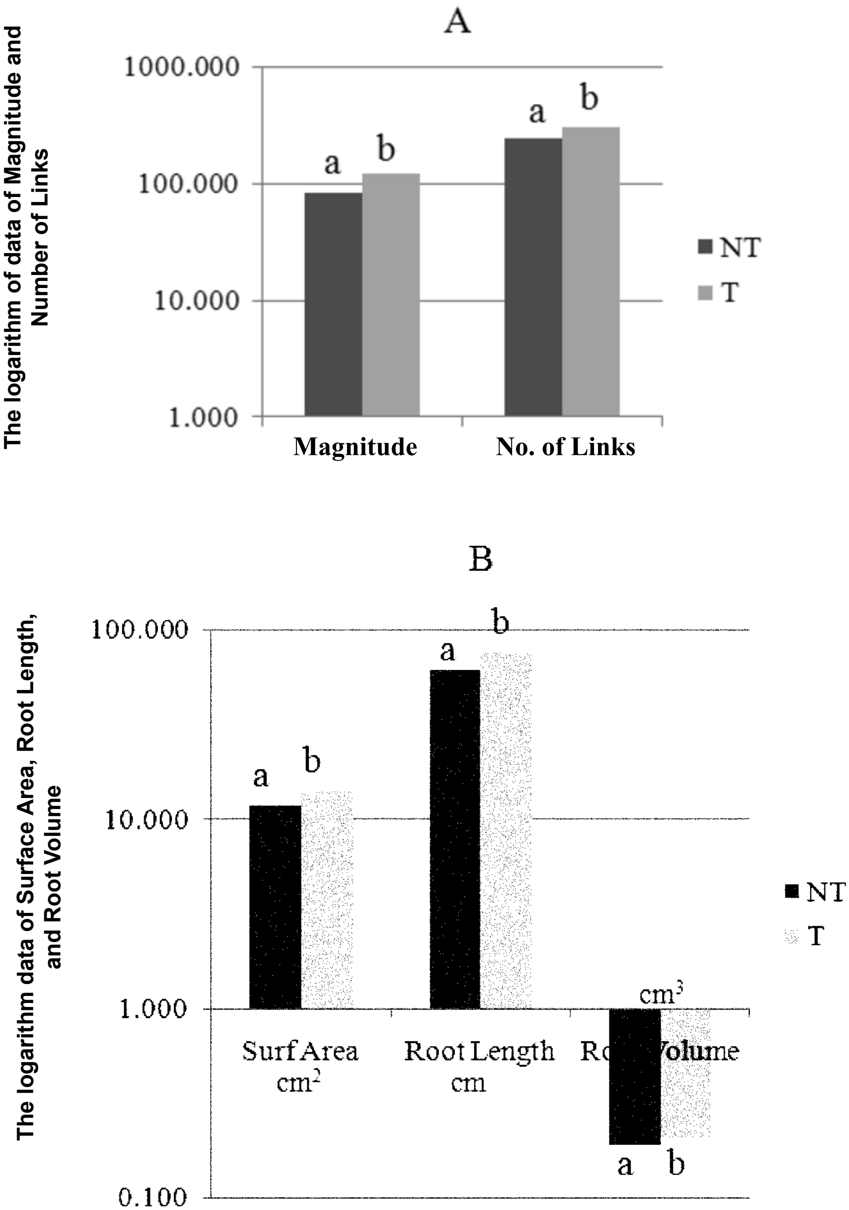

Fig. 1. Telone II effects on cotton root architecture (A) and root growth (B) in June 2009.

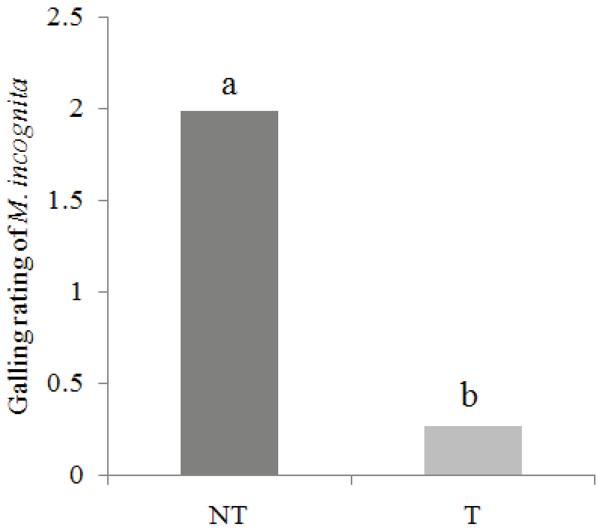

Fig. 2. Field strips fumigated with Telone II (T) or no Telone II effect (NT).

Has Bio-Tech Cotton Production Reduced Carbon Emissions? A Scan Level Cotton Carbon Life Cycle Assessment

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RESEARCH PROBLEM

Given increased consumer awareness and demand for products with lower greenhouse gas (GHG) emissions coupled with the increasing reality of a government policy to lower net GHG emissions, row crop producers in the United States may have to adjust to both consumer wants and government demands. There are two distinct ways to reduce GHG per pound of cotton produced: (1) increase yield per acre holding inputs constant, and (2) decrease inputs per acre while maintaining yield. Advances in cotton breeding have simultaneously captured the benefits of both of these attributes. While there are existing studies on GHG emissions from cotton production, there is a void in the literature on what the effect of the adoption of advanced seed technology has had on total GHG emissions per acre and GHG emissions per pound of cotton produced. The objective of this project was to determine the GHG emissions of cotton production across the range of seed technology available to producers from 1997 to 2008.

RESEARCH DESCRIPTION

Using a scan level Life Cycle Assessment (LCA) approach, this analysis assessed GHG emissions, in their carbon-equivalents, in cotton production. The analysis included emissions, direct and indirect, required to produce a pound of cotton from field preparation through harvest. Using actual application records, estimates were made of direct GHG emissions from combustion of diesel and N_2O emissions from N-fertilizer as well as indirect emissions from embedded carbon in agrochemical, fertilizer and fuel inputs.

Data are from approximately 100 fields in a northeast Arkansas farm with detailed production and yield records for over 7,000 acres of cotton in 1997, 2005 and 2008. Seed types were conventional in 1997, Roundup Ready® Bollgard® in 2005, and Roundup Ready® Flex Bollgard II® in 2008. Tillage was conventional

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in 1997. With adoption of herbicide tolerant cultivars conservation tillage practices were expanded across the farm, and by 2005 and 2008 most of the farm was either reduced till, ridge-till or no-till. Fuel use was estimated from the Mississippi State Budget Generator using the specific tractors and implements combined with the number of passes per acre per tractor and implement. Tractor efficiencies were standardized across years by using the same fuel estimates for the same operation. Fertilizer and agrochemical application rates were based upon the actual application of the active ingredient. Carbon equivalent emissions estimates were taken from engineering literature for each of the different inputs (Ecoinvent, 2009; Lal, 2004; US EPA, 2009; West and McBride, 2005). Average emissions per acre and per pound of lint were weighted by their acreage for three years. Yields were adjusted each year based upon the farm's yearly yield trend to account for higher or lower production than typical due to weather, pest pressure or other factors.

RESULTS AND DISCUSSION

Table 1 shows yield, GHG emissions, and agrichemical use for the three analyzed years. Results show that total GHG emissions per acre, in their carbon equivalents, decreased from an average of 536 lb/acre in 1997 to 464 lb/acre in 2008. These comparisons are based on differences in input usage for over 300 individual fields. One of the main drivers of this GHG reduction is the adoption of imbedded seed technology which required fewer trips across the field for pesticide applications and tillage. As input usage decreased over time, the observed yields increased. This can be attributed to many factors (efficiency, management practices, boll weevil eradication, etc.) as well as increased yield potential from seed technology. The combination of increased yield and decreased input usage resulted in a reduction in the amount of GHG emitted to produce a pound of lint. The carbon equivalents per pound of cotton produced reduced from 0.67 lb in 1997 to 0.34 in 2008.

PRACTICAL APPLICATION

Many agricultural commodities face increased consumer, industry, and government pressure to reduce GHG emissions. It just takes one of these three entities to gain enough momentum to bring about changes in agricultural production. This study analyzed technological change in imbedded seed technology from 1997 through 2008 for one farm in northeast Arkansas with over 100 fields of monoculture cotton. The carbon equivalents required to produce one pound of cotton decreased by 49% from 1997 to 2008. This decrease can be attributed to both an increase in yield and a decrease in inputs. Producers did not adopt new cotton cultivars based on carbon emissions; cultivar selection was based on yield potential and production input requirements, which is directly tied to carbon emissions. That is, producers' main motive for seed adoption is driven by profitability not

GHG levels. This study concludes that while profitability is the motive, a positive externality of this adoption of imbedded seed technology (Roundup Ready, Bollgard, etc.) has been a reduction in GHG emissions both per acre and per pound of cotton produced. While the results of this study are from only one farm, this farm is representative of the Mid-south in adoption of technology and representative of best management practices for northeast Arkansas cotton production.

ACKNOWLEDGMENTS

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Table 1. The average and standard deviation of yield, greenhouse gas emissions in their carbon equivalent (CE) per acre, CE per pound of cotton produced, and use of agricultural chemicals per acre.

	1997	2005	2008
Average Yield (lb/acre)	822	1251	1362
St. Dev of Yield (lb/acre)	*118*	*242*	*167*
Avg CD/acre	536	561	464
St. Dev CD/acre	*37*	*40*	*30*
Avg CD/lb of Cotton	0.67	0.47	0.34
St. Dev CE/lb of Cotton	0.10	0.09	0.05
Avg oz AgChemicals/acre	173	198	153
St Dev oz AgChemicals/acre	*97*	*12*	*7*

Cotton Yield Potential by Planting Date Based on Observational Data from the Arkansas Cotton Research Verification Program

T.W. Griffin[1], B. McClelland[2], and L.T. Barber[3]

INTRODUCTION

The Cotton Research Verification Program (CRVP) was created in 1980 and represents a public demonstration of the implementation of research-based recommendations in actual field-scale farming environments. Until recently, data from the University of Arkansas Cotton Research and Verification Program (CRVP) have only been subjected to analyses based upon the current year results. The CRVP has been conducted on 218 irrigated cotton fields in 33 cotton-producing counties in Arkansas. This study uses the entire dataset in a panel-context with cross-sectional and time-series attributes to evaluate long-term trends for use in a whole-farm decision making model. Observational data from 1986 to 2010 were analyzed to estimate the yield potential by planting date. The estimation results reveal the expected yield potential based on planting dates measured as weeks of year (WOY).

The specific objective of this study is to use cross-sectional and time-series data from the Cotton Research Verification Program to estimate yield potential by planting week. This study fits the authors' overall objective of estimating yield potential by planting:harvest date combination to include in a whole-farm mathematical programming model for use in a farm-level Extension context.

RESEARCH DESCRIPTION

Data for the study comes from the CRVP during the previous 25 years. The CRVP has been conducted on 218 commercial cotton fields from the cotton-producing counties in Arkansas. The CRVP collects a range of data from yields, inputs, soil types, machinery use, planted date, emergence date, to harvest date. This study used yields and planted dates to estimate yield potential.

Data and results are discussed in terms of the week number or week of year.

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Since we used a dataset with multiple years of data, we converted the date to a WOY so that it would be comparable across years and that the duration was long enough to include a meaningful number of observations. The same calendar date does not always fall in the same WOY. April 1 is in WOY14, 90% of the time and WOY13 otherwise. May 10 is in WOY19, 55% of the time and WOY20 otherwise. In 2011, April 1 occurs in WOY14, April 15 in WOY16, May 1 in WOY19, May 15 in WOY21 and June 1 in WOY23.

Figure 1 presents the frequency of CRVP planting dates throughout its 25 years. Since WOY19 was the most frequently planted for both Northeast and Southeast Arkansas, it was assigned to be the base time period for each year.

Normalizing Data

The data were normalized across weeks to obtain a more accurate relationship of the impact of planting date on yields. The BASE yield for year (t) is the average yield in the given year during WOY19. The equation is as follows:

$$BaseYLD_t = \frac{\sum_{i=19} YLD_{it}}{n}$$

To calculate normalized yield potential (NYP), each observation in year (t) was divided by the base yield ($BaseYLD_t$) calculated for year (t). The equation for this step is as follows:

$$NYP_i = \frac{YLD_{it}}{BaseYLD_t}$$

The resulting data are evaluated based on the number of first, second, third (and so on) ranks as well as average normalized yield potential for the whole panel dataset.

RESULTS

Southern Arkansas yields were at maximum potential at WOY17, the earliest planting date observed in the truncated database while northern Arkansas yield potential peaked in WOY18, the second WOY observed. As expected, yield potential for cotton planting was relatively more stable for southern Arkansas than northern Arkansas with respect to planting dates.

SUMMARY

The results indicate that yield potential is maximized in southern Arkansas when cotton is planted during WOY17 and a week later in northern Arkansas in WOY18; after which yield penalties are expected, although early planting may have greater risk of poor stands and replanting. The general trend is that earlier planting, beginning with WOY17 and WOY18, results in higher yields.

This six-week planting window generally provides producers sufficient time to complete planting operations assuming that their equipment complement and acreage allocation are appropriately matched to the local days suitable for fieldwork.

Implications for Farm Management

Knowledge of yield potential and alternatively yield penalty by planting date is paramount in machinery management. Combined with climatic data such as days suitable for fieldwork and price data of cotton and machinery, yield potential by planting dates is necessary information to determine the optimal planting equipment size and capacity in order to complete planting within a reasonable time period. Depending upon price ratios of cotton lint and planting equipment, profit maximizing farmers will be willing to accept differing levels of yield penalty.

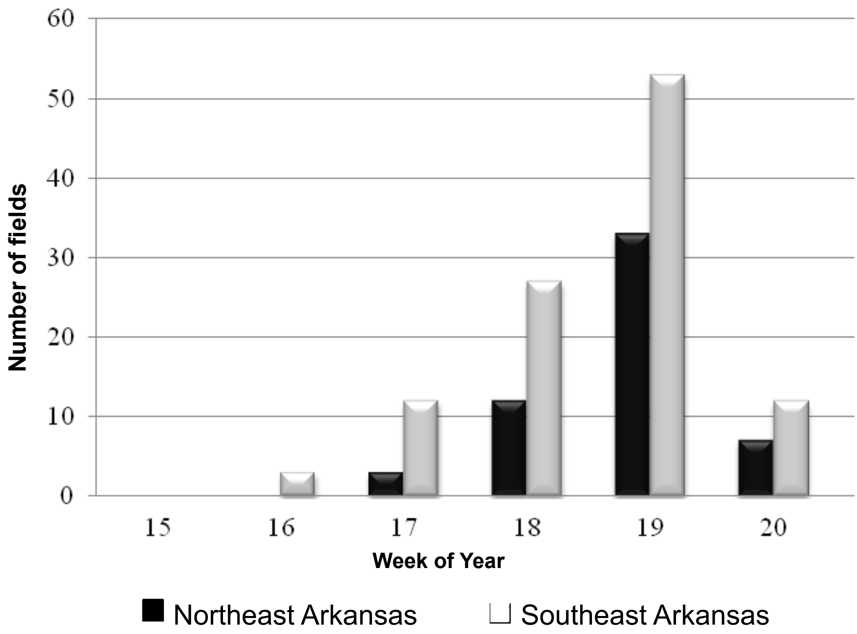

Fig. 1. Frequency of fields planted by week of year in the Cotton Research Verification Program.

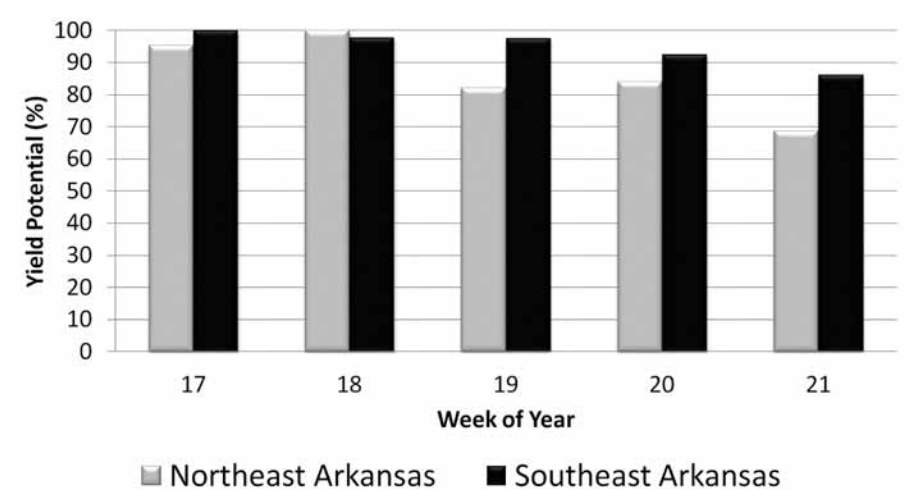

Fig. 2. Proportion of Top and Bottom Tiers.

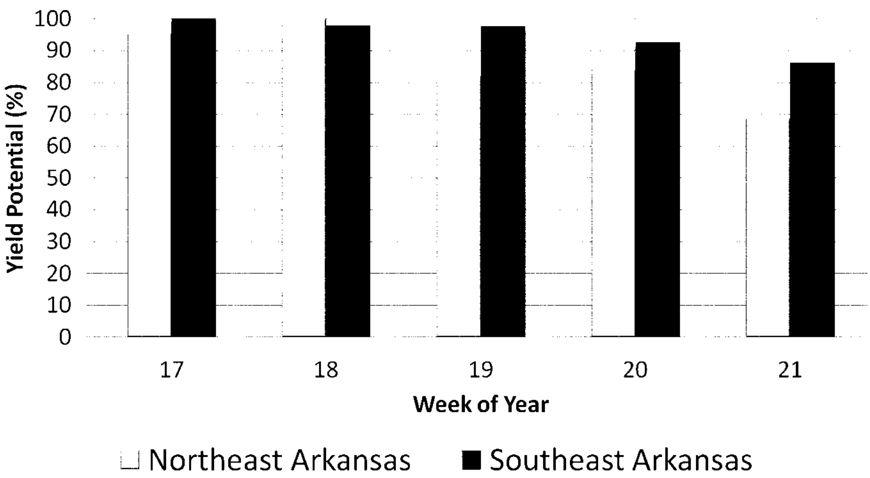

Fig. 3. Relative cotton lint yield by week of the year planted in Cotton Research Verification Program (sorted by n > 3).

The Effects of Urea Application with N-(n-Butyl) Thiophosphoric Triamide and Dicyandiaminde on the Growth and Yield of Cotton

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RESEARCH PROBLEM

The addition of urease and nitrification inhibitors to nitrogen (N) fertilizers has been recommended for increasing plant N use efficiency. Since N fertilization is expensive and crops are known to recover only 30-35% of the N fertilizer applied (Constable and Rochester, 1988), improved plant N use efficiency is a key factor in the pursuit for a sustainable agricultural system. Urease inhibitors delay hydrolysis of urea fertilizer diminishing ammonia volatilization losses and nitrification inhibitors hinder the conversion of ammonium to nitrate lowering N loss by leaching. Although, many studies have been done with urease and nitrification inhibitors in different crops; only limited research has been done with cotton, particularly on the effects related to plant growth.

BACKGROUND INFORMATION

Use of an urease inhibitor in urea fertilization has the objective of decreasing losses of N by NH_3 volatilization; which depending on fertilizer practices, soil type and environmental conditions can reach values close to 50% of the total N applied (Cai et al., 2002). The urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) has the advantage being highly efficient in inhibiting urease at low concentration in a wide variety of soils (Vittori et al., 1996).

On the other hand, use of a nitrification inhibitor is aimed at reducing N losses by nitrate leaching and denitrification. Nitrification inhibitors work by keeping the applied N in the ammoniacal form, which can be 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, that inhibits *nitrosomonas* bacteria stopping the oxidation of NH_4^+ to NO_2^- (Amberger, 1989). Inhibition of *nitrosomonas* is mediated by the reaction of the C-N group of

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DCD with sulfhydryl or heavy metal groups of the bacteria's respiratory enzymes (Amberger, 1989). The objective of this research was to evaluate the effect of side-dress application of urea with NBPT and DCD on growth and yield of cotton.

RESEARCH DESCRIPTION

A field study was conducted in 2009 and 2010 at the Lon Mann Cotton Branch Station at Marianna, Ark. in a Memphis silt loam (fine-silty, mixed, active, thermic Typic Hapludalfs) soil using the cotton (*Gossypium hirsutum* L.) cultivar ST4554B2RF. Except for N, which was applied according to treatments, the experiment was uniformly fertilized following preseason soil tests. Weed and insect control was performed according to state recommendations and 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. The full recommended N rate consisted of 125 kg N ha^{-1} and 94 kg N ha^{-1} was used for 75% of the recommended N rate treatment. Nitrogen treatment application was side-dressed split applied half when the cotyledons unfolded and half at the pinhead square stage. Treatments with urea plus NBPT and urea plus NBPT and DCD were applied using the commercial fertilizers Agrotain (Agrotain Int. LLC, St. Louis, Mo.) and Super U (Agrotain Int. LLC), respectively. A randomized complete block design with five replications was used. Statistical analysis was conducted using JMP (SAS Institute, Cary, N.C.) software and treatment differences were detected using LSD with a 0.05 alpha level.

Leaf chlorophyll content was measured using methods of Dillenburg et al. (1995) and of Knudson et al. (1977), on the oldest fully-expanded main-stem leaf collected at 4 weeks after the first flower stage. Growth analysis was collected at 4 weeks after first-flower and measurements included plant height, number of fruits, leaf area, and total plant dry matter. Seedcotton yield was recorded by a machine harvesting the two middle rows of each plot and lint yield was estimated by multiplying seedcotton yield by gin-turnout. A hand-picked one-meter length of row was used to determined cotton gin-turnout.

RESULTS AND DISCUSSION

There was a significant effect of the N treatments on plant height (Table 1), number of fruits (Table 1), leaf area (Table 1), and plant total dry matter (Table 1). The effects on the number of fruits and leaf area were similar, with significant differences observed only between the control and the N-fertilized treatments. Plant height was increased by all N treatments with the Urea-100% and Urea-75%+NBPT exhibiting the highest values. Measurement of total plant dry matter indicated highest values for the treatment Urea-100% and lowest values for the control treatment. Similar to plant height data, all N treatments increased total plant dry matter and the Urea-75%+NBPT was the only treatment among the 75% recommended N rate treatments, that did not have a decrease in total dry matter compared to the Urea-100% treatment.

All N treatments significantly increased leaf chlorophyll (Fig. 1), with the treatments Urea-100% and Urea-75%+NBPT having the highest values and the control treatment the lowest. Comparison among the N fertilized treatments indicated significant differences between Urea-100% and Urea-75%, Urea-75% and Urea-75%+NBPT, and between Urea-75%+NBPT and Urea-75%+NBPT +DCD. No statistical differences were observed between the treatments Urea-100% with Urea75%+NBPT+DCD, and Urea-75% with Urea75%+NBPT+DCD.

There was a significant treatment effect on seedcotton yield (data not shown) and fiber yield (Fig. 2). The control treatment exhibited the lowest yield followed by Ure-75% and Urea-75%+NBPT+DCD (Fig. 2). The highest yield was experienced by the treatments Urea (100%) and Urea-75%+NBPT, all of which were significantly different than the control and Urea 75% treatments. No statistical differences were observed between the treatments Urea-100% and Urea-75%+NBPT, Urea-100% and Urea-75%+NBPT+DCD, Urea-75%+NBPT and Urea-75%+NBPT +DCD and between Urea-75% and Urea-75%+NBPT+DCD.

In summary, the results of this research indicated that addition of NBPT to urea in cotton had a significant effect on increasing, leaf chlorophyll, plant total dry matter, and yield. In these cases, the treatment Urea-75%+NBPT had significantly higher values than the Urea-75% treatment. On the other hand, based on the results that the treatment Urea-75%+NBPT+DCD was not significantly different than the Urea-75% treatment, the addition of DCD negatively affected the performance of NBPT. In this experiment, since no differences were observed between the treatments Urea-100% and Urea-75%+NBPT, we are able to conclude that addition of NBPT to urea fertilizer resulted in a 25% decrease in losses of N by NH_3volatilization.

PRACTICAL APPLICATION

In conclusion, N fertilization with urea and 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 the potential to decrease the rate of urea application without compromising yield.

ACKNOWLEDGMENTS

The authors thank Cotton Incorporated and Agrotain International LLC for partial funding of this research.

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Table 1. Effect of N treatments on plant height, number of cotton fruits, leaf area, and total plant dry matter.

Treatments	Plant Height	No. of Fruits	Leaf Area	Plant Total DM
	cm	#	cm^{-2}	g
Control	41.33 c*	43.90 b	7960.00 b	255.82 d
Urea (100%)	66.58 a	104.90 a	18844.61 a	546.45 a
Urea (75%)	59.65 b	90.44 a	17280.20 a	456.67 c
Urea(75%)+NBPT	65.15ab	100.44 a	19476.83 a	547.80 ab
Urea(75%)+NBPT+DCD	60.32 b	99.10 a	17326.61 a	487.87 bc
P- Value	< 0.0001	< 0.0001	< 0.0001	< 0.0001

*Numbers within each column sharing a common letter are ot significantly different ($P \leq 0.05$)

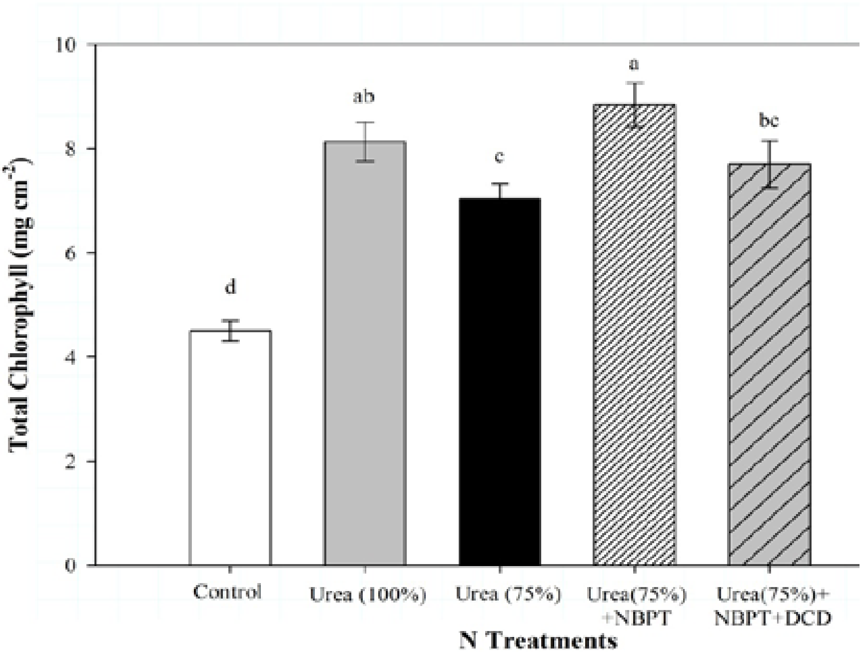

Fig. 1. Effect of N treatments on leaf total chlorophyll. Columns sharing a common letter are not statistically different.

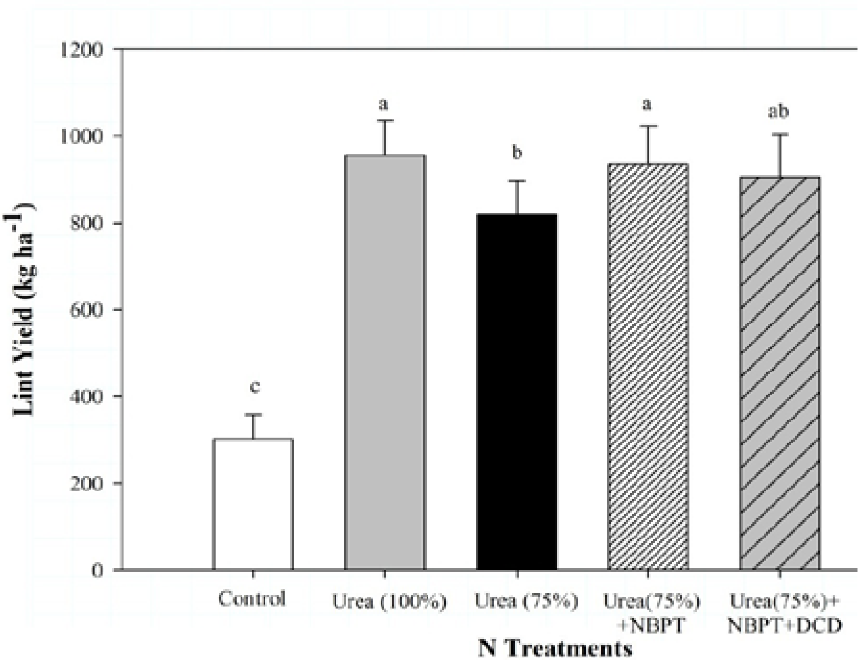

Fig. 2. Effect of cultivar on superoxide dismutase (SOD; A) and glutathione reductase (GR; B) activity of G. hirsutum grown under 30/20 °C day/night temperature regime. All values are means ± standard error (n = 6). Columns sharing a common letter are not significantly different (Student's *t*-test;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

Effect of Salinity on Cotton Nitrogen Uptake and Assimilation of Urea Applied with N-(n-Butyl) Thiophosphoric Triamide and Dicyandiaminde

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

RESEARCH PROBLEM

Salinity is an abiotic stress factor that can cause significant crop yield losses. Nitrogen (N) is an essential plant element that is usually limited in most agricultural soils. Recently, incorporation of additives such as N-(n-butyl) Thiophosphoric triamide (NBPT) and Dicyandiaminde (DCD) into N fertilizers has been done with the purpose of increasing N use efficiency of crops. To our knowledge little is known about the physiology of N metabolism in cotton plants grown in soils with condition of salinity stress. Hydroponic experiments with cotton indicated that high levels of salinity reduced N uptake and medium salinity increased tissue N concentrations (Pessarakli and Tucker, 1985). The toxic effect of DCD in cotton under high salinity has been reported (Reeves and Touchton, 1989), but studies on the performance of NBPT under salinity conditions are lacking.

BACKGROUND INFORMATION

Salinity is a common occurrence in irrigated areas with arid or semi-arid climates (Letey, 1984). In Arkansas, many counties in the Mississippi Delta have experienced soil salinity, mainly caused by poor irrigation water quality (Tacker, 2003). Cotton is classified as a medium salt-tolerant species with a salinity threshold level of 7.7 $dS\ m^{-1}$ (Maas and Hoffman, 1977). However cultivation of cotton in high salinity soils is known to cause significant reductions in growth and lint yield (Ashraf et al., 2002).

Nitrogen is an essential plant element that is usually limited in most agricultural soils. It is reported that cotton is able to recover only 30% of the total N applied (Constable and Rochester, 1988). NBPT (N-(n-butyl) thiophosphoric triamide) is a urease inhibitor compound that works by delaying hydrolyzes of urea fertilizer, resulting in decreased losses of N by ammonia volatilization. DCD (Dicyandia-

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minde) is a nitrification inhibitor that hinders the conversion of ammonium to nitrate lowering N loss by leaching and denitrification.

The objectives of this study were to evaluate the effect of salinity and N on the growth and stress physiology of cotton and to investigate if toxic effects of NBPT and DCD would occur in salt-stressed cotton plants.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum* L.) cultivar ST4554 B2RF was grown in a large walk-in growth chamber, with day/night temperatures of 30/20 ^{o}C, relative humidity of 70% and 14 h photoperiods at 500 µmol m-2 s-1 of photosynthetically active radiation. Two plants per 1.5-liter pot were grown in soil (Memphis silt loam) from a typical cotton growing area in Marianna, Ark. The study was repeated twice in the Altheimer Laboratory, Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. The experiment was arranged in a completely randomized design with two factors: salinity levels and N treatments.

Five N treatments were used in the study: (T1) untreated control, (T2) full recommended N rate with urea, (T3) 80% of the recommended N rate with urea, (T4) 80% of the recommended N rate with urea plus NBPT and, (T5) 80% of the recommended N rate with urea plus NBPT and DCD. The full recommended N rate consisted of 62.5 kg ha^{-1}, and for the 80% of recommended N rate 50 kg ha^{-1} of N was used. Treatments with urea plus NBPT and urea plus NBPT and DCD were applied using the commercial fertilizers Agrotain (Agrotain Int. LLC, St. Louis, Mo.) and Super U (Agrotain Int. LLC), respectively. Nitrogen fertilization was side-dressed applied at 3 days after the unfolded cotyledons stage and incorporated 7 days later with ample water (12mm). Three levels of salinity treatment were used for this experiment, low (0.45 dS m^{-1}), medium (8 dS m^{-1}), and high (16 dS m^{-1}). The salinity levels were achieved using sodium chloride dissolved in DI water and added to each pot according to the treatments when cotton seedlings exhibited unfolded cotyledons.

At the pinhead-square stage, stomatal conductance was measured and growth analysis was conducted separately for each plant. One plant was taken and immediately stored at -80 ^{o}C for subsequent protein, glutathione reductase (GR), and superoxide dismutase (SOD) determination, and the second plant was oven dried for N uptake determination.

RESULTS AND DISCUSSION

Data of N uptake showed significant interaction effect between salinity and N treatment parameters (P = 0.0473). At low salinity level (Fig.1), N treatment resulted in a significant decrease in N uptake in the control treatment compared to all N fertilized treatments (P < 0.0001). In addition, the Urea-80% also resulted in a significant decrease in N uptake compared to Urea-100%, Urea-80%+NBPT, and Urea-80%+NBPT+DCD. For example, Urea-80%+NBPT had an increase of 22% in N uptake compared to Urea-80%. No differences were observed between Urea-100%, Urea-80%+NBPT, and Urea-80%+NBPT+DCD treatments. Under medium salinity (Fig.1), significant differences were only observed between the control treatment and all N fertilized treatments. The effect of N treatment on high salinity (Fig.1) condition resulted in no significant differences among the treatments. The overall effect of increased salinity was to decrease N uptake.

Stomatal conductance data showed a significant salinity (Fig. 2; $P < 0.0001$) and N treatment (Fig. 3; $P = 0.0410$) effect, but no significant interaction effect. Overall results showed that stomatal conductance decreased with increased salinity level. Significant differences were observed between the salinity levels low and medium, and between low and high. Comparative analysis of the N treatment effect (Fig. 3), indicated that stomatal conductance was decreased 83% and 90% in the untreated control treatment compared to Urea-100% and Urea-80%+NBPT respectively. Values of stomatal conductance of the treatments Urea-80% and Urea-80%+NBPT+DCD were not significantly different than the rest of the N fertilized treatments.

The data of protein, GR, and SOD did not have any significant interaction effect, only a significant salinity main effect was observed for all parameters (Table 1). The protein results showed no differences between low and medium ($P = 0.2329$) salinity, and between medium and high ($P = 0.1893$) salinity levels. However protein values from high salinity were significantly ($P = 0.0147$) lower than values from low salinity. The magnitude of the decrease in protein of high salinity compared to low salinity was 15%. Measurements of GR among salinity treatments showed that low salinity exhibited significantly lower levels of GR compared to medium ($P = 0.0174$) and high ($P = 0.0002$) salinity. The SOD measurements indicated only a significant difference between low and high salinity levels ($P = 0.0008$). Plants grown under high salinity level exhibited a 52% increase in leaf SOD activity compared to plants from low salinity.

In summary high salinity resulted in decreases of stomatal conductance and leaf protein content, and increased stress (higher GR and SOD). Cotton is known to be tolerant to salinity; however our study showed that under a medium level of salinity cotton showed a negative effect on stomatal conductance and GR. The N uptake data showed that addition of NBPT to urea is beneficial; however, due to a decrease in N uptake this effect was not observed with increasing levels of salinity. No benefit of addition of DCD was observed. In addition, no NBPT and/or DCD phytotoxicity was observed in any of the parameters measured in the salinity levels.

PRACTICAL APPLICATION

The addition of NBPT to urea fertilizer resulted in improved cotton N uptake. However, use of NBPT should not be recommended in cases of salinity occurrence. Our data of stomatal conductance and GR indicated that cotton can be negatively affected by medium (8 dS m^{-1}) levels of salinity.

ACKNOWLEDGMENT

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Table 1. Effect of salinity on leaf protein content, and on leaf activity of glutathione reductase (GR) and superoxide dismutase (SOD).

Salinity (dSm^{-1})	Protein (mg g FW^{-1})	GR (units g FW^{-1})	SOD (units g FW^{-1})
Low (0.45 dS m^{-1})	13.74* ± 0.59 a**	17.87 ± 3.62 b	400.02 ± 52.28 b
Medium (8 dS m^{-1})	12.91 ± 0.38 ab	29.78 ± 4.24 a	529.94 ± 61.09 ab
High (16 dS m^{-1})	11.99 ± 0.47 b	37.46 ± 1.93 a	607.12 ± 47.39 a
P-value	0.0499	0.0008	0.0444

*Numbers within each column sharing a common letter are not significantly different ($P \leq 0.05$).

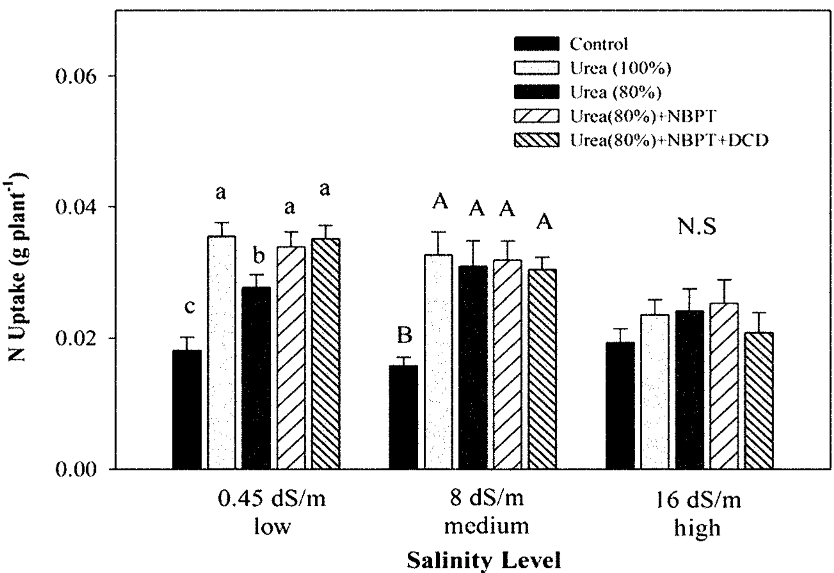

Fig. 1. Effect of salinity and N treatments on cotton N uptake. Columns within each salinity level sharing a common letter are not statistically different ($P \leq 0.05$).

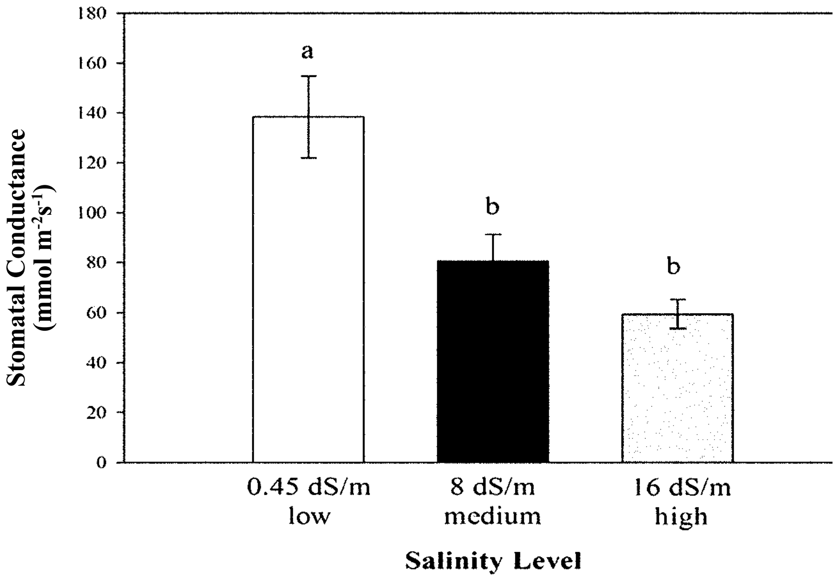

Fig. 2. Effect of salinity levels on stomatal conductance. Columns sharing a common letter are not statistically different ($P \leq 0.05$).

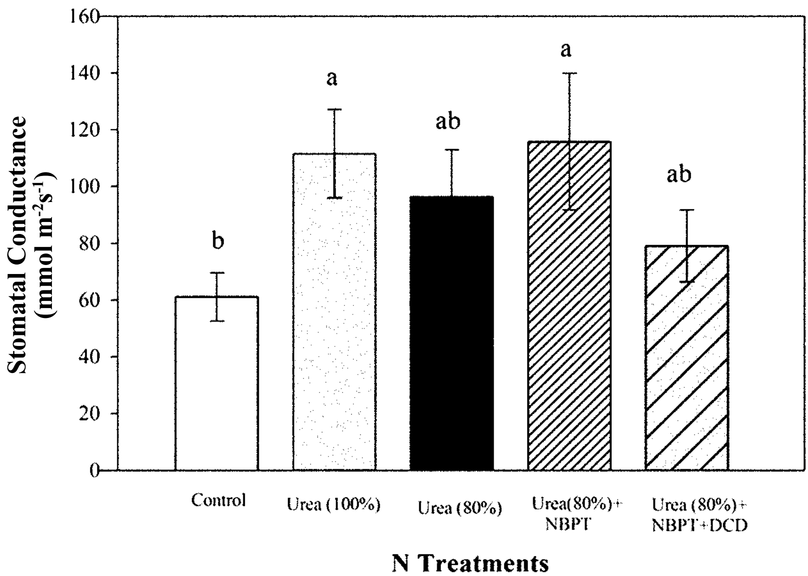

Fig. 3. Effect of N treatments on stomatal conductance. Columns sharing a common letter are not statistically different ($P \leq 0.05$).

Effect of Foliar Application of Urea with N-(n-Butyl) Thiophosphoric Triamide on the Physiology and Yield of Cotton

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

RESEARCH PROBLEM

Foliar application of nitrogen (N) is used to supplement soil N application in order to meet high N requirements of crops (Oosterhuis, 1999). Urea is the most common foliar N source in cotton, due to its relatively low toxicity, quick absorption, and low cost (Maples and Baker, 1993; McConnell et al., 1998, Oosterhuis and Bondada, 2001). However in the literature, reports of yield increments with foliar urea application are not consistent and it is not clear whether the occurrence of phytotoxicity from foliar urea application is caused by toxic accumulation of urea or ammonia.

BACKGROUND INFORMATION

Foliar application of N has the advantages of low cost and rapid plant response, and the disadvantages of possible foliar burn, incompatibility problems with other chemicals and limitations on the amount of nutrient that can be applied (Oosterhuis, 1999). Maples and Baker (1993) conducted a number of experiments with supplemental foliar N applications and reported that the results varied according to the location, due mainly to differences in soil characteristics. The studies of Oosterhuis and Bondada (2001) showed that the results of foliar fertilization in cotton may vary depending on the size of boll load, such that cotton plants with high boll loads exhibited significantly higher cotton yields in treatments that received foliar N.

Once foliar applied urea is absorbed by the leaves, it is converted to ammonia, by the enzyme urease (Sirko and Brodzik, 2000), and ammonia is incorporated into glutamate by the enzyme glutamine synthetase (Blevins, 1989). The use of an urease inhibitor with foliar urea application can be an effective method to help study the fate of urea in cotton leaves. The compound N-(n-butyl) thiophosphoric triamide (NBPT) is the urease inhibitor most commonly used in agriculture. The

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objectives of this research were to study foliar urea assimilation in cotton and to test the effect of the urease inhibitor N-butyl thiophosphoric triamide (NBPT) in cotton foliar urea application.

RESEARCH DESCRIPTION

The study consisted of a growth chamber and a field experiment. In the growth chamber study, cotton (*Gossypium hirsutum* L.) cultivar ST4554B2RF was planted in 1.5-liter pots filled with soil from a representative cotton growing area in Marianna, Ark. (Memphis silt loam-fine-silty, mixed, active, thermic Typic Hapludalfs). The growth chamber was set with day/night temperatures of 30/20^{o}C, relative humidity of 70% and 14 h photoperiods. No soil N fertilization was applied in this experiment and pots were watered daily only with double deionized water. The treatments consisted of: (1) untreated control with no foliar urea application; (2) foliar urea application; (3) foliar urea applications with NBPT, and (4) foliar NBPT without urea. Each foliar urea application was calculated to supply 11.2 kg of N per hectare. The treatment with urea plus NBPT was applied using the commercial fertilizer Agrotain (Agrotain Int. LLC, St. Louis, Mo.). Leaf samples were collected 2 and 24 h after treatment application for urea and urease determination.

The field experiment was conducted in 2009 and 2010 at the University of Arkansas Lon Mann Cotton Branch Station at Marianna, Ark. The experiment was uniformly fertilized following preseason soil tests and state recommended rates, except for N, which was applied according to the treatments. Treatments consisted of: (A) full recommended N soil rate with no foliar N application, (B) 75% of recommended N soil rate with no foliar application, (C) 75% of recommended N soil rate with two foliar urea applications (at first flower and two weeks later), and (D) 75% of recommended N soil rate with two foliar urea plus NBPT applications (at first flower and two weeks later). Each foliar urea application was calculated to supply 11.2 kg of N per hectare. The treatment with urea plus NBPT was applied using the commercial fertilizer Agrotain. The experimental unit consisted of a plot with 4 rows spaced 0.96 m apart and15 m in length. Measurement of seedcotton yield was collected from the two middle rows using a mechanical harvester.

RESULTS AND DISCUSSION

Growth Chamber Study

There was no significant treatment effect in the measurements made 2 h after foliar application (data no shown). However, at 24 h after foliar application (Fig. 1) there was a significant treatment effect, in which the foliar urea treatment exhibited significantly higher urease activity values than the rest of the treatments. Furthermore, the Foliar Urea+NBPT treatment did not exhibit increased urease activity; its values were not significantly different than the control treatment.

Leaf urea content exhibited a decrease 2 h after foliar application (data not shown) in the Foliar NBPT treatment. At the 24 h after foliar application (Fig. 2), leaf urea content was significantly increased by Foliar Urea and Foliar Urea+NBPT compared to the control.

Field Study

In 2009 (Fig. 3) there was a significant effect with the treatments 100% N Soil–No Foliar and 75% N Soil–Urea+NBPT-Foliar exhibiting the highest yields. A significant difference was observed between the treatments 75% N Soil–Urea Foliar and 75% N Soil–Urea+NBPT-Foliar. In 2010 (data not shown), the treatment effect on seedcotton yield was not significant. Differences were expected between the treatments 100% N Soil–No Foliar and 75% N Soil–No Urea Foliar, but the comparison was not significant at $P = 0.05$.

In summary, the growth chamber study showed that the addition of NBPT to foliar urea application decreased urease activity and it showed a trend for increasing leaf urea content. In the field study, seedcotton yield improvements were observed with addition of NBPT to foliar urea in 2009 but not in 2010. If the addition of NBPT to foliar urea has an effect on cotton yield a third field experiment will be conducted in 2011.

PRACTICAL APPLICATION

The addition of NBPT to foliar urea fertilizer was effective in inhibiting cotton leaf urease; however, in this study, we were not able to confirm the positive effect of NBPT on cotton yields. On the other hand, no negative effect of NBPT addition to foliar urea was observed, thus the use of Agrotain (urea+NBPT) can be safely used as a source of foliar N in cotton.

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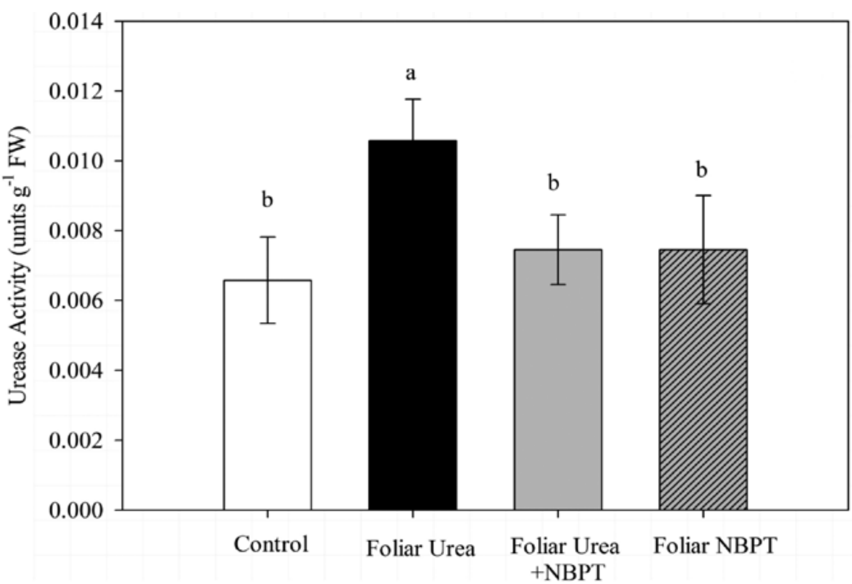

Fig. 1. Effect of foliar treatments on leaf urease activity in cotton grown in growth room conditions, measured at 24 h after treatment application.

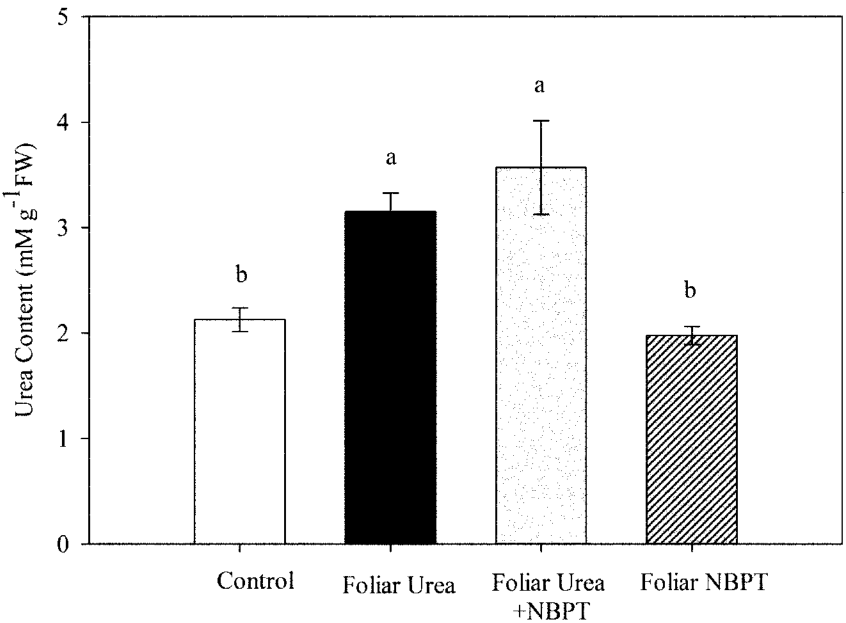

Fig. 2. Effect of foliar treatments on leaf urea content in cotton grown in growth room condition, measured at 24 h (B) after treatment application.

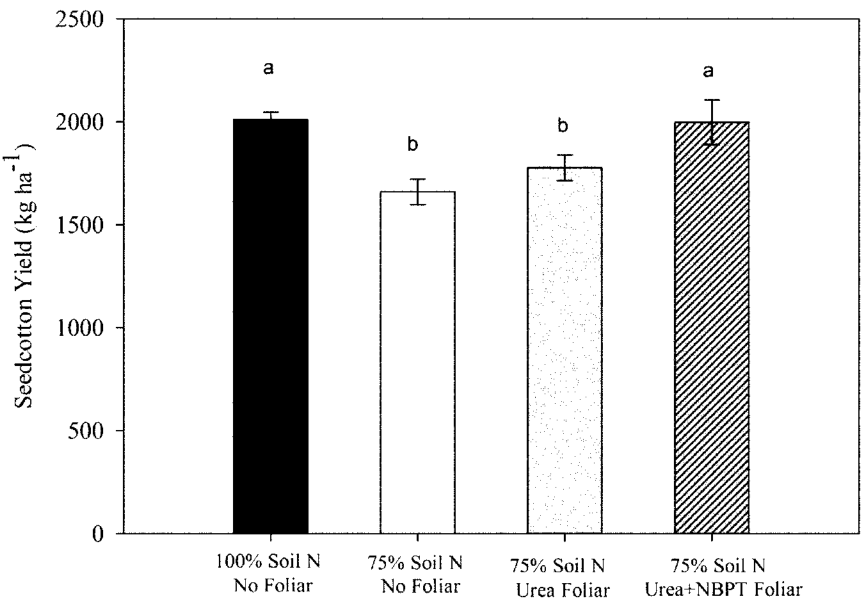

Fig. 3. Effect of foliar treatments on seedcotton yield in field experiment conducted in 2009.

The Effect of Water-Deficit Stress on the Biochemistry of the Cotton Flower

D.A. Loka[1], D.M. Oosterhuis[1], C.J. Fernandez[2], and B.A. Roberts[3]

RESEARCH PROBLEM

Even though cotton originates from hot and dry climates, plant growth and yield reductions still occur when water supply is limited or interrupted. Extensive research has been conducted on the physiological and metabolic effects of water-deficit stress on the vegetative parts of the plant; however, little attention has been given to the metabolic responses of the cotton flower under water limiting conditions. Since reproductive units are severely affected by water deficits, further research is needed to elucidate the metabolic responses of cotton reproductive units under conditions of water stress in order to facilitate methods of amelioration. In this study, it was hypothesized that water-deficit stress would severely impair gas exchange functions consequently resulting in perturbation of carbohydrates of cotton reproductive units.

BACKGROUND INFORMATION

Adequate supply of water is a prerequisite for optimum plant growth and satisfactory yield in every crop. Water-deficit stresses occur in about 70% of arable land around the world (LeHouerou, 1996) and have been shown to have an effect on every aspect of plant growth (Kramer, 1983). In cotton, cell expansion, division and differentiation are the first functions to be affected by water-deficit stress, followed by reductions in stomatal conductance (Ackerson et al., 1977). As a result, photosynthetic rates, plant height and leaf area are reduced while rate of squaring and node production decline resulting ultimately in yield reduction (Pettigrew, 2004).

Specifically for cotton leaves, past research has indicated that water-deficit stress results in decreased water potential and osmotic adjustment (Wullschleger and Oosterhuis, 1990), lower photosynthetic rates (Pettigrew, 2004), while res-

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piration rates have a biphasial response (Pallas et al., 1967). Leaf carbohydrate results have been variable concerning water stress (Eaton and Ergle, 1948; Ackerson, 1981), while no significant effect was observed on the antioxidant glutathione reductase activity (Mahan and Wanjura, 2005). Cotton bolls themselves have been shown to be relatively insensitive to plant water-deficits. Trolinder et al. (1993) and Van Iersel and Oosterhuis (1996) observed that boll water potential remained unaffected under variable water stress conditions. Similarly, Guinn (1976) showed that carbohydrate content of 4-day-old bolls remained unaffected, whereas ethylene and ABA concentrations increased, while auxin content decreased.

The pathways of carbohydrate metabolism and subsequent energy production, as well as antioxidant metabolism of cotton flowers 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 flowers and their subtending leaves when they are subjected to limited water supply.

RESEARCH DESCRIPTION

Growth chamber experiments were conducted in 2009-2010 at the Altheimer Laboratory in Fayetteville, University of Arkansas. Cotton (*Gossypium hirsutum* L.) cultivar ST5288B2F was planted into 1L pots with Sun-Gro horticulture mix and growth chambers were set for normal conditions of 32/24 °C (day/night), ±60% relative humidity, and 12 h photoperiods. Plants were arranged in a completely randomized block design with 15 replications and half-strength Hoagland's nutrient solution was applied daily. The water-deficit treatments consisted of: (1) an untreated control, where an optimum quantity of water was applied all through the experiment and (2) a water-deficit stress during flowering treatment, where water was withheld until a wilting point was reached and after that plants were watered with half the quantity of water needed for ten days. Measurements of stomatal conductance, water potential, photosynthesis and respiration were taken from the fourth main-stem leaf. White flowers for water potential estimates, as well as carbohydrate and antioxidant content were sampled whenever they were available for ten days after the induction of stress.

Field studies were conducted in 2010 in four locations: Fayetteville and Marianna, Ark.; Corpus Christi, Texas; and Fresno, Calif. Cotton cultivar ST5288B2F was planted in all locations and treatments consisted of: (1) an untreated control and (2) a water-deficit stress during flowering treatment. The experimental design was a split-block and measurements of stomatal conductance were taken weekly. White flowers for carbohydrate, antioxidant and polyamine content were collected weekly, along with their subtending leaves. Seed set efficiency was estimated as seed number per boll.

RESULTS AND DISCUSSION

Results from both growth chamber and field studies showed that water-deficit stress significantly decreased leaf photosynthesis (Fig. 1A) and respiration (Fig. 1B). Leaf water potential was also significantly decreased, whereas pistil water potential remained unaffected (Table 1). Sucrose content of water-stressed pistils was significantly higher compared to the control, while pistil hexose concentration remained unaffected (Table 1). The opposite pattern was observed in leaf carbohydrate content, where leaf hexose concentration of water-stressed plants was significantly higher compared to the control, whereas leaf sucrose content was at the same levels as the control (Table 1). Glutathione reductase activity in the pistil was increased under conditions of limited water supply, while in the leaf it remained at the same levels as the control (Table 1). Concerning polyamine content of the pistils, putrescine levels in both the style and the ovary remained unaffected under water-deficit stress, however both spermidine and spermine concentrations were significantly decreased under water-deficit stress (data not shown). Seed set efficiency was not significantly affected at the Arkansas location (Fig. 2A) however, at the Texas location there was a dramatic decrease (Fig. 2B).

In general, water-deficit stress during flowering significantly decreased leaf physiological functions, while pistils appeared to be more tolerant. However, biochemical functions of the pistils appeared to be more sensitive compared to the leaf with significant compromises in carbohydrate, antioxidant and polyamine metabolism. Those compromises resulted in a significant decrease of seed set efficiency at one location.

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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Table 1. Effect of water-deficit stress on leaf and pistil water potential, glutathione reductase activity, hexose and sucrose content. Columns with the same letter are not significantly different ($P = 0.05$).

	Water Potential (MPa)		Glutathione Reductase (GR units/g FW)		Hexose Content (mg Hexose/mg DW)		Sucrose Content (mg Sucrose/mg DW)	
Treatment	**LEAF**	**PISTIL**	**LEAF**	**PISTIL**	**LEAF**	**PISTIL**	**LEAF**	**PISTIL**
Well watered	-1.82 a	-1.75 a	23.17 a	13.278 b	0.00546 b	0.0165 a	0.00195 a	0.00834 b
Water stressed	-3.4 b	-1.82 b	22.61 a	26.81 a	0.00973 a	0.147 a	0.002645 a	0.13115 a

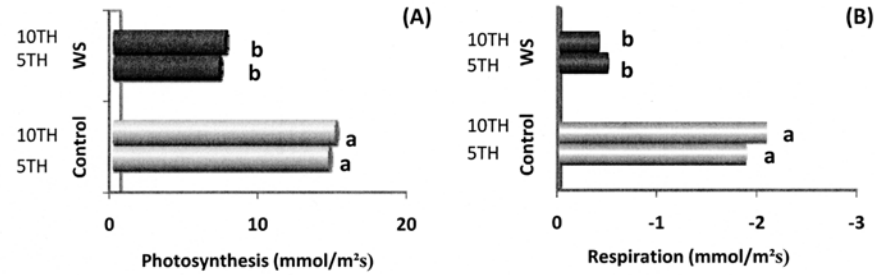

Fig. 1. Effect of water-deficit stress on leaf photosynthesis (A) and respiration (B) on the 5th and 10th day after induction of stress. Bars with the same letter are not significantly different (P = 0.05).

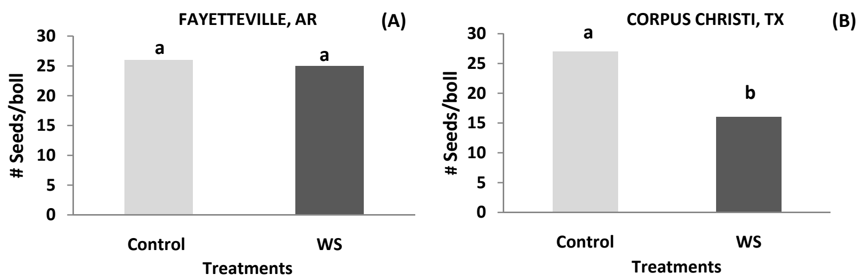

Fig. 2. Effect of water-deficit stress on number of seeds per boll at Arkansas (A) and Texas (B) locations. Columns with the same letter are not significantly different (P = 0.05).

Effects of Moderately High Temperature on Diurnal Pollen Tube Growth and Fertilization in Field-Grown Cotton

J.L. Snider[1], D.M. Oosterhuis[2], and E.M. Kawakami[2]

RESEARCH PROBLEM

A number of events must occur in a highly concerted fashion during flowering for successful fertilization and seed production to occur. As a result, the yield of crop species with reproductive structures of agronomic importance is substantially more sensitive to environmental stress than the yield of crops with vegetative structures of agricultural importance. High temperature during flowering is known to limit fertilization and lint yield in cotton, but information regarding the temperature sensitivity of key reproductive processes under field conditions during flowering is limited.

BACKGROUND INFORMATION

The day of flowering is a critical event in the reproductive development of cotton. A white flower opens at dawn, pollination occurs within a few hours after flower opening, and pollen germination occurs within 30 minutes following pollination (Stewart, 1986). The pollen tube extends through the transmitting tissue of the style, and fertilization of the ovule occurs between 12 and 24 h later (Stewart, 1986). Abiotic stress that limits any of the aforementioned processes leading to successful fertilization and seed development will necessarily limit yield since the number of seeds produced and the amount of fiber per seed are the basic components of yield in cotton. Consequently, high temperature has been shown to limit fertilization in cotton (Snider et al., 2009), and a negative correlation has been reported between high temperature during flowering and lint yield (Oosterhuis, 2002).

RESEARCH DESCRIPTION

To evaluate the effects of high temperature on *in vivo* diurnal pollen tube growth and fertilization, cotton (*Gossypium hirsutum* L.) cv. ST4554B2RF seeds

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were sown at a density of eight plants per meter in a Captina silt loam (Typic Fragidult) soil at the Arkansas Agricultural Research and Extension Center, Fayetteville, Ark. in 1-m rows. Seeds were planted on different dates (28 May and 5 June 2009) to obtain flowers at the same developmental stage (i.e. same node) that had developed under different environmental conditions. Only pistils collected on 4 and 14 August 2009 (from plants corresponding to the 28 May and 5 June planting dates, respectively) were subsequently used for anatomical analysis because air temperatures from these dates showed the greatest contrast with minimal differences in other climatological parameters.

Diurnal quantification of air temperature, pistil temperature, and pollen tube growth was performed at five different times throughout the day: 0600, 0900, 1200, 1500, and 1800 h. Air and pistil temperatures were measured using a digital thermometer and a type K thermocouple. Styles from pistils collected at each time of day were fixed in a 3:1 solution of ethanol:acetic acid, cleared and softened in 1M NaOH, and stained in decolorized aniline blue. Pollen tubes were visualized within the style using UV microscopy, pollen tube length was measured in mm, and pollen tube growth rate was expressed in mm h^{-1}. Pollen germination was expressed as a percent and calculated as follows: (number of germinated pollen grains)/(30 pollen grains scored on the stigmatic surface). For fertilization efficiency determination, flowers were collected 24 h after anthesis to allow sufficient time for fertilization to occur (Stewart, 1986) and prepared for UV microscopy as described above. Ovules containing a pollen tube were considered fertilized and fertilization efficiency was calculated as follows: [(number of fertilized ovules per ovary)/(total number of ovules per ovary)] × 100.

RESULTS

Air temperature was significantly higher on 4 August at all sample times throughout the day than on 14 August (Fig. 1A). For example, the maximum air temperatures were recorded at 1500 h and were 34.6 and 29.9 °C on 4 and 14 August, respectively (Fig. 1A). Compared with diurnal air temperatures recorded on 14 August, air temperatures recorded on 4 August ranged from 7.1 °C higher at 0600 h to 2.2 °C higher at 1800 h. There was a significant two-way interaction between time of day and sample date for both pistil temperature (Fig. 1B; $P < 0.0001$) and pollen tube length through the style (Fig. 1C; $P < 0.0001$). Pistil temperature was significantly higher on 4 August at all sample times throughout the day than on 14 August (Fig. 1B). The maximum pistil temperatures observed were recorded at 1500 h and 1200 h on 4 August (34.9 °C) and 14 August (32.8 °C), respectively. Compared with diurnal pistil temperatures recorded on 14 August pistil temperatures recorded on 4 August ranged from 8.4 °C higher at 0600 h to 0.85 °C higher at 1800 h (Fig. 1B).

Figure 1C shows that pollen tubes were first measureable within the style at 1200 h on 4 August and at 1500 h on 14 August. These were also the first of the sample times utilized in this study in which pollen grains were first visible on the stigmatic surface. Pollen tubes continued to elongate through the style throughout the day, and the final pollen tube lengths observed at 1800 h were statistically indistinguishable at 13.4 and 12.1 mm on 4 and 14 August, respectively (Fig. 1C). Pollen tube growth rate through the style was significantly slower on the warmer sample date (4 August) than on the cooler sample date (14 August), where pollen tube growth rates from 1500 to 1800 h were 2.05 mm h^{-1} on 4 August and 3.35 mm h^{-1} on 14 August (Fig. 1C; P = 0.0058). In contrast with pollen tube growth, pollen germination on the stigmatic surface was not significantly affected by sample date (Fig. 2A; P = 0.088), and fertilization efficiency was unaffected by sample date (Fig. 2B; P = 0.412).

DISCUSSION AND PRACTICAL APPLICATION

Because high temperature slowed pollen tube growth rate through the style without declines in pollen germination or ovule fertilization, we conclude that diurnal pollen tube growth rate may be more sensitive than either of these processes to moderately high temperature. Identification of the most heat-sensitive stages of reproduction in cotton is an important first step in developing strategies for mitigating the negative impacts of high temperature on yield.

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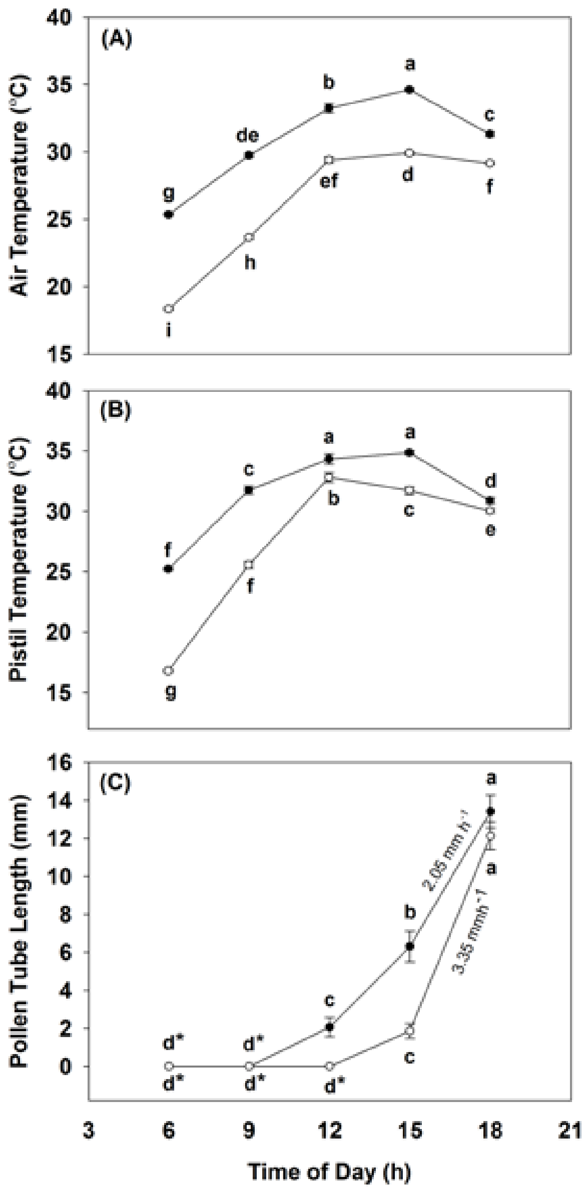

Fig. 1. Diurnal air temperature (A) pistil temperature (B) and *in vivo* pollen tube growth (C) on 14 August (T_{max} = 29.9 °C; open circles) and 4 August (T_{max} = 34.6 °C; closed circles) from 06:00 to 18:00 h in 3 h increments. An asterisk next to a data point indicates that no pollen grains were present on the stigmatic surface at that time of day (pollen tube length = 0). All values are means ± standard error (n = 6), and values not sharing a common letter are significantly different (LSD; *P* < 0.05). Pollen tube growth rates (in mm h^{-1}) under optimal and high temperature conditions are shown adjacent to the corresponding line.

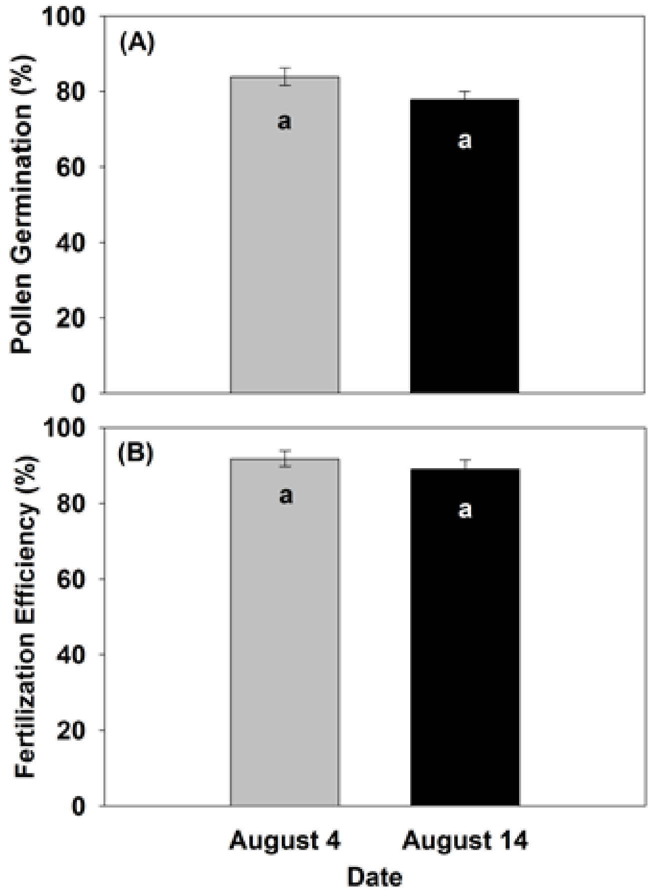

Fig. 2. *In vivo* pollen germination (A) and fertilization efficiency (B) for *Gossypium hirsutum* pistils collected on 4 August (gray bars) and 14 August 2009 (black bars). All values are means ± standard error (n = 6), and values not sharing a common letter are significantly different (Student's *t*-test; $P < 0.05$).

Effect of 1-Methylcyclopropene on Yield of Field-Grown Cotton

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

RESEARCH PROBLEM

One of the main problems in cotton production is the extreme year-to-year variability in yield (Lewis et al., 2000), which is a major concern to cotton farmers and the industry in general. Variability in cotton yield is associated with many factors and temperature appears to play a major role. High temperatures limit growth and development processes in much of the cotton producing areas (Reddy et al., 2002). Cotton has been shown to be particularly sensitive to high temperature stress during flowering (Snider et al., 2010). When plants are under stress they increase the production of the plant hormone ethylene, which is a stress hormone known for its role in the regulation of fruit abscission processes (Guinn, 1982). The current project was designed to evaluate the effectiveness of 1-Methylcyclopropene (1-MCP) to counteract the effects of stress and maintain fruit and seed numbers for increased yield. As a result, higher and less variable yields could be achieved without undue changes in management and production costs.

BACKGROUND INFORMATION

1-Methylcyclopropene is a plant growth regulator that works by occupying the ethylene receptors of plants and thereby inhibiting ethylene from binding and initiating a response such as abscission or senescence (Sisler and Serek, 1997). The affinity of 1-MCP for the ethylene receptor sites is 10 times greater than that of ethylene. 1-MCP has been shown to prevent and delay abscission in both citrus and cherry tomatoes (Beno-Mousalem et al., 2004). It has been reported that a 1-MCP application on field-grown cotton increased the yield (Kawakami et al., 2006). The objective of this study was to evaluate the effectiveness of 1-MCP to counteract the effects of high temperature stress during flowering and maintain fruit and seed numbers for increased yield on field-grown cotton.

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RESEARCH DESCRIPTION

Field studies were conducted at the University of Arkansas Lon Mann Cotton Research Station in Marianna, Ark. and also at the Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. Both Experiments were planted with cotton (*Gossypium hirsutum* L.) cultivar ST4288B2F. Weed and pest management were performed according to state recommendations.

The field study at the Marianna location was arranged in a completely randomized block design with five replications. The plot size was four rows, 15-m in length. The trial was furrow irrigated as needed and fertilized according to recommended practices for cotton. Treatments consisted of: (T1) an untreated control; (T2) 1-MCP at 10g ai/ha applied at first flower (FF) and again one week after first flower; (T3) 1-MCP at 10g ai/ha applied at one and two weeks after first flower; (T4) 1-MCP at 10g ai/ha applied at two and three weeks after first flower; (T5) 1-MCP at 10g ai/ha applied when temperatures were predicted to exceed 95 ^{o}F for three consecutive days or more after first flower. All 1-MCP (Rohm Hass, Philadelphia, Pa.) treatments were sprayed with a backpack CO_2 sprayer calibrated at 20 gal/acre. The adjuvant Silwet L-77 was added to the spraying solution at a rate of 0.035% v/v. The individual plots were machine picked.

The field study at the Fayetteville location was arranged in a completely randomized block design with five replications. The trial consisted of three planting dates at one week apart to ensure higher temperatures during peak flowering. The plot size was four rows, 6 m in length. The trial was furrow irrigated as needed and fertilized according to recommended practices for cotton. Treatments consisted of: (T1) an untreated control; (T2) 1-MCP at 10g ai/ha applied at first flower. All 1-MCP treatments were sprayed with a backpack CO_2 sprayer calibrated to 20 gal/acre. The adjuvant Silwet L-77 was added to the spraying solution at a rate of 0.035% v/v. the individual plots were machine picked. The lint yield per hectare was calculated from a 1-m length of row hand-picked for each plot.

RESULTS AND DISCUSSION

In the Marianna field study, there was no significant effect of the 1-MCP application times (Fig. 1). While there was no significant difference between the timing of applications, there was a trend showing that a later application of 1-MCP or an application when temperatures exceed 95 °F appeared to have a positive effect. The trend showed that all 1-MCP treatments yielded higher than the untreated control.

The Fayetteville field study was successful in achieving high temperatures during peak flowering for the second and third planting dates and there was a significant effect of the 1-MCP application on yield for two of the three planting dates (Fig. 2). There was an 18% to 37% yield increase with 1-MCP application applied at first flower. Average temperatures for 4 days after 1-MCP application were 90 °F, 99 °F, and 98 °F for the first, second and third planting dates, respectively. Previous research has shown that temperatures above 95 °F cause significant decreases in photosynthesis (Bibi et al., 2008) and reproductive success (Snider et al., 2009). However even the early planting when temperatures were 90 °F exhibited an increase in yield. The yield increases were attributed to improved pollen tube growth and successful fertilization of the ovules (Snider et al., 2009).

PRACTICAL APPLICATION

In conclusion, 1-MCP had a significant effect on the yield of field-grown cotton in Fayetteville but not in Marianna. These results indicate that 1-MCP has the potential to increase yield, and the data suggest that an application of 1-MCP later during the flowering period has a positive effect on yield.

ACKNOWLEDGMENTS

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

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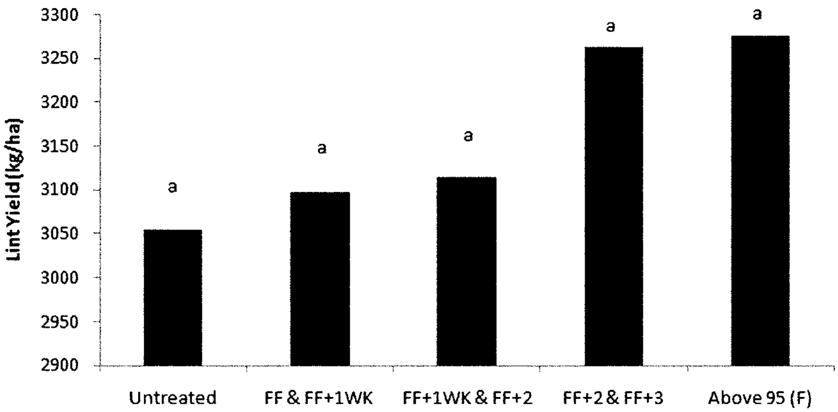

Fig. 1. Machine picked lint yield in the Marianna field study. Columns with the same letters are not significantly different at the $\alpha = 0.05$ level.

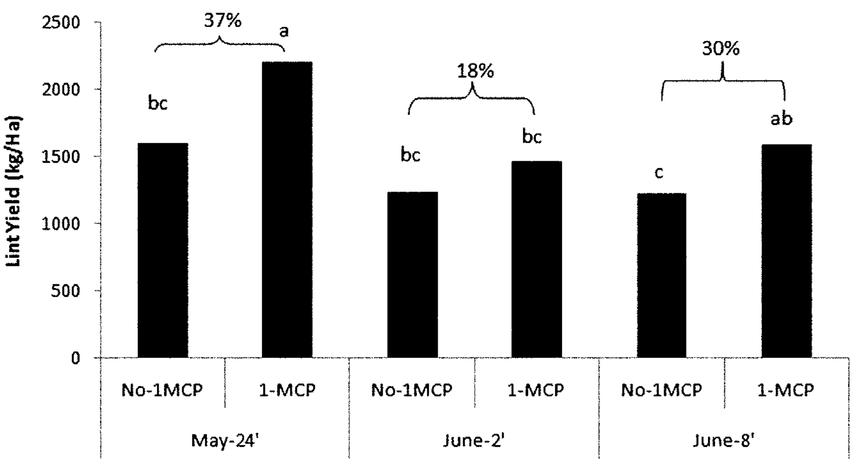

Fig. 2. Lint yield of 1-MCP treatments in Fayetteville, Ark. for three planting dates. The 1-MCP was foliar applied at first flower in each planting date. The percent increase for each treatment compared to the untreated control is shown. Average temperatures for 4 days after 1-MCP application were 90 °F for the first planting date, 99 °F for the second, and 98 °F for the third planting date. Columns with the same letters are not significantly different at the $\alpha = 0.05$ level.

Effect of 1-Methylcyclopropene on the Cotton Flower Under Water-Deficit Stress

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

RESEARCH PROBLEM

Drought is the main abiotic factor limiting more than 70% of the arable land around the world. Ethylene, a plant hormone, has often been observed to increase under environmentally unfavorable conditions, resulting in abscission of leaves and fruiting forms and ultimately in yield reduction. Concerning cotton, however, the effects of water-deficit stress on ethylene production have been uncertain. In this study it was hypothesized that application of an ethylene inhibitor 1-Methylcyclopropene (1-MCP) would prevent ethylene production and result in alleviation of water-deficit stress effects on the cotton flower and consequently prevent yield loss.

BACKGROUND INFORMATION

Water deficit is a major abiotic factor limiting plant growth and crop productivity around the world (Kramer, 1983). Cotton (*Gossypium hirsutum* L.) is considered to be relatively tolerant to drought, i.e. by osmotic adjustment (Oosterhuis and Wullschleger 1987; Nepomuceno et al., 1998). However, plant growth and yield are compromised when water supply is limited (Basal et al., 2005).

Production of ethylene, a senescence promoting hormone, is usually increased under conditions of environmental stress such as drought, high or low temperatures and hypoxia (Morgan and Drew, 1997). In cotton, studies with detached leaves (Morgan et al., 1990) and petioles (McMichael et al., 1972) indicated that ethylene production is increased under water-deficit conditions whereas, the opposite was observed for intact cotton plants (Morgan et al., 1990). In addition, Guinn (1976) observed an increase in ethylene synthesis in 4-day-old bolls under water-deficit conditions and speculated that boll abscission was caused by ethylene production. However, Bugbee (2011) in experiments that were conducted with intact plants observed a decrease in ethylene production under conditions of water-deficit stress.

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1-Methylcyclopropene (1-MCP), an ethylene inhibitor that acts by binding on ethylene receptors (Sisler and Serek, 1997) has been shown to result in a decrease or a delay of the ethylene activity (Blankenship and Dole, 2003). Kawakami et al. (2010) observed that application of 1-MCP on 4-week-old plants resulted in a decrease in leaf stomatal resistance, however no data exist on the effect of 1-MCP on the biochemistry of the cotton flower under water-deficit stress conditions. The objective of these studies was to evaluate the possible ameliorating effect of the anti-ethylene plant regulator, 1-MCP on cotton's floral buds and subtending leaves under conditions of limited water supply during reproductive development.

RESEARCH DESCRIPTION

Growth chamber studies were conducted in 2008-2009 in the Altheimer laboratory of the University of Arkansas in Fayetteville. Cotton (*Gossypium hirsutum* L.) ST5288B2F was planted into 1-L pots containing a horticultural mix (Sun-Gro horticulture mix). The growth chambers were set for normal conditions of 30/20 °C (day/night), ± 60% relative humidity, and 14/10 h photoperiods, while half-strength Hoagland's nutrient solution was applied daily in order to maintain adequate nutrients and water. Plants were arranged in a completely randomized block design with 15 replications and the experimental design was a 2 × 2 factorial with water-deficit stress being the main effect and 1-MCP application the secondary effect.

1–MCP was applied at 10g ai/ha with a CO_2-backpack sprayer calibrated to deliver 20 gal/acre and using the adjuvant AF-400 at 0.375% v/v the second day after the initiation of stress (after water was withheld from the plants). The treatments consisted of: 1) an untreated control, where an optimum quantity of water was applied throughout the duration of experiment; 2) an untreated control + 1-MCP, where an optimum quantity of water was applied throughout the duration of the experiment and plants were sprayed with 1-MCP; 3) a water-deficit stress during flowering treatment, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and; 4) a water-deficit stress during flowering + 1-MCP treatment, where water was withheld during flowering and the plants were subjected in two cycles of drying for six days each and were sprayed with 1-MCP.

Measurements of leaf stomatal conductance were taken daily between 11:00 am-1:00 pm from the fourth main-stem leaf from each plant using a leaf porometer Decagon SC-1 (Decagon Inc., Pullman, Wash.). Photosynthetic and respiratory rates were measured the first and fourth day after spraying, between 11:00 am-1:00 pm from the fourth main-stem leaf from each plant using the LiCor 6200 gas analyzer (LiCor Inc., Lincoln Neb.). Total non-structural carbohydrate content was estimated from white flowers (pistils) and their subtending leaves that were collected when available from all four treatments. Carbohydrate extraction was done according to Zhao et al. (2008) and the supernatants were analyzed with a Multiscan Microplate Reader (Diversified Equipment Co., Lorton, Va.).

RESULTS AND DISCUSSION

Water-deficit stress treatments resulted in a significant decrease in both leaf photosynthesis (Fig. 1A) and respiration rates (Fig. 1B) of water stressed plants compared to the control. Similarly, leaf stomatal conductance rates of water stressed cotton plants were significantly lower than the control. Concerning leaf carbohydrate content, leaf glucose concentration was increased under conditions of water-deficit stress (Fig. 2A), whereas leaf fructose and sucrose concentration remained unaffected. On the other hand, pistil glucose and fructose concentrations remained similar to the control levels, while pistil sucrose concentration of water stressed plants was significantly increased compared to the control (Fig. 2B).

1-MCP application had no significant effect on cotton's gas exchange functions and failed to ameliorate the effects of water-deficit stress on leaf photosynthesis, respiration and stomatal conductance. However, application of 1-MCP resulted in a decrease in sucrose of the pistil. We speculate that this decrease was due to more efficient cleavage of sucrose into glucose and fructose and ultimately a better utilization of the carbohydrates.

PRACTICAL APPLICATION

Application of 1-MCP had no alleviating effect on leaf photosynthesis, respiration and stomatal conductance under conditions of water-deficit stress. Leaf and pistil total soluble carbohydrate content remained unaffected, with the exception of pistil sucrose content. 1-MCP decreased sucrose accumulation resulting in more efficient utilization. In conclusion, leaf gas exchange functions of cotton remained unaffected from application of 1-MCP, however, carbohydrate metabolism of the pistil appeared to be more responsive. Further research is required in order to elucidate the implications of ethylene in the biochemistry of the cotton flower and the potential alleviating effect of anti-ethylene plant growth regulators.

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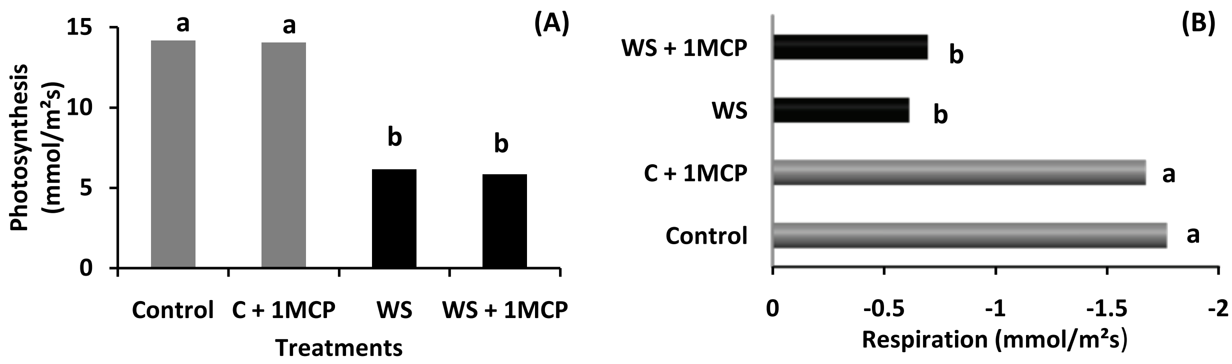

Fig. 1. Effect of water-deficit stress and 1-MCP application on leaf photosynthesis (A) and respiration (B) four days after induction of stress. Bars with the same letter are not significantly different (P = 0.05).

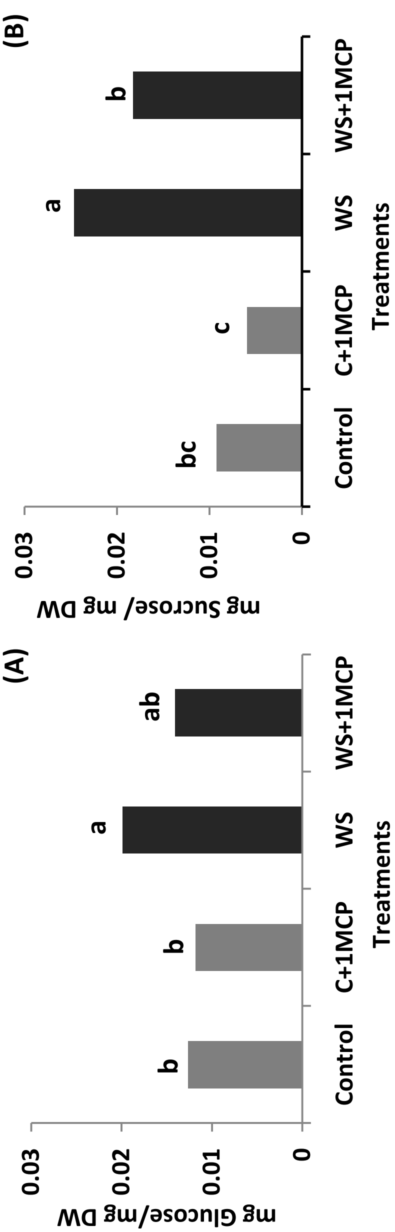

Fig. 2. Effect of water-deficit stress and 1-MCP application on leaf glucose content (A) and pistil sucrose content (B). Columns with the same letter are not significantly different (*P* = 0.05).

Effect of 1-Methylcyclopropene on Antioxidant Activity and Gene Expression of Acc-Synthase and Acc-Oxidase in Cotton Flowers

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

RESEARCH PROBLEM

Cotton yields in the Mid-south are well below the theoretical potential (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 ethylene, a plant growth regulator known to cause various plant physiological responses, including control fruit abscission. This study was designed to evaluate the possible use of the plant growth regulator 1-methylcyclopropene (1-MCP) to alleviate the adverse effect of environmental stresses on cotton reproductive development.

BACKGROUND INFORMATION

Methylcyclopropene (1-MCP) is a competitive inhibitor of the plant senescence hormone, ethylene (Sisler and Serek, 1997), and has been successfully and widely used in post-harvest to prevent fruit ripening. Our research with cotton has shown that foliar application of 1-MCP can result in yield increase in field-grown cotton (Kawakami et al., 2011), and that 1-MCP is able to ameliorate oxidative stress of drought-stressed cotton plants grown in the growth chamber (Kawakami et al., 2010). The objective of the current research was to evaluate the response of cotton flowers to 1-MCP application on plant oxidative stress activity and on the expression of genes (ACC-synthase and ACC-oxidase) involved in ethylene synthesis.

RESEARCH DESCRIPTION

The field experiment was conducted at the Arkansas Agricultural Research and Extension Center in Fayetteville, Ark. in a Captina silt loam (Typic Fragi-

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udult) soil using the cotton (*Gossypium hirsutum* L.) cultivar ST5288 BRF. The experiment was uniformly fertilized following preseason soil tests and mepiquat chloride was applied as needed to control vegetative growth. The treatments consisted of a control treatment with application of water plus adjuvant (AF-400 at 0.375% v/v) and a 1-MCP treatment at 10g a.i./ha plus adjuvant. Treatment application was done directly to open flowers on the day of anthesis (white flowers) and flower ovaries were collected at 1 day past anthesis, and kept in -80 °C for subsequent quantification of gene expression, antioxidant activity (glutathione reductase, GR, and superoxide dismutase, SOD) and membrane decomposition (Malondialdehyde, MDA. The experiment was arranged in a completely randomized design with 10 replications.

RESULTS AND DISCUSSION

There was no significant treatment effect on ACC-synthase (data not shown), only a numerical decrease in relative gene expression values was observed in the 1-MCP treated flowers. On the other hand, expression of ACC-oxidase (Fig. 1) was significantly decreased by application of 1-MCP. The ACC-oxidase enzyme is responsible for the conversion of ACC (1-Aminocyclopropane 1-Carboxcylic Acid) to ethylene; thus in addition to blocking ethylene binding sites, 1-MCP could also have an indirect effect on decreasing synthesis of ethylene in cotton flowers.

A significant treatment effect was also observed in the antioxidants GR (Fig. 2) and SOD (Fig. 3). In both cases, application of 1-MCP significantly decreased the values of antioxidant enzymes in cotton flowers. These results indicate that 1-MCP decreases the stress level of cotton flowers, since under stress condition plants respond by increasing activity of antioxidant enzymes as a protection mechanism against reactive oxygen species compounds. Furthermore, the absence of a significant treatment effect on MDA measurement (data not shown) also supports this evidence, in which 1-MCP treated flowers even with low activity of antioxidant did not exhibit an increase in membrane decomposition.

CONCLUSIONS

We observed that application of 1-MCP to cotton flowers decreased the expression of ACC-oxidase, the enzyme responsible for ethylene synthesis, and resulted in decreased stress response of cotton flowers. In addition to blocking ethylene active binding sites, 1-MCP also showed potential for decreasing ethylene synthesis by lowering the gene expression of the ACC-oxidase enzyme.

ACKNOWLEDGMENTS

This research was funded by AgroFresh, Inc. The authors thank Dr. Scott Finlayson for providing the primers for the gene expression measurement.

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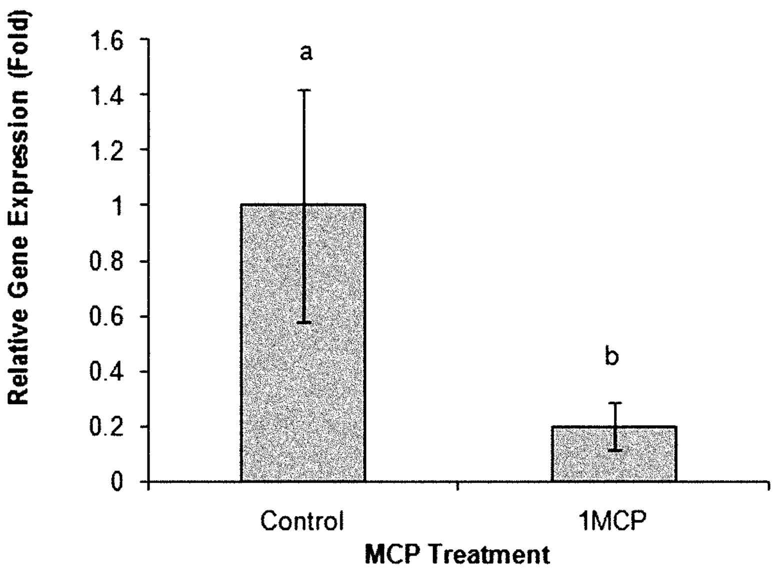

Fig. 1. Effect of methylcyclopropene (1-MCP) treatment on ACC-oxidase gene expression. Columns not sharing a common letter are significantly different (*P* ≤ 0.05).

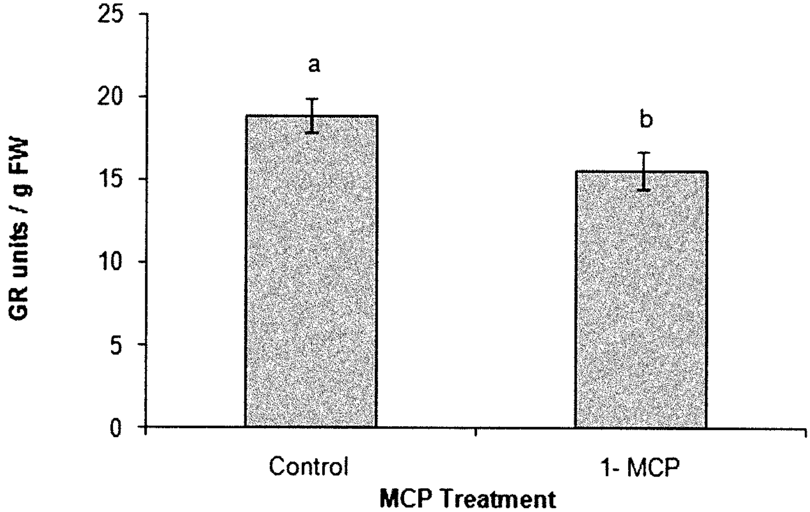

Fig. 2. Effect of methylcyclopropene (1-MCP) treatment on glutathione reductase (GR) activity. Columns not sharing a common letter are significantly different ($P \leq 0.05$).

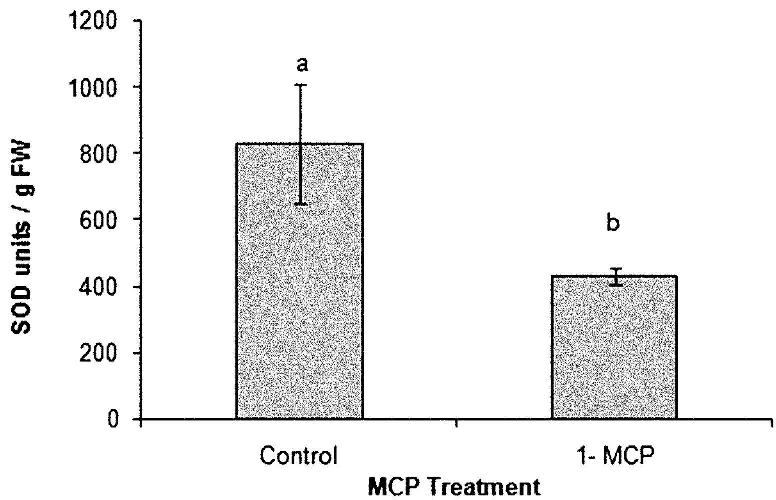

Fig. 3. Effect of methylcyclopropene (1-MCP) treatment on superoxide dismutase (SOD) activity. Columns not sharing a common letter are significantly different ($P \leq 0.05$).

Cotton Response to Urea and an Enhanced Efficiency Fertilizer

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

RESEARCH PROBLEM

Nitrogen (N) fertilizer is usually required for producing optimum cotton (*Gossypium hirsutumn* L.) yields in Arkansas. Improving N use efficiency will increase the growers' profit margin and reduce potential environmental risks of excessive N application. Enhanced efficiency N fertilizers were developed to meet that dual need.

BACKGROUND INFORMATION

A polymer-coated urea (44% N, Agrium Advanced Technologies, Loveland, Colo.) is currently being marketed in Arkansas under the trade name of Environmentally Smart Nitrogen or ESN[3]. According to the manufacturer, the polymer coating protects the urea-N against rapid loss to the environment with the N release rate controlled by temperature. Oosterhuis and Howard (2008) reported positive yield results and improved N use efficiency with slow-release N fertilizer. The objectives of this study were to evaluate cotton response to ESN and urea fertilizers applied on two representative Arkansas soils.

RESEARCH DESCRIPTION

Two N fertilization experiments were conducted to evaluate the effect of five preplant N rates applied as urea or ESN on cotton growth and yield. The experiments were located on a Loring silt loam at the Lon Mann Cotton Research Station in Marianna (LMCRS) and on a Dundee loam at the Judd Hill Research Farm. Before applying any fertilizer, soil samples were collected from the 0-to 6-inch depth, composited by replication, and tested by current methods used by the University of Arkansas Soil Testing Laboratory. Agronomically important in-

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

formation for the two experiments are presented in Tables 1 and 2. Each cotton trial was a randomized complete block design with five blocks of treatments arranged in a factorial structure as described. Urea and ESN were each applied at 30, 60, 90, 120, and 150 lb N/acre and compared to a no N control. Cotton plots were 40-ft long and 12.6-ft wide allowing for four rows of cotton with 38-inch wide row spacings. Nitrogen treatments were surface applied and incorporated with a Do-all before planting. Muriate of potash was surface applied at the LMCRS site shortly after planting to supply 60 lb K_2O/acre. No P and K fertilizers were applied at the Judd Hill site. The two center rows of cotton in each plot were harvested with a spindle-type picker. Analysis of variance was performed using the GLM procedure of SAS (SAS Institute, Inc., Cary, N.C.). Cotton experiments were analyzed by site. When appropriate, means were separated by the least significant difference (LSD) method and interpreted as significant when $P \leq 0.10$.

RESULTS AND DISCUSSION

Soil analysis indicated that pH ranged from 6.0 to 6.8 and Mehlich-3 extractable P and K were medium (K) or above optimum (P) for the cotton experiment at LMCRS, and each was low for the Judd Hill cotton trial (Table 1). Soil NO_3-N ranged from 15 to 28 ppm and suggested that cotton should respond favorably to N fertilization.

Seedcotton yield at the LMCRS was affected only by N source ($P = 0.0429$), yield means for each N source and rate combination are listed in Table 3. Averaged across N rates, cotton fertilized with ESN (2053 lb/acre, $LSD_{0.10} = 195$) produced numerically greater and statistically similar seedcotton yields as urea (1932 lb/acre), but both yielded greater than cotton receiving no N (1264 lb/acre). At Judd Hill, seedcotton yields were not affected by N source, N rate, or their interaction (Table 3). Application of 30 lb N/acre, the lowest N rate, maximized cotton yield producing a 675 lb seedcotton/acre increase compared to the no N control. At Judd Hill, the mean seedcotton yields produced with ESN and urea, averaged across N rates (P-value for N source = 0.6758), differed by only 26 lb/acre. The results from these two sites suggest that ESN provided equal or slightly better N availability than urea at these sites during 2010.

PRACTICAL APPLICATION

The 2010 summer was drier than normal making fertilizer N losses from denitrification less likely than in wet years. Cotton yields were not different between urea and ESN. These results indicate that ESN is a suitable, alternative N fertilizer (to urea) for cotton. Additional research, encompassing several years and various field and weather conditions common to Arkansas, is needed to determine the frequency and magnitude of yield increases from which benefits may be realized when ESN is used in place of urea for preplant N applications. Cost also needs to be addressed.

ACKNOWLEDGMENTS

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Table 1. Selected soil property means of soil samples (0-to 6-inch depth) taken before applying fertilizers to cotton trials established at the Lon Mann Cotton Research Station (LMCRS) and Judd Hill Research Farm in 2010.

Site	Soil pH[a]	Soil NO_3-N[b]	Mehlich-3-extractable Nutrients					Soil Physical Properties			
			P	K	Ca	Mg	Zn	Sand	Silt	Clay	Texture
		-----(ppm)-----						-----%-----			
LMCRS	6.8	28	57	104	1487	196	2.7	4	73	23	silt loam
Judd Hill	6.0	15	25	85	985	164	2.7	43	39	19	loam

[a]Soil pH was measured in a 1:2 (weight:volume) soil-water mixture.
[b]NO_3-N measured by ion-specific electrode.

Table 2. Selected agronomically important information for the two cotton N fertilization trials established at the Lon Mann Cotton Research Station (LMCRS) and Judd Hill Research Farm in Arkansas during 2010.

Site ID	Previous Crop	Cultivar	Planting Date	N Application Date	Leaf Sampling Date	Harvest Date
LMCRS-cotton	cotton	DeltaPine 192	2 Jun	19 May	no samples	9 Sep
Judd Hill-cotton	cotton	Stoneville 4288	8 May	21 May	no samples	23 Aug

Table 3. Seedcotton yield as affected by the non-significant (NS, *P* > 0.10) N rate and source interaction and N rate, averaged across N sources, for trials located at the Lon Mann Cotton Research Station (LMCRS) and Judd Hill Research Farm during 2010.

	Judd Hill Research Farm			Lon Mann Cotton Research Station		
N rate	**Urea**	**ESN[a]**	**Source mean**	**Urea**	**ESN**	**Source mean**
lb N/acre	(lb/acre)					
0	1795		1795	1264		1264
30	2501	2438	2470	1804	1968	1895
60	2319	2548	2434	1807	2006	1893
90	2542	2510	2528	2036	2046	2041
120	2277	2387	2338	1929	2212	2071
150	2468	2388	2423	2055	2081	2067
$LSD_{0.10}$	NS		NS	NS		NS
p-value	0.4669		<0.4958	0.6005		<0.4609

[a]ESN, Environmentally Smart N, polymer coated urea.

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

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

BACKGROUND INFORMATION AND RESEARCH PROBLEM

Potassium (K) plays an important role in fiber development and fiber quality. Deficient amounts of this nutrient will result in reduced yields and short fibers since K provides pressure inside the fiber cell walls, which is necessary for elongation (Ruan et al., 2001). The decrease in root activity after flowering, and the use of high-yielding, faster-fruiting cotton (*Gossypium hirsutum* L.) cultivars requiring a greater demand during boll filling (Oosterhuis, 1999) makes the correction of a nutrient deficiency in cotton difficult. Understanding when soil applied fertilizers are no longer effective is critical for optimizing cotton yield. The objective of this experiment was to assess the yield response of cotton to K fertilizer applied at different growth stages, under deficient soil-K levels, and to determine at what growth stage granular K is no longer an option.

PROCEDURES

An experiment was established at the Lon Mann Cotton Research Station, near Marianna, Arkansas during the 2010 season. The soil has been mapped as a Memphis silt loam (fine silty-mixed, thermic, Typic Hapludalfs). Treatments consisted of 0 and 60 lb K_2O/acre, as muriate of potash, applied once at first square, first flower, and 200, 400, 600, and 800 heat units after first flower. The K-fertilizer was hand broadcast to designated plots and later incorporated with irrigation. Plants began squaring on 15 June, with the K-fertilizer applied on 17 June (first square treatment). The remaining treatments were applied on 7, 15, and 21 July and 8 August 2010. Each plot consisted of 4 rows (38-in wide) by 45 ft long. Treatments were arranged as a randomized complete block design and were replicated four times. Cotton (*Gossypium hirsutum*) cultivar Phytogen 375 WRF was planted at the rate of 40,000 seeds per acre on 6 May 2010. Nitrogen was applied at the rate of 100 lb N/acre, with 40 lb N/acre applied at emergence and 60

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lb N/acre applied at first square. Irrigation (furrow) and weed and insect control were performed according to Cooperative Extension Service recommendations.

Soil samples (0-6-in deep) were collected prior to planting and analyzed according to Mehlich-3 standard procedure, with soil pH measured in a 1:2 (volume) soil-water mixture. Petiole samples were collected throughout the season, beginning two weeks prior to first flower, and were analyzed for K. The COTMAN crop monitoring program (Oosterhuis and Bourland, 2008) was used to assess differences in crop development among treatments from squaring to physiological cutout. Prior to harvest, ten whole plants were collected from three of the replicates, with cotton manually harvested according to position. At harvest, the two middle rows from each plot were harvested with a plot picker equipped with a weight system. Average yields were calculated and analyzed using ANOVA with mean separation using LSD at the 0.10 level.

RESULTS AND DISCUSSION

Average soil pH for the surface soil samples was 6.6. The soil test P (43 ppm) and soil test K (101 ppm) were considered "Optimum" and "Medium", respectively, according to University of Arkansas' guidelines. The study site has not received K fertilizer since 2005. Typical K-deficiency symptoms (interveinal chlorosis initially that changes to a bronze-orange color) were obvious in plants receiving no K fertilizer. Potassium deficiency symptoms first appeared on the first week of flowering (7-14 July).

Petiole-K concentrations were within the optimum level according to established sufficiency guidelines for plots fertilized with K by first square (Table 1). A similar trend was observed for plots fertilized with K by first flower. However, the petiole-K levels for the control treatment were in the deficient range during each sampling period, with the petiole-K levels for the remaining treatments showing a high degree of variability among replicates. The high variability is a probable cause for the lack of significant differences among sampling dates.

COTMAN graphs show earlier squaring initiation in plants that received K by first flower (Fig. 1B), compared to the no K control treatments (Fig 1A). Plants growing under both, deficient- and sufficient-K, conditions developed similar numbers of fruiting structures, with the effect of deficient-K levels becoming obvious after the plants had flowered. It is commonly accepted that the onset of K-deficiency symptoms in cotton occurs relatively late in the season as most of the demand for K occurs during the boll filling period (Oosterhius, 1999).

These preliminary results show that applications of granular K-fertilizer after flowering were effective in recovering some of the potential yield losses due to suboptimal soil K availability (Table 2). Compared to cotton receiving no K, seedcotton yields were increased by 13% to 32% from K application with earlier K applications resulting in the largest yields. When the fertilizer was applied by first square, 721 lb/acre seedcotton, above the control, were obtained. As applications were delayed, yield gains were reduced. The 2010 growing season was characterized by low rainfall and high temperatures, resulting in heat units accumulating significantly faster than in previous years. The yield response of cotton to applications of K-fertilizer during a year that more closely follows historical weather trends could be drastically different than the response observed during 2010. This study will be repeated in the coming years to validate the results obtained so far.

Figure 2 shows the yield distribution among sympodial nodes of cotton plants growing under K-sufficient and -deficient conditions. As stated before, the number of fruiting nodes, and associated plant height, were similar for plants growing under both conditions. The detrimental effects of K deficiency in cotton are not typically obvious before the 1st or 2nd week of flower. In this study, plants growing under K-deficient conditions had similar numbers of first position bolls, when compared to plants growing with sufficient K. When yields were separated by boll position on a sympodial node (data not shown) it was obvious that a significant percentage of the yield differences among plants growing under deficient and sufficient K, could be attributed to reduced 2nd and 3rd positions bolls. Additionally, yield resulting from top fruiting branches (nodes 14-17) represented nearly 20% of the total yield for plants growing under optimum soil-K levels, compared to only 8% for the plants growing under K-deficient conditions.

PRACTICAL APPLICATIONS

The objective of this study was to determine when granular K fertilizer is no longer effective for ameliorating K deficiency of cotton. Results of this preliminary study show that granular K fertilizer applied as late as 800 heat units beyond first flower was effective in reducing the yield loss associated with deficient soil-K levels. Higher seedcotton yields were obtained when the fertilizer was applied at first square, and were significantly reduced when the fertilizer was applied 600 and 800 heat units after first flower. Growing cotton at suboptimal soil test-K levels resulted in the loss of more than 700 lb/acre seedcotton. These results underscore the importance of soil testing and proper fertilization.

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Table 1. Average petiole-K concentrations (n = 3) for selected treatments, according to growth stage and associated statistical significance.

	Petiole K				
Treatment	**2 weeks pre-flower**	**1 week pre-flower**	**1 week post-flower**	**2 weeks post-flower**	**3 weeks post-flower**
	------------------------------- % K -------------------------------------				
Control (no K)	3.7	2.8	1.4	1.3	0.7
First Square	5.1 [a]	3.9 [a]	2.3 [a]	4.1 [a]	2.3 [a]
First flower	3.7 [a]	3.6 [a]	2.7 [a]	3.0 [a]	2.5 [a]
First flower + 200 Heat Units	4.2	3.4	1.4 [a]	2.7 [a]	2.0 [a]
First flower + 400 heat units	3.9	3.5	1.9	2.8 [a]	1.4 [a]
Minimum Sufficiency Level[b]	4.0	4.0	3.5	3.5	3.0
LSD (0.10)	NS[c]	NS	NS	NS	NS

[a]K fertilizer had been applied when petiole samples were collected.
[b]The minimum sufficiency levels are those reported by Snyder et al. (1995).
[c]NS, not significant ($P > 0.10$)

Table 2. Average seedcotton yield response to K treatments. Potassium was applied at a single rate of 60 lb K_2O/acre.

Treatment Description	Date of Fertilization		Mean Seedcotton Yield
			lb/acre
First Square	17 June		2945 a
First Flower	7 July		2811 a
First Flower + 200 Heat Units	15 July	(222)	2897 a
First Flower + 400 heat units	21 July	(378)	2697 ba
First Flower + 600 Heat unit	28 July	(585)	2551 b
First Flower + 800 Heat units	5 August	(798)	2514 b
Control (no K)	---------		2224 c
LSD (0.10)			249
CV (%)			8.8
p-value			0.0004

Yields followed by the same letter are not statistically different. The number in parentheses following date of fertilization is the actual cumulative heat units after first flower on the day the K fertilizer was applied.

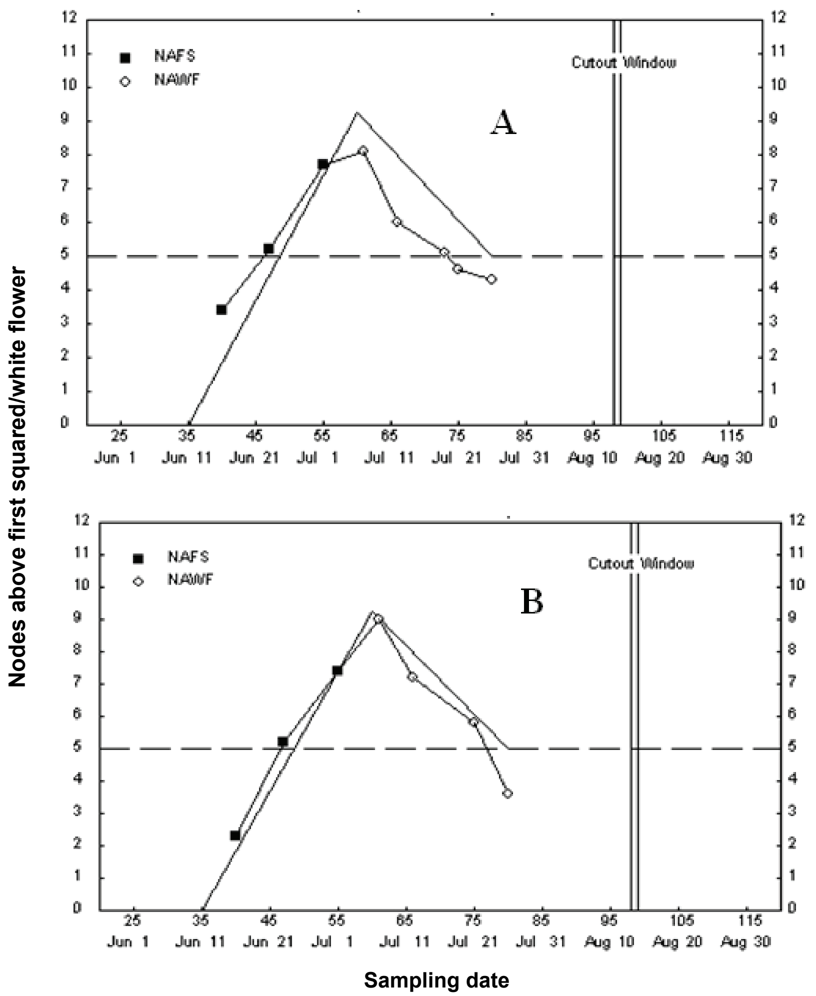

Fig. 1. Average nodes above first square (NAFS) and nodes above white flower (NAWF) development for the control treatment (A), and for the treatment consisting of 60 lb K_2O/acre at first flower (B). Each point in the graph represents the average of 30 plants. The dotted line represents NAWF at physiological maturity. The solid line represents the typical development curve for cotton growing under optimum conditions.

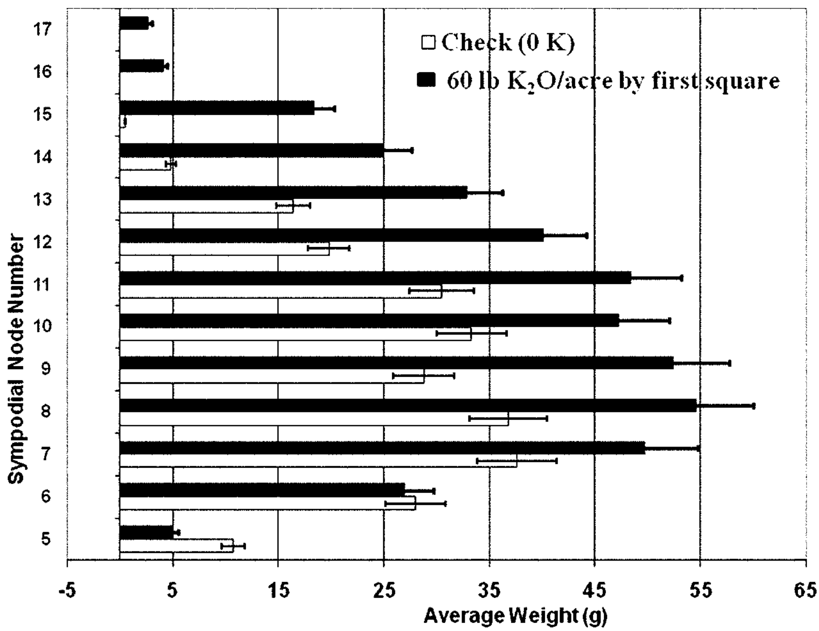

Fig. 2. Average seedcotton yield, and associated standard deviations, according to sympodial node for cotton receiving 60 lb K_2O/acre by first square or no K fertilizer (n = 30).

Evaluation of Nitrogen Use of Modern Cotton Cultivars Based on Seed Size

T. Barber[1]

RESEARCH PROBLEM

Introduction of new transgenic traits in current cotton cultivars has resulted in both rapid release as well as rapid turnover of available cotton cultivars for planting. Due to this rapid turnover, little is known in regard to performance and management of these cultivars once released. Research has been conducted to evaluate the nutrient requirements and nutrient removal of high performing cotton cultivars. However little research has been conducted to evaluate whether or not there is a difference in nitrogen requirements or removal between large and small seeded cultivars. The variability in cotton seed size has been recorded for many years and current cultivars range from 4,000 to 5,800 seed per pound. The objectives of this research proposal were to: (1) compare the nitrogen use of cultivars based on their seed size, (2) determine the effect of seed size on nitrogen use requirement, (3) determine the utility of nitrate testing in non-arid and arid environments, (4) evaluate possible maturity changes due to nitrogen utilization by seed size, and (5) evaluate nitrogen response of modern cotton cultivars across the cotton belt.

BACKGROUND INFORMATION

A study to compare nitrogen uptake and response of multiple cotton cultivars based on their seed size was established on the Lon Mann Cotton Branch Station (*Gossypium hirsutum* L.) near Marianna, Ark. A uniform Calloway silt loam field was selected and all plots were irrigated.

RESEARCH DESCRIPTION

Six-row small plots were configured in a randomized complete block design with a factorial arrangement of treatments and four replications. Three seed sizes

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(Stoneville 5288B2F, Deltapine 0924B2RF, and Fibermax 1740B2F) were planted to represent the small (5750 sd/lb), medium (4800 sd/lb) and large (4382 sd/lb) seed size, respectfully. All cultivars were subject to 0 lb, 40 lb, 80 lb, 120 lb, and 160 lb of total applied nitrogen per acre. Liquid UAN (urea ammonium nitrate 32, 0, 0) was the nitrogen source utilized and was applied prior to pinhead square.

Prior to planting, two soil samples were taken from each plot to a total depth of 24 in. The first sample was representative of a 0-6-in. depth and a total nutrient analysis was conducted. The second was a 12-in. sample taken from 6-24-in., and only available nitrate nitrogen (NO_3) was measured. Both samples were combined to determine total available nitrate nitrogen in a 24-in. depth.

Plant height, node above white flower (NAWF), total main-stem nodes, and nodes above cracked boll (NACB) were recorded during the season. Defoliation was done when each plot displayed 60% open bolls. Lint turnout, lint yield, micronaire, fiber length, fiber, strength, uniformity, and color grade were all measured after harvest. Seed index was calculated by taking the weight of 100 seed from three seed subsamples from each plot, followed by a seed nitrogen concentration analysis.

RESULTS AND DISCUSSION

A factorial analysis of variance was conducted and results indicated that no variety by nitrogen rate interaction existed among the data. Therefore all results are reported as main effects of cultivar seed size or nitrogen rates. Data analysis suggests that differences did exist among cotton cultivars. Fibermax 1740B2F was the shortest variety at harvest by approximately 4 inches and had the least total nodes by maturity (Table 1). Further analysis suggests that cultivars were different in regard to lint yield but not lint turnout. Deltapine 0924B2RF was the highest yielding variety in the study followed by Stoneville 5288B2F and Fibermax 1740B2RF. Differences also existed with fiber quality properties such as micronaire. Stoneville 5288B2RF had the highest micronaire at harvest at 5.28 (Table 1). Differences recorded among cultivars appear to be related to genetic background and do not appear to correspond to differences among seed sizes. There was no interaction between seed size and nitrogen rate, therefore most differences in cultivars can be attributed to performance and genetic variability.

Main effects of nitrogen rate were significant for multiple observations (Table 2). Increased nitrogen rates resulted in increased plant heights, total number of nodes and total number of bolls per plant, which was expected (Table 2). Higher nitrogen rates also led to later maturing cotton. As nitrogen rates increased, nodes above cracked boll (NACB) also increased resulting in delays of overall crop maturity and boll opening (Table 2). Gin turnout was also affected, where higher turnouts were associated with lower total nitrogen rates. This indicates that the number of seeds per boll may decrease with lower nitrogen rates, causing an increase in fiber sites on individual seeds resulting in an increase of lint turnout. Lint yield was positively affected by nitrogen rates, where highest lint yields were achieved with nitrogen rates between 80 and 120 lbs of applied nitrogen per acre (Table 2). Micronaire readings ranged from 5.37 to 4.89 and were much higher under low nitrogen applications (Table 2). Adjusting nitrogen rates to match cultivars could potentially provide another management tool for managing micronaire levels. Figure 1 contains cotton yield data when plotted over total nitrogen available through both soil nitrate levels as well as applied nitrogen. According to the regression curve, the optimum range for nitrogen application on silt loam soils, under irrigated conditions is from 130 lb to 140 lb/acre total available nitrogen.

PRACTICAL APPLICATION

Based on the data collected, producers should deep-sample cotton fields to ascertain levels of available nitrate nitrogen. Once soil levels are determined supplemental nitrogen should be applied to total no more than 140 lb/acre for irrigated silt loam soils. This recommendation closely resembles current recommendations provided by the University of Arkansas Division of Agriculture. Measuring residual nitrogen levels will become very important in the future, especially with nitrogen prices increasing. If residual levels are known, producers could potentially save money by figuring the amount of residual nitrogen in the overall nitrogen application, especially when following rotational crops such as corn and soybean.

Table 1. Effects of plant characteristics and cotton lint variables for main factor of cotton seed size.

Cultivars	Seed Size	Plant Heights (in)	Total Nodes	Total Bolls/Plant	NACB	Lint Percent	Lint Yield (lb/acre)	Mic	Length	Uniformity	Strength
ST 5288B2RF	Small	39.9	19.07	12.69	3.69	45.12	1496.3	5.28	1.111	82.35	26.56
DP 0924B2RF	Medium	39.5	18.41	12.2	3.3	44.39	1533.6	5.16	1.086	82.64	27.6
FM 1740B2RF	Large	35.41	17.83	11.38	3.01	44.92	1435.4	4.89	1.104	82.1	27.77
$LSD_{(0.05)}$		1.39	0.86	NS	NS	NS	55.9	0.2	0.014	NS	NS

Table 2. Effects of plant characteristics and cotton lint variables for main factor of nitrogen rate.

Nitrogen Rate (lb N/acre)	NO_3 Nitrogen[1]	NO_3^+ Applied[2]	Plant Heights (in)	Total Nodes	Total Bolls/Plant	NACB	Lint Percent	Lint Yield (lb/acre)	Mic	Length	Uniformity	Strength
0	33.1	33.1	30.85	15.8	10.08	1.73	46.18	1235.3	5.37	1.083	81.99	25.96
40	33.5	70.5	37.13	17.62	11.53	2.8	45.35	1462.7	5.08	1.098	82.31	27.32
80	36.1	116.1	37.9	18.65	12.65	3.3	45.08	1558.2	5.23	1.107	82.77	27.48
120	41.9	162	42.4	20	13.2	4.38	44.12	1602.3	4.98	1.113	82.56	27.94
160	39.7	200	43.07	20.12	12.98	4.45	43.32	1583.7	4.89	1.101	82.18	27.84
$LSD_{(0.05)}$	NS		1.8	1.4	1.5	0.85	0.69	71.4	0.25	0.18	NS	0.66

[1]NO_3 Nitrogen: Plant available nitrate nitrogen levels present from 0 to 24-inch depth.
[2]NO_3^+ Applied: Sum of measured plant available nitrate nitrogen and applied nitrogen.

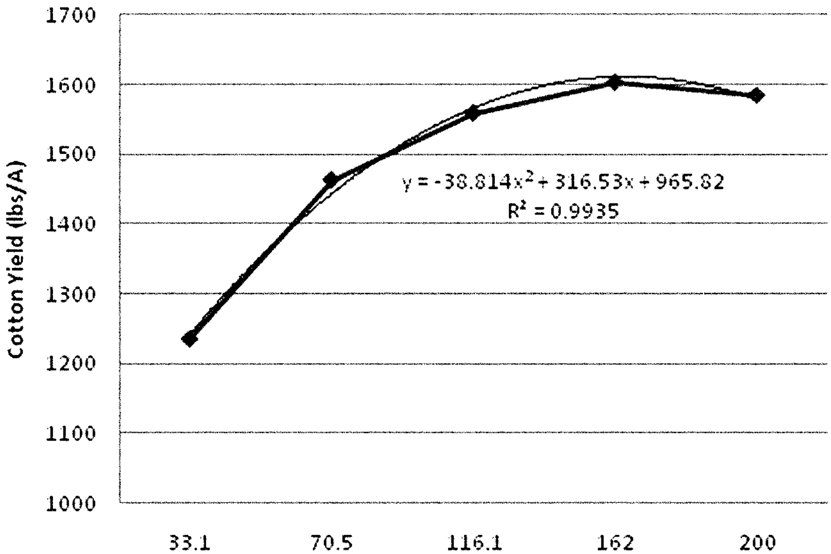

Fig. 1. Total nitrogen requirements for maximum yield potential.

Achieving Profitable Cotton Production: Irrigation Initiation and Termination

T. Barber[1] *and P. Francis*[2]

RESEARCH PROBLEM

Traditionally, initiation of irrigation occurs after the lay-by operations are completed in the field. Yet, improvements in pre-harvest management allow producers to initiate irrigation earlier. It is thought that changing the timing of irrigation initiation may also affect the timing of irrigation termination. In 2010, Arkansas harvested cotton on approximately 540,000 acres, with over 85% of those acres irrigated (NASS, 2010). Timely irrigation of cotton has been shown to increase yields, making irrigation a matter of importance. Vories et al. (2002) estimated that the cost of delayed irrigation was $106.00 per acre. Early and timely irrigation management is one way to manage environmental stresses and aid the cotton plant in cooling, thus increasing photosynthetic activity and productivity. Knowledge of the interaction effects of irrigation initiation and termination timing are limited. The objective of this research is to expand the current knowledge bases regarding the timing of irrigation initiation in Arkansas and determine if initiation affects COTMAN based irrigation termination timing for Arkansas cotton.

BACKGROUND INFORMATION

Initiated in 2007, two Upland cotton study sites with differing soil types were selected in Desha County. Site one (Ross field) was located on silt loam soil; site two (Center field) was located on clay loam soil. Study plots extended the full length of the field. Buffer strips were established between each termination treatment to help control error. Standard grower practices were utilized throughout the study. COTMAN data was collected weekly (Oosterhuis and Bourland, 2008). Partial budgeting and economic techniques were employed to identify yield and profit maximizing irrigation initiation and termination points.

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RESEARCH DESCRIPTION

The experimental design of the study was a split-plot design with irrigation representing main-plot treatments and irrigation termination representing subplot treatments. Three treatments were used to test the effect of irrigation initiation. Treatments were (1) initiating irrigation prior to a traditional lay-by (Early Initiation), (2) initiating irrigation after an early lay-by (Mid-Initiation), and (3) initiating irrigation after a traditional lay-by (Late Initiation). Three treatments were used to test the effect of irrigation termination. Treatments were (1) terminating irrigation at nodes above white flower (NAWF) = 5 + 300 accumulated DD60 heat units (Early Termination), (2) terminating irrigation at NAWF = 5 + 450 accumulated DD60 heat units (Mid Termination), and (3) terminating irrigation at NAWF = 5 + 600 accumulated DD60 heat units (Late Termination). In 2010, Early initiation irrigation timings occurred on 22 June Mid-initiation on 30 June and Late initiation on 7 July. Frequent rainfall early season, and record accumulations late season affected initiation and termination treatments in both fields. Cotton was harvested from both study sites the first week in September. Yield Monitor data was utilized to separate treatment mean differences. Cotton data were analyzed by ANOVA of ARM Research Manager (Gylling Data Management, Inc., Brookings, S.D.). In the presence of significant treatment effects ($P < 0.05$), means were separated using least significant differences.

RESULTS AND DISCUSSION

The 2010 growing season was one of the hottest and driest in recent memory. Although sporadic rainfall events did occur, 2010 was an excellent year in regard to weather for the irrigation initiation/termination project. Irrigation was started when cotton growth reached 10 nodes, 13 nodes, and the first week of full first flower for the early, mid and late timings, respectively. Irrigation was terminated as close to 300, 450 and 600 heat units after NAWF as possible. Due to high heat unit accumulation and irrigation logistics, actual termination heat units varied for each termination. Rainfall in the amount of 2.4 inches was received at approximately 600 heat units after cutout which corresponded to the last irrigation termination. Therefore it was decided to extend the last termination by one week to determine if any differences would occur when watering late in a hot dry year like 2010. Cotton plants on the silt loam soil in the Ross field were taller and had increased NAWF numbers when irrigation was initiated prior to first flower. Irrigation after first flower resulted in shorter plants and less nodes at first flower which correlates to delays in cotton growth and development and could result in early or premature plant cutout. Plants in the silty-clay loam soil of the Center field did not vary as greatly across irrigation treatments. The clay soil maintained higher moisture content longer and therefore plants were not under as much water stress as those in the Ross field.

Cotton yields for the Ross field in 2010 were highest when irrigation was initiated at the mid timing, or one week prior to first flower, where cotton lint yields were increased 120 lb/acre over the late timing. The three year average yields for the Ross field show similar results (Fig. 1). Mid initiation timings yielded higher than any late initiation timing on the silt loam soil (Fig. 1). However, irrigation termination plays a large role as well. The three year average results for the Ross field indicate that if irrigation is started late, yields can be increased by extending irrigation late in the season or terminating around 600 heat units after cutout (Fig. 1). Results from the Center field are quite different than the Ross (Fig. 2). The clay loam soil of the Center field apparently had a much higher water holding capacity than the Ross field. The three year average cotton yield data, even the dry year of 2010, resulted in no significant differences in cotton lint yield under any irrigation initiation or termination treatment.

Data from the Ross field was broken down further from 2010 and cotton fiber quality, number of irrigations, as well as gross returns after irrigation were evaluated. The mid irrigation initiation and early termination resulted in the highest return over irrigation investment at $979.27 (Table 1). This return is based on the cotton lint yield, a base cotton price of $0.75/lb, before premiums and discounts, and a cost of $9.00/acre for each irrigation. Fiber quality was also affected by irrigation initiation and termination. All values were listed in the discount range for micronaire but were lower when irrigation was started at the mid timing and terminated at 300 heat units (Table 1).

PRACTICAL APPLICATION

The results of this three-year study indicate that the critical period for irrigating a silt loam soil is the week prior to first flower. The peak water uptake period for cotton is two to three weeks after first flower, when cotton bolls require high amounts of moisture and nutrients to fill out and mature. Providing the soil with ample moisture before this boll fill period is critical especially under hot and dry conditions. Every year is different, but producers should be prepared to irrigate by the time the cotton reaches 11-12 nodes of growth. The appropriate time to terminate irrigation on a silt loam soil appears to be between 350 and 450 heat units, based on these data. The clay loam soil responded differently and irrigation could be delayed until first flower and potentially terminated earlier with cotton grown on heavier soil types similar to the Center field. Producers should always use local knowledge of fields when deciding when to start or stop irrigation; results will vary from field to field. Soil type and cotton rooting depth play a big role in irrigation scheduling, but critical periods for water demand in cotton will be constant.

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Table 1. Cotton lint yield, turnout, plant characteristics, fiber quality, number of irrigations and gross returns after irrigation costs for the Ross field, silt loam soil 2010.

Irrigation Timing	Lint Yield	Lint Percent	Total Nodes	NAWF 6/21/10	Heights 6/28/10	Length	Strength	Uniformity	Micronaire	Number of Irrigations	Returns after Irrigation Cost
Early - 300[a]	1388	41.00	19.37	8.00	37.7	1.167	31.8	83.67	5.27	5	$931.24
Early – 450	1363	42.00	19.67	8.00	30.7	1.153	31.23	83.2	5.37	6	$904.40
Early – 600	1344	40.00	19.9	8.70	34	1.17	31.9	84.17	5.37	7	$881.12
Mid – 300	1444	42.00	20.43	8.30	32.3	1.173	31.2	83.8	5.1	5	$979.27
Mid – 450	1431	42.00	20.47	7.00	35.3	1.143	31.1	83.03	5.37	6	$953.40
Mid – 600	1419	43.00	21.47	7.70	32.7	1.17	30.73	83.04	5.23	7	$935.77
Late – 300	1366	42.00	21.4	6.70	24	1.173	33.07	84.27	5.4	4	$917.47
Late – 450	1299	41.00	21.17	6.70	24	1.167	31.87	83.4	5.27	5	$867.05
Late – 600	1346	42.00	21.23	6.00	25	1.13	31.33	83	5.37	6	$891.82
$LSD_{(0.05)}$	57	0.014	1.342	2	4.5	0.05	2.1	1.7	0.25		

[a]"Early, Mid and Late" represents irrigation initiation timing and "300, 450 and 600" represents heat unit accumulation targets for irrigation termination.

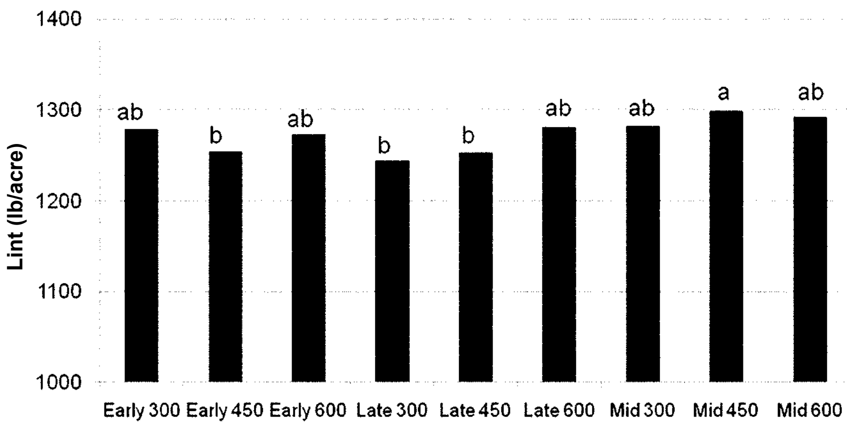

Fig. 1. Three year average cotton lint yields (lb/acre) listed by irrigation initiation and termination for the Ross field. "Early" represents irrigation initiation and "300" represents heat unit accumulation for irrigation termination. Yield means with similar letters are not significantly different.

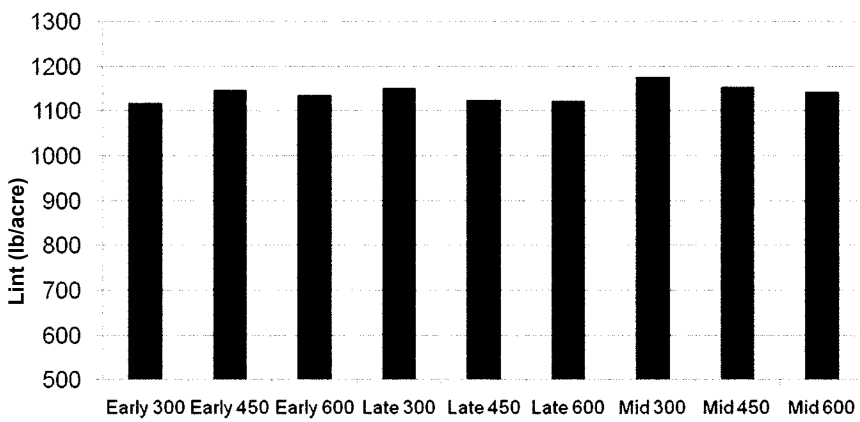

Fig. 2. Three year average cotton lint yields (lb/acre) listed by irrigation initiation and termination for the Center field. "Early" represents irrigation initiation and "300" represents heat unit accumulation for irrigation termination. Yield means with similar letters are not significantly different.

Sustainable Cotton Production: The Effects of Best Management Practices on Water, Sediment, and Soil Quality

J.L. Bouldin[1], R.A.F. Warby[1], P. Yu[1], and T.G. Teague[1]

RESEARCH PROBLEM AND BACKGROUND INFORMATION

Sustainable farming practices such as conservation tillage and cover crops are often adapted as Best Management Practices (BMP) by Mid-south cotton farmers. Studies show that land management practices can reduce the runoff of sediment, pesticides, and nutrients resulting in positive impacts on waterways adjacent to agricultural lands (Phillips et al., 2006). Sustainable agriculture is of utmost importance to maintain food and fiber production for a growing global population. According to the EPA (US EPA, 2008) sediments are the leading contributor to non-point source pollution. Past studies have noted that agricultural BMPs such as conservation tillage (NT), cover crops (CC), and riparian zones can be incorporated with vegetative processes to minimize contaminant transport to downstream water bodies (Bouldin et al., 2004a,b; 2007). Increased cotton lint yields have also been measured with some CC studies (Daniel et al., 1999) measuring economic and environmental benefits of this BMP. Management practices to improve water quality can be attained in the production field and at the edge of field. This study focuses on the use of on-field BMPs to measure water and soil qualities from field plots using conventional tillage (T), NT and CC management techniques.

RESEARCH DESCRIPTION

The experiment was carried out at the Judd Hill Foundation Cooperative University Research Farm, Poinsett County, Ark. It was arranged as a split-plot design with three tillage systems: conventional tillage (T), no-till (NT), and NT plus legume/cereal cover crops (CC), considered main plots. Insect pest control regimes were considered sub-plots: fertilizer and pesticide application data are found in Table 1. Main plots were 16-rows wide and 450-ft long. Sub-plots were 16-rows wide, 75-ft long with 10-ft alleys. Test plots were installed in 2007. For the 2010 crop, the wheat cover crop was planted in November 2009 at 10 lbs

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wheat seed /acre. The cover crop was terminated with glyphosate ca. 30 days before planting. Cruiser treated (thiamethoxam) Stoneville 4554 B2RF was planted on 7 May 2010 in the Dundee silt loam soil at 3-4 seeds/ft. Production practices were similar across all tillage treatments in-season with the following exceptions used only in T main plots: disk bedders (hippers) used to re-form beds in early spring, tops flattened just prior to planting with a DO-ALL, row middles (water furrows) cleared with sweep plows prior to first furrow irrigation. No cultivations were made in any treatments.

Water and sediment were collected from field plots following four irrigation and two rainfall events (Table 2). Five-gallon (11-liter) buckets were placed flush with the ground in each field plot and a 4-gallon (8-liter) collection bucket was placed within the larger bucket for water collection. A plastic drop cloth was used to funnel water into the collection bucket through the water furrows within the respective treatment. An 8-L aqueous grab sample was extracted from each bucket following sampled runoff events. Transported sediment for laboratory bioassays was collected up-trench from the buckets. Water and sediment samples were placed on ice and transported to Arkansas State University (ASU) Ecotoxicology Research Facility for analyses.

Soil samples were collected from 3 rows within each plot and at three locations within each row (at the ends and in the middle) resulting in nine main sampling locations within each plot. Soil for bulk density determination was collected from the hip to a 10-cm depth. Furrow samples were collected from the furrows behind and in front of the bulk density sample. Due to time constraints and the timing of farming activities, No Till plot 3 and Till plot 3 only had 8 and 4 main sampling locations, respectively. Soil pH was measured on both hip and furrow samples.

Water Quality Analyses

Water quality measures included temperature, dissolved oxygen (DO, mg/L), pH, conductivity (µS/cm) tested on site using a VWR™ SympHony meter (VWR, Radnor, Pa.). Water was then placed on ice, transported to ASU and tested for alkalinity (mg $CaCO_3$/L), hardness (mg $CaCO_3$/L), total suspended solids (TSS mg/L), and turbidity (NTU). Nutrient measurements included dissolved nitrites, nitrates, phosphorus–filtered on-site immediately following collection and frozen following transport–and total N and P. Nitrogen and P were determined on unfiltered waters frozen following transport and to determine total (dissolved + particulate) N and P. Nutrients were determined using a LACHAT Quikchem 8500 Flow Injection Analysis (FIA) automated nutrient analyzer (Lachat Instruments, Loveland, Colo.) following American Public Health Association (APHA, 2005) guidelines.

Laboratory Bioassays

Ceriodaphnia dubia and *Pimephales promelas* 7-d chronic bioassays were used to assess the water quality of runoff samples in accordance with EPA guidelines (US EPA, 2002a). Sediment quality was tested using *Chironomus dilutus* in a 10-d acute toxicity test in accordance with EPA guidelines (US EPA, 2000b).

Soil pH and Bulk Density

The soil pH was determined in both distilled water and 0.01 M $CaCl_2$. The pH of mineral soils was prepared by adding 20 mL of solution to 20 g of soil. The pH electrode was placed in the supernatant of the soil suspension. After a stable reading was achieved, the soil pH was measured to the nearest 0.01 pH unit. The bulk density of the soil was determined by the corer method. A soil core, using a hammer, stainless steel barrel, and an acetate sleeve, was collected from the top 10 cm of the soil profile (on the hip). Soil bulk density was calculated on a soil dry-mass basis.

Statistical Analyses

Results of aqueous bioassays were calculated using ToxCalc™ Version 5.0 (Tidepool Scientific Software, 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 Version 13 (Minitab, Inc., State College, Pa.).

RESULTS AND DISCUSSION

Water Quality

Total suspended solids in runoff from irrigation events were significantly lower than the rainfall event on 12 July 2010 for all test plots (Fig. 1). This storm event mobilized more suspended solids than the other measured events combined. Mean TSS and turbidity values for all events (Figs. 1 and 2) illustrate the effectiveness of cover crops in reducing soil loss from production fields. Although no significant differences of turbidity were measured in runoff from cover crop plots, numerical differences illustrate reduction of mobilized sediment from production fields.

Total N and P measurements include particulate and dissolved, representing a more comprehensive view of nutrients present in runoff. Dissolved phosphorus was significantly higher in the rainfall event following defoliation on 11 September 2010 (Fig. 3). These high values most likely resulted from water soluble phosphorus leaching from the defoliated leaves and also accounts for the higher mean values for cover crop treatments. The highest nitrate values were measured following the irrigation event on 9 July 2010 (Fig. 4), most likely resulting from residual urea following application in late June.

Cover crop treatments resulted in significantly lower total P measurements in irrigation runoff events. Total mean values ranged from 0.16-0.24 mgP/L (CC and T, respectively). A comparison of the mean total P of all runoff events (irrigation and rainfall) illustrates the conservation of P with cover crop treatments. Dissolved PO_4 as seen in Fig. 3 does not reveal a savings of P on the agricultural field; however when the particulate and dissolved P are measured, these savings are noted. When comparing total N and P in the runoff, it is important to note that dissolved values are reported as mg PO_4/L and total P is reported in mg P/L (the same is true for dissolved and total N). Thus care must be taken in making a direct comparison of these measured results. Mean total N values are comparable as averaged for all runoff events measured. No significant differences are seen as these values range only from 1.68 -1.82 mg N/L.

Laboratory Bioassays

Water collected following irrigation and rainfall events elicited toxic responses to aquatic test organisms fewer times than during 2009 studies (Bouldin et al., 2010) (Table 3). Decreased survival and reproduction in the test organisms, *C. dubia*, was the measured toxic response most often measured. *Ceriodaphnia dubia* are sensitive bioindicators of pesticide contamination (Bailey et al., 1996). Decreased survival and reproduction were measured in no till plots following runoff events on 18 June 2010, 4 August 2010, and 11 September 2010, following pesticide applications (Table 1). Runoff collected from a cover crop plot following the 4 August 2010 irrigation event also elicited toxicity. Low TSS values measured in runoff from that event indicate that the toxicity was unrelated to sediment-associated contaminants. Decreased survival in *P. promelas* measured in runoff from no till and cover crop following the rainfall event on 11 September 2010 can be attributed to excess organic matter in aqueous samples. Hypoxic conditions (DO $\leq$ 3.5mg/L) resulted in mortality of test fish. Although samples are aerated prior to test setup to compensate for hypoxic waters, lack of continued aeration resulted in low DO during test duration. No toxicity was measured in sediment collected after irrigation and rainfall events. Fewer aqueous and sediment toxic events measured in the 2010 production season than in 2008 and 2009 may have been a result of improved experimental design, collection techniques, and a dry 2010 cropping season.

Soil Quality

Bulk density for cover crops and tilled plots were lower than no till plots by 0.05 g/cm^3 (Table 4). This difference is neither statistically significant at the $P = 0.05$ level nor is it practically different. Soil pH of 5.5 to 6.8 is an optimum range for maximum soil nutrient availability and microbial activity (Mullins and Hansen, 2006). All pH values measured in plots were within this optimum range (Table 4). Soil pH of the tilled plots was likely higher than the other plots for two reasons. Firstly, in the no till plots a mixing of fertilizer in the soil layers does not occur; urea on the surface can lower the surface pH (soil samples were collected in the upper 10 cm of the soil proifile). Secondly, in the cover crop plots the organic matter from the cover crop will produce organic acids on decomposition, also resulting in a lower soil pH. It is very important to note that generally soil properties are slow to change. Given that this is only the third year of study, we can expect more definitive and greater magnitude changes in the coming years.

CONCLUSIONS

Improved collection methods for aqueous testing resulted in fewer toxic events measured through bioassays. Results of this study also illustrate the effectiveness in cover crops in reducing associated contaminants from agricultural fields. Sediment is listed as the leading contributor in non-point pollution (US EPA, 2008), thus sediment reduction is of primary concern with BMP implementation. Sediment reduction also results in decline of contaminants associated with runoff which are also detrimental to aquatic ecosystems. Fewer measured toxic responses to aquatic organisms may be resulting from improved aqueous collection techniques or improved management techniques. Soil quality measured in this study reflected subtle changes and more definitive differences are expected with long-term studies.

Soil and water sustainability are vital to maintaining production of food and fiber to meet present and future global needs. As Midsouth cotton producers strive to maintain the natural resources to meet this challenge, studies such as this are vital to explore the most attainable management practices for production.

ACKNOWLEDGMENTS

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Table 1. Pesticide and harvest-aid chemical application dates in 2010 for specific tillage treaments.

Date	Pesticide Product	Treatments Applied
16 May 2010	Prowl + cotoran	T, NT
18 May 2010	Roundup weathermax	T, NT, CC
28 May 2010	Roundup weathermax	T, NT, CC
2 Jun 2010	Urea	T, NT, CC
10 Jun 2010	Roundup weathermax	T, NT, CC
16 Jun 2010	Pix	T, NT, CC
22 Jun 2010	Centric	T, NT, CC
23 Jun 2010	Urea	T, NT, CC
30 Jun 2010	Pix	T, NT, CC
7 Jul 2010	Centric	T, NT, CC
22 Jul 2010	Centric	T, NT, CC
30 Jul 2010	Pix	T, NT, CC
2 Aug 2010	Bidrin	T, NT, CC
27 Aug 2010	Def + Prep	T, NT, CC
3 Sep 2010	Finish + Ginstar	T, NT, CC

Table 2. Water sampling events at Judd Hill in 2010 including runoff source and rainfall amount.

Date	Type of Event	Amount
18 Jun 2010	Irrigation	Surge - furrow
24 Jun 2010	Irrigation	Surge - furrow
9 Jul 2010	Irrigation	Surge - furrow
12 Jul 2010	Rainfall	3.06 inches
4 Aug 2010	Irrigation	Surge - furrow
11 Sep 2010	Rainfall	0.43 inches

Table 3. Toxic responses in aqueous runoff collected from field plots following irrigation and rainfall events. Numbers denote an occurrence of toxic response measured as significantly different from controls.

	C. dubia		*P. promelas*	
Field Plot	**Survival**	**Reproduction**	**Survival**	**Growth**
Till A	0	1	0	0
Till B	0	1	0	0
Till C	0	0	0	0
No Till A	2	1	0	0
No Till B	1	2	0	0
No Till C	0	1	1	1
Cover Crop A	0	0	1	0
Cover Crop B	0	0	0	0
Cover Crop C	1	1	0	0

Table 4. Average bulk density (g/cm^3) and soil pH (pH units) in 18 MΩ water and 0.01M $CaCl_2$ for the cover crop, no till, and till field plots.

	Bulk Density (g/cm^3)	pH (pH Units)	
Field Plot		**18 MΩ water**	**0.01M $CaCl_2$**
Cover Crop	1.40	6.49	5.88
No Till	1.45	6.52	5.87
Till	1.40	6.74	6.16

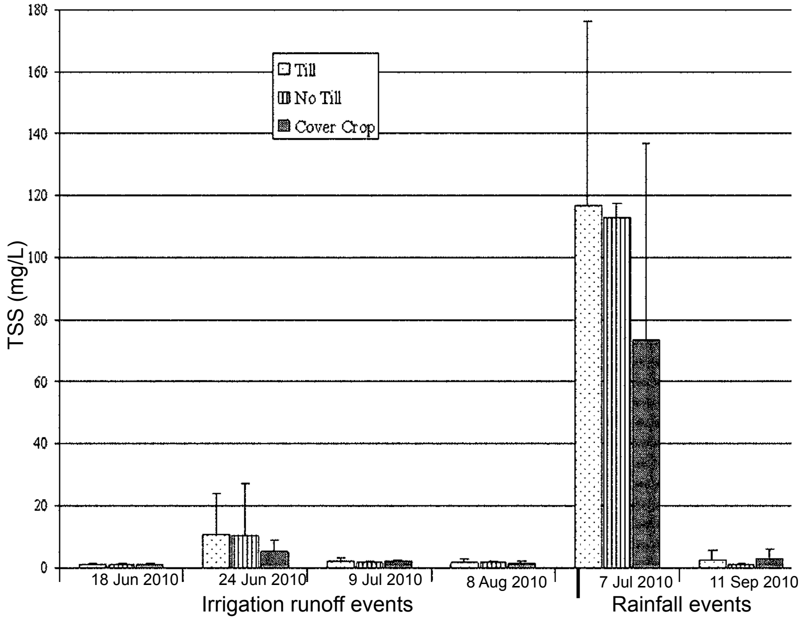

Fig. 1. Total suspended solids in mg/L from 2010 irrigation and runoff events collected from field plots at Judd Hill Plantation.

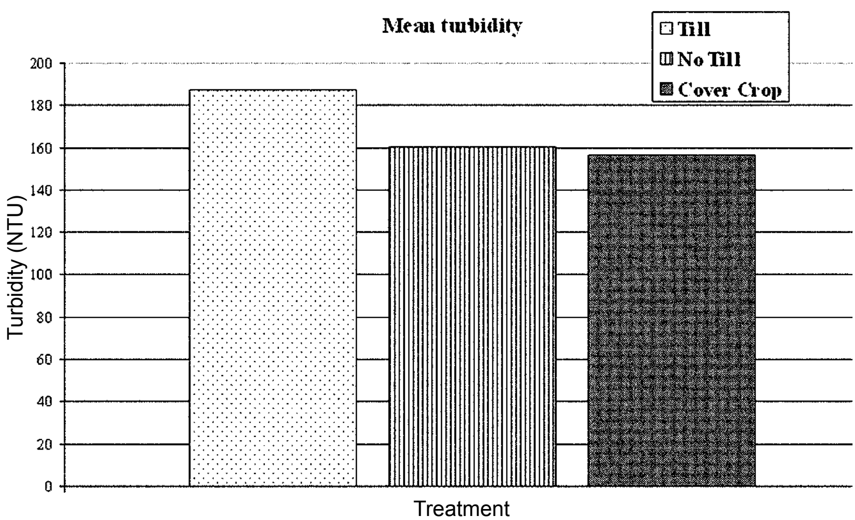

Fig. 2. Mean turbidity (NTU) averaged from 2010 irrigation and rain runoff events collected from field plots at Judd Hill Plantation.

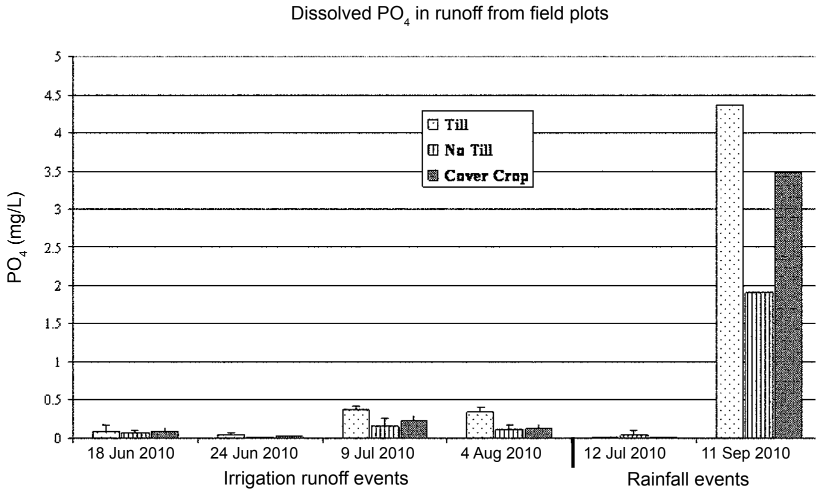

Fig. 3. Dissolved PO_4 collected following irrigation and rain events from field plots at Judd Hill Plantation. Only a single replicate sampled in till and cover crop on 11 September 2010.

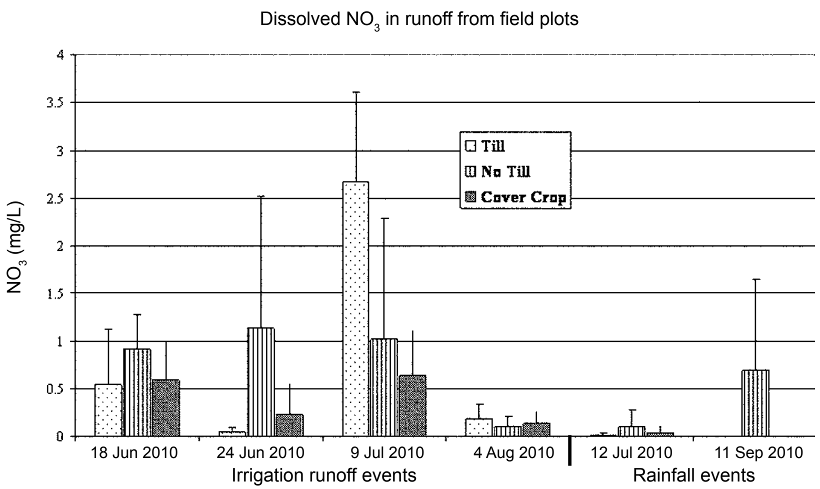

Fig. 4. Dissolved NO_3 collected following irrigation and rain events from field plots at Judd Hill Plantation. Values for till and cover crop represent only one replicate on 11 September 2010 measured as 0.0 mg/L.

Decreased Sensitivity of Palmer Amaranth to Glyphosate Through Selection

J.K. Norsworthy[1]

RESEARCH PROBLEM

The evolution of glyphosate-resistant Palmer amaranth is the result of over-reliance on glyphosate alone for weed control in glyphosate-resistant crops. It is believed that the use of reduced glyphosate rates may have contributed to the evolution of resistance in Palmer amaranth; however, data to support this hypothesis are lacking. Therefore, an experiment was conducted in the greenhouse at the University of Arkansas in Fayetteville to evaluate the increase in tolerance of progenies of Palmer amaranth from plants that had been treated with increasing rates of glyphosate at each generation.

BACKGROUND INFORMATION

Multiple applications of glyphosate are relied upon for weed management in glyphosate-resistant cotton, which comprises approximately 98% of the cotton acres in Arkansas (Norsworthy et al., 2007). Furthermore, glyphosate-resistant soybean was rapidly adopted by Arkansas producers. Palmer amaranth has historically been easily controlled with glyphosate, and its use in glyphosate-resistant crops was ideal for control of biotypes resistant to acetolactate synthase-inhibiting herbicides, such as pyrithiobac (Staple) and trifloxysulfuron (Envoke) among others. However, the continued use of glyphosate in these crops has resulted in glyphosate-resistant Palmer amaranth, which is now widely documented across the southern United States (Nichols et al., 2009; Norsworthy et al., 2007).

Field evidence indicates that multiple biotypes of glyphosate-resistant Palmer amaranth exist in Arkansas (Smith et al., 2008). One biotype has a high level of resistance to glyphosate, with little or no symptomology following treatment with glyphosate. A different biotype exists that has a low level of resistance, with partial control resulting from a field rate of glyphosate. Subsequent generations from this biotype appear to have less sensitivity to glyphosate (Smith et al., 2008). Similarly in neighboring states, a glyphosate-resistant Palmer amaranth biotype evolved having a low level of resistance (Steckel et al., 2008).

[1]Associate professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

Cotton consultants in Arkansas reported that lower-than-labeled glyphosate rates were sometimes used for weed control and noted that glyphosate rates have had to be increased each year to obtain satisfactory weed control (Norsworthy et al., 2007). Another common occurrence, especially in soybean, is that producers delay application of glyphosate with the hope of controlling more weeds with a single application. This strategy leads to glyphosate being applied to weeds larger than recommended on product labels, which is likely a low or suboptimal rate based on weed size.

RESEARCH DESCRIPTION

Palmer amaranth seeds were collected from a soybean field in Clarendon County, S.C., in 1986 and placed in cold storage. This population of Palmer amaranth was believed never to have been exposed to glyphosate. Based on previous dose response experiments, it was confirmed that this population is highly sensitive to glyphosate (Norsworthy et al., 2008). Progenies from the initial Palmer amaranth population from the South Carolina population were treated with increasing doses of glyphosate that were sublethal to a portion of the population over four generations. Plant death (live or dead) was determined at 21 days after treatment of each generation. Plants that survived the glyphosate application were transplanted to larger pots and allowed to produce seeds. A total of 300 plants from the first generation (F_0) was treated with glyphosate at 0.094 lb ae/acre. Glyphosate at 0.112 lb ae/acre was applied to 320 plants of the second generation (F_1 - progeny from treated survivors of F_0). For the third generation (F_2), 203 plants were treated with glyphosate at 0.188 lb ae/acre. A total of 153 plants of the fourth generation (F_3) were treated with glyphosate at 0.375 lb ae/acre. Seed produced by the F_3 survivors (F_4) and seed from the initial non-selected population (F_0) was sown in separate trays and then treated with a range of glyphosate rates at the eight-leaf stage. Twenty-four individual F_0 and F_4 plants were treated with a range of glyphosate rates, and plant death recorded at 21 days after treatment. A nontreated control was included. The lethal rate needed to kill 50% and 95% of each accession (LD_{50} and LD_{95}) was determined in PROC PROBIT in SAS.

RESULTS AND DISCUSSION

Of the 300 plants from the initial population that were treated with glyphosate, 42 plants survived the application, a 14% survival rate (Table 1). Further selection with increased rates of glyphosate appeared to reduce the sensitivity of Palmer amaranth to the herbicide. Following a glyphosate rate of 0.375 lb ae/acre for the fourth selection, there were 21 survivors from a total of 153 treated plants, a 13.7% survival rate. The probability of death from increasing rates of glyphosate for the initial population and F_4 population are shown in Fig. 1. Glyphosate at 0.188 lb ae/acre resulted in 100% mortality of the initial population (F_0) and 75%

mortality of the F_4 population (data not shown). The LD_{50} values differed between initial and final populations, with the initial population needing a glyphosate dose of 0.131 lb ae/acre to achieve 50% mortality compared to a glyphosate dose of 0.193 lb ae/acre for the F_4 population. Furthermore, the LD_{95} value for the initial population was 0.163 lb ae/acre glyphosate while that of the F_4 population was 0.349 lb ae/acre glyphosate.

PRACTICAL APPLICATION

Although survival of the seedlings at a recommended field rate of 0.75 lb ae/acre glyphosate was not achieved, reduced sensitivity of Palmer amaranth following repeated selection with sub-lethal rates of glyphosate was demonstrated. Under field conditions, there are numerous means by which Palmer amaranth can receive a sublethal rate of an herbicide. One such means is through application of a lower than recommended rate. Such practice was common in Arkansas in cotton prior to the widespread evolution of glyphosate-resistant weeds, where lower-than-label glyphosate rates were routinely applied, with increased rates needed in subsequent years to obtain adequate control (Norsworthy et al., 2007). These lower than recommended rates were applied in an attempt to reduce weed management costs. An additional contributing practice has been the delay of glyphosate applications, with hopes of controlling more weeds or managing to achieve season-long weed control with a single application, a common practice in soybean (Norsworthy, 2003). The practice of delaying applications results in sublethal rates as applications are made to weeds larger than those recommended on product labels. Furthermore, lack of adequate spray coverage can result in plants receiving sublethal herbicide rates. Regardless of the cause, it is apparent that lower-than-label rates of glyphosate do select for reduced sensitivity of Palmer amaranth to glyphosate, which could have contributed to some of the current widespread resistance problems that producers are facing with Palmer amaranth.

ACKNOWLEDGMENTS

The authors appreciate the financial support for this research provided by Cotton Incorporated.

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Table 1. Sequence of selection with glyphosate, glyphosate rate used to select for increased tolerance, number of seedlings treated with glyphosate, and number of seedlings surviving the glyphosate dose at 21 days after treatment.

Selection sequence	Glyphosate rate	Seedlings treated	Survivors
	lb ae/acre	#	# (%)
F_0	0.094	300	42 (14.0)
F_1	0.112	320	57 (17.8)
F_2	0.188	203	100 (49.3)
F_3	0.375	153	21 (13.7)

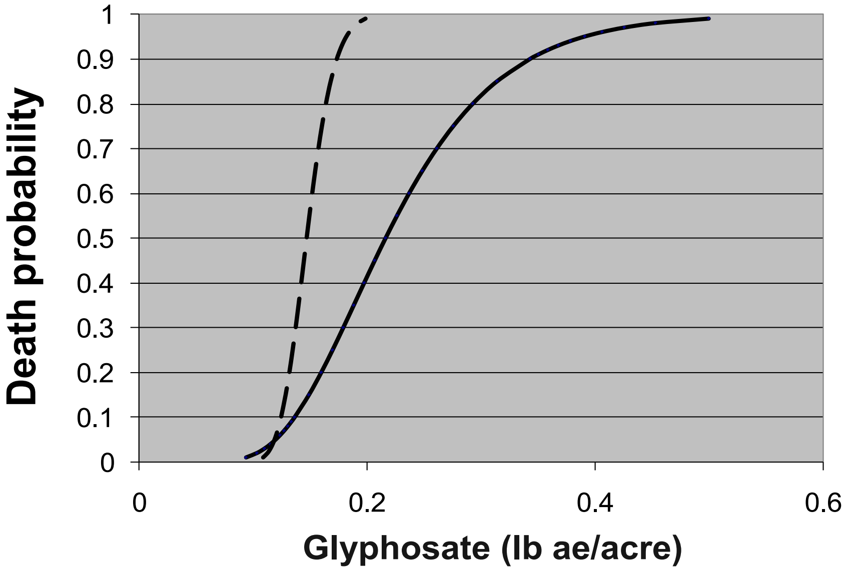

Fig. 1. Probit analysis to predict the glyphosate rate needed to kill F_0 (broken line) and F_4 (solid line) Palmer amaranth plants when treated with glyphosate at the eight-leaf stage.

Palmer Amaranth and Barnyardgrass Control as Influenced by Weed Size, Glufosinate Rate, Volume, and Spray Tip

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. The lack of control provided by glufosinate on large weeds may be caused by coverage issues. The objective of this study was to evaluate the effects of weed size, glufosinate rate, carrier volume, and spray tip on Palmer amaranth and barnyardgrass control.

BACKGROUND INFORMATION

Liberty Link® cotton was introduced in 2004 and grown on 1.9% of total cotton acreage. In 2010, 39% of total U.S. cotton acreage was established in Liberty Link® cotton. Liberty Link® technology is the preferred technology for controlling glyphosate-resistant Palmer amaranth in cotton. More information was needed on control of Palmer amaranth and barnyardgrass with glufosinate as influenced by weed size, glufosinate rate, carrier volume, and spray tip.

RESEARCH DESCRIPTION

A trial was established at in 2010 at Rohwer, Ark. in a Hebert silt loam soil. The trial was arranged in a randomized complete block design with a factorial treatment arrangement of three factors (glufosinate rate, volume, and spray tip) and four replications. Glufosinate was applied at two rates 19 and 29 oz/acre and four volumes 6, 8, 10, and 12 gal/acre (GPA). Tips used were Green Leaf Air Mix, Green Leaf AI XR, Tee Jet XR Flat Fan, and Tee Jet AI XR. Palmer amaranth and barnyardgrass control was recorded on a 0-100 scale with 0 being no control and 100 being complete control. Weed sizes evaluated were 12 inch and 18 inch Palmer amaranth and 12 inch barnyardgrass.

[1]Program technician, weed specialist/professor, program technician, and program technician, respectively, Southeast Research and Extension Center, Monticello.

RESULTS AND DISCUSSION

Twenty eight days after application Green Leaf Air Mix provided 66% control of 18 inch Palmer amaranth which was statistically lower than all other tips. Tee Jet AI XR provided lower control (96% and 87%) of 12 inch Palmer and barnyardgrass respectively (Fig. 1). Lower control was noted with 19 and 29 oz/A rates of glufosinate at 6 GPA (Figs. 2 and 3). At 6 GPA, Tee Jet AI XR provided less weed control than all other tips (Fig. 4). Weed control at 8, 10, and 12 GPA among tips and herbicide rates was equal. Treatments applied at 12 GPA provided the highest percent weed control (Fig. 4).

PRACTICAL APPLICATION

Liberty Link® technology can be a useful tool in controlling glyphosate–resistant Palmer amaranth. 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.

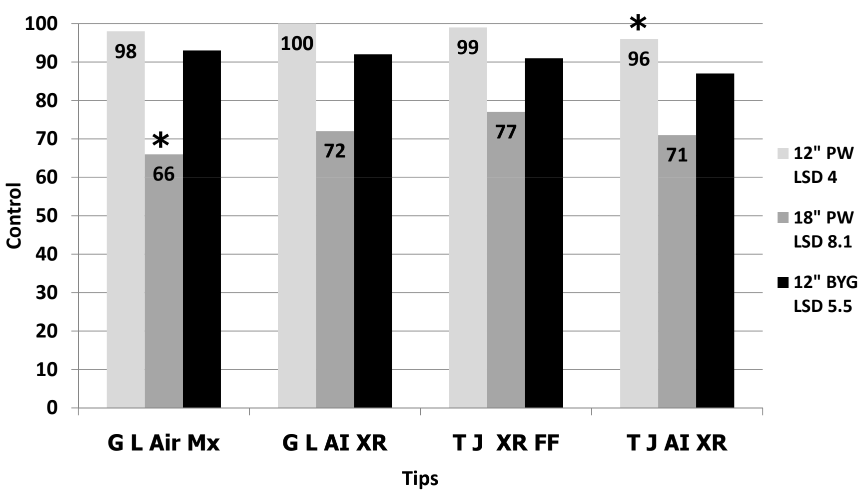

Fig. 1. Weed control differences among tips. *Indicates significant differences (*P* = 0.05).

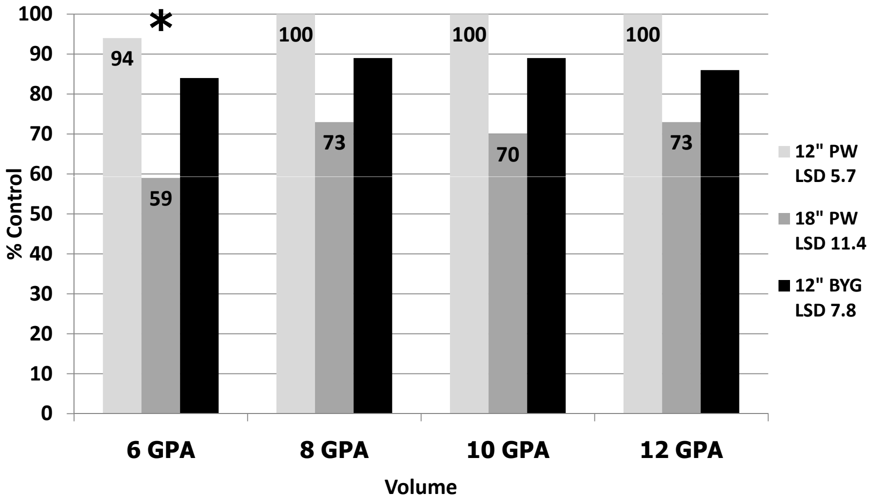

Fig. 2. Weed control differences among volumes at 19 oz/acre. *Indicates significant differences (*P* = 0.05).

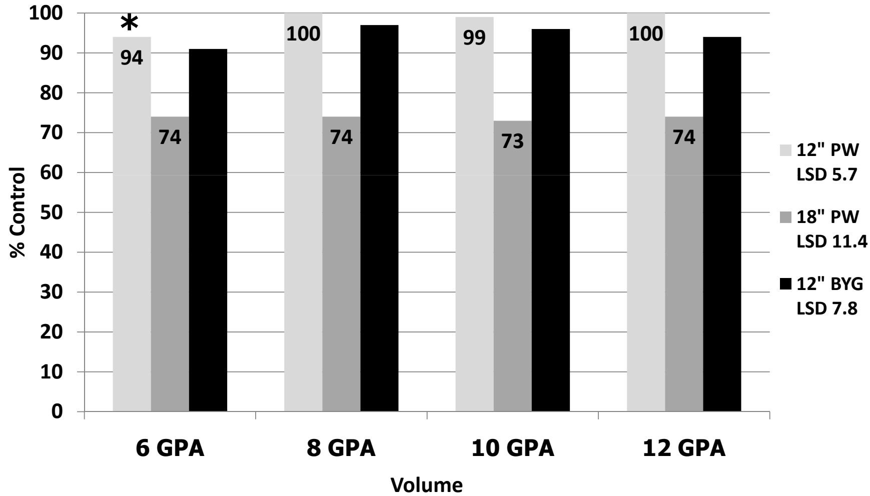

Fig. 3. Weed control differences among volumes at 29 oz/acre. *Indicates significant differences (*P* = 0.05).

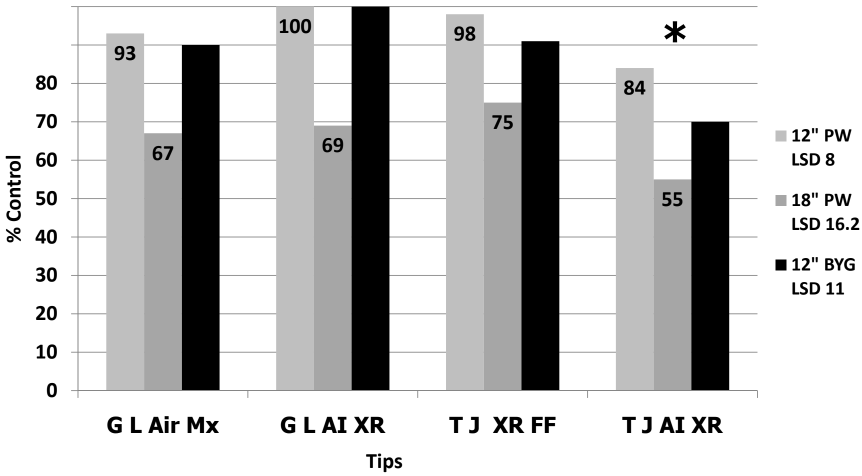

Fig. 4. Weed control at 6 GPA. *Indicates significant differences (*P* = 0.05).

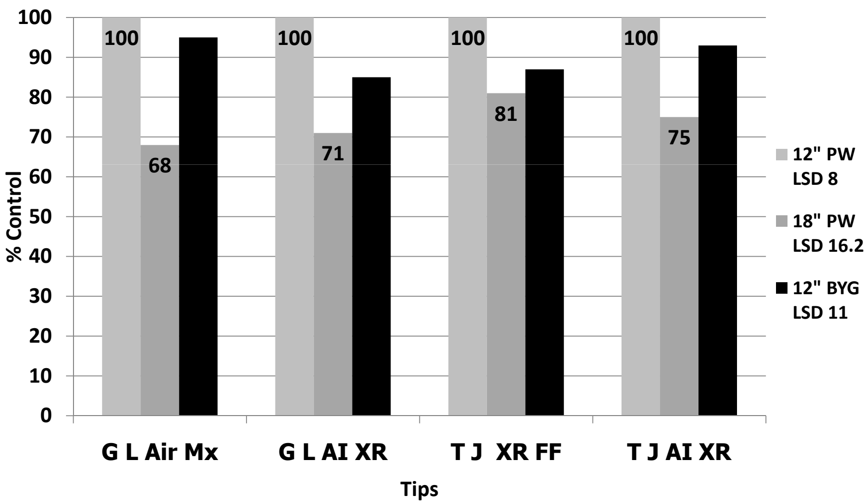

Fig. 5. Weed control at 12 GPA.

Influence of Deep Tillage and a Rye Cover Crop on Palmer Amaranth Emergence in Cotton

J.D. DeVore, J.K. Norsworthy, M.J. Wilson, G.M. Griffith, and D.B. Johnson[1]

RESEARCH PROBLEM

Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) is one of the most troublesome weeds Arkansas cotton producers are dealing with today. Palmer amaranth is causing problems in Arkansas cotton fields by lowering yields and reducing harvesting efficiency. Arkansas cotton producers are relying primarily on glyphosate-resistant cotton and heavily on the use of glyphosate, and as a result, glyphosate-resistant Palmer amaranth is not being adequately controlled in many fields. Therefore, an alternative solution to controlling glyphosate-resistant Palmer amaranth is needed.

BACKGROUND INFORMATION

For more than a decade, many producers have relied on glyphosate as their primary herbicide for weed control. In 2007, glyphosate was used on 91% of the cotton grown in the U.S. (Dill et al., 2008). With such extensive use of glyphosate, weeds such as Palmer amaranth have evolved resistance to glyphosate because of repeated applications annually. Some of the reasons Palmer amaranth is a troublesome weed 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 (Heap, 2011), 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). Since Palmer amaranth is so troublesome, an effective management strategy must be developed. Control is critical in small infested areas to prevent further spread of this resistant weed. 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 ft in just one year. The importance of controlling an outbreak of glyphosate-resistant Palmer amaranth is evident.

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

RESEARCH DESCRIPTION

A field experiment was conducted during 2009 and 2010 at the Lon Mann Cotton Research Station in Marianna, Ark., in which a rye cover crop was tested in combination with deep tillage using a moldboard plow to determine the impact on Palmer amaranth emergence in cotton. This experiment was organized in a randomized complete block design with a two by two factorial arrangement of treatments replicated four times. Factor A was deep tillage using a moldboard plow. Factor B was the use of a rye cover crop. In the fall of 2008, 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. At this point, all plots were bedded, and the rye cover crop was planted in appropriate plots. In 2010, plots that did not have a rye cover crop were re-bedded because beds had weathered away during the winter months. During each growing season, five counts were taken to determine the number of Palmer amaranth that emerged within each plot, following a glyphosate application.

RESULTS AND DISCUSSION

During 2009, both deep 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 at the end of the season (Table 1). In 2010, re-bedding brought buried Palmer amaranth seeds back near the soil surface in plots with no rye cover crop, increasing Palmer amaranth emergence over plots with a rye cover crop even if deep tillage had been used. A 68% reduction in emergence from plots with a cover crop alone, averaged over tillage, was the greatest level of reduction achieved in 2010 (Table 2). Because re-bedding was necessary, a significant year by treatment interaction occurred. Over the 2 year study, the use of deep tillage reduced Palmer amaranth emergence 38%; however, the use of a rye cover crop reduced Palmer amaranth emergence by 67% (data not shown). Treatments had no effect on cotton stand counts or yield either year (data not shown). Cover crops and deep tillage will not eliminate glyphosate-resistant Palmer amaranth or other problematic weed species; however, use of these tools will reduce the number of weeds needed to be controlled with soil-applied and postemergence herbicides. Additional efforts should focus on the integration of the practices evaluated 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 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 resistant Palmer amaranth evolves in a small area, then a one-time turning of the soil with a moldboard plow in the infested area should effectively bury most Palmer amaranth seeds such that the population can then be managed using a cover crop and a non-glyphosate herbicide program.

ACKNOWLEDGMENTS

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

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Table 1. Cumulative Palmer amaranth emergence in cotton in 2009. Different letters within each column represent a statistically significant difference in mean emergence between treatments.

		Counting Date				
Tillage	**Cover crop**	**May 21**	**June 15**	**July 9**	**Aug 4**	**Aug 19**
		#/plot				
None	None	2064 a[1]	3814 a	4332 a	4362 a	4382 a
None	Rye	471 bc	1083 b	1469 b	1497 b	1499 b
Moldboard	None	631 b	1256 b	1602 b	1628 b	1630 b
Moldboard	Rye	108 c	406 c	622 c	645 c	645 c

[1]Numbers in a column with the same letters are not significantly different ($P = 0.05$).

Table 2. Cumulative Palmer amaranth emergence in cotton in 2010. Different letters within each column represent a statistically significant difference in mean emergence between treatments.

		Counting Date				
Tillage	**Cover crop**	**May 19**	**June 8**	**June 28**	**July 20**	**Aug 17**
		#/plot				
None	None	318 a[1]	1014 ab	1096 ab	1237 ab	1301 ab
None	Rye	163 a	349 b	364 b	407 b	422 b
Moldboard	None	288 a	1309 a	1458 a	1805 a	1916 a
Moldboard	Rye	130 a	286 b	339 b	464 b	515 b

[1]Numbers in a column with the same letters are not significantly different ($P = 0.05$).

Influence of a Rye Cover Crop on the Critical Weed-Free Period in Cotton

J.D. DeVore, J.K. Norsworthy, M.J. Wilson, G.M. Griffith, C.E. Starkey, and D.B. Johnson[1]

RESEARCH PROBLEM

Many cotton producers have relied on total POST herbicide programs in cotton in recent years. Research was conducted over two years to better understand the critical period of weed control (CPWC) and the extent that a rye cover crop could be used to change the CPWC in cotton, in turn reducing the need for glyphosate and/or optimizing the timing of the initial glyphosate application.

BACKGROUND INFORMATION

Historically, the CPWC has been studied in order to determine the time interval in which it is essential to maintain weed-free conditions to prevent crop yield loss (Swanton and Weise, 1991). By better understanding the time period in which weeds could and could not interfere with a crop, producers could reduce the amount of herbicide applications needed in a growing season (Hall et al., 1992; Van Acker et al., 1993). With the adoption of herbicide-resistant crops, there has been a renewed interest in studying the CPWC in order to optimize timing of POST herbicide applications, particularly glyphosate. Since the CPWC can be greatly influenced depending on management practices imposed by the producer, a better understanding of how certain practices affect the CPWC is needed. Cover crops have been demonstrated to affect weed emergence in cotton, but no research has been conducted to determine a cover crop's effect on the CPWC in cotton.

RESEARCH DESCRIPTION

A field experiment was conducted during 2009 and 2010 at the Lon Mann Cotton Research Station in Marianna, Ark. in which a rye cover crop was used to determine its effect on the critical weed-free period in cotton. This experiment was

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

organized in a split-plot design replicated four times. The main factor was the use of a rye cover crop and the subplot factor was the duration of the weed-free period and the duration of the weed-interference period. Both the weed-free period and the weed-interference period had durations of 0, 1, 2, 3, 4, 5, 7, and 9 wk, as well as season long. Initial weed control consisted of glyphosate plus *S*-metolachlor followed by glyphosate alone as needed. Weed biomass was collected from a 0.5-m^2 area at each treatment in the weed-interference plots and once at the end of the growing season in the weed-free period plots. Yield data were collected in all plots, and all data were subjected to regression analysis.

RESULTS AND DISCUSSION

In 2009, in weeks 2 through 7, there was at least a two-fold reduction in weed biomass in the presence of a rye cover crop compared to the absence of rye. In 2009, in both the presence and absence of a rye cover crop, weed removal needed to begin prior to 150 g/m^2 of weed biomass or approximately 4 wk after planting to prevent greater than 5% yield loss (data not shown). Weed biomass and density were lower in 2010 than in 2009, so weed removal did not need to begin until 385 g/m^2 of weed biomass were present when no cover crop was used or when 175 g/m^2 of weed biomass was present when a cover crop was used (data not shown). In 2009, the critical weed-free duration was 30 to 52 days after planting (Fig. 1), whereas in 2010, a critical weed-free duration was not established because of the low density of weeds (Fig. 2). In 2010, keeping cotton free of weeds for 20 days after planting was sufficient to prevent yield loss, regardless of cover crop.

PRACTICAL APPLICATION

Although no changes were observed in the CPWC when a rye cover crop was used, a reduction in weed biomass was observed. This study, along with others (Hall et al., 1992; Van Acker et al., 1993) show that the CPWC can vary between years and locations. The added value of a rye cover crop is the reduction in weed populations and size of weeds that must be controlled. This will aid in management by reducing the potential for additional weed seed to enter the soil seedbank.

ACKNOWLEDGMENTS

Assistance with this research provided by the staff at the Lon Mann Cotton Research Station, Marianna, Ark., is gratefully acknowledged.

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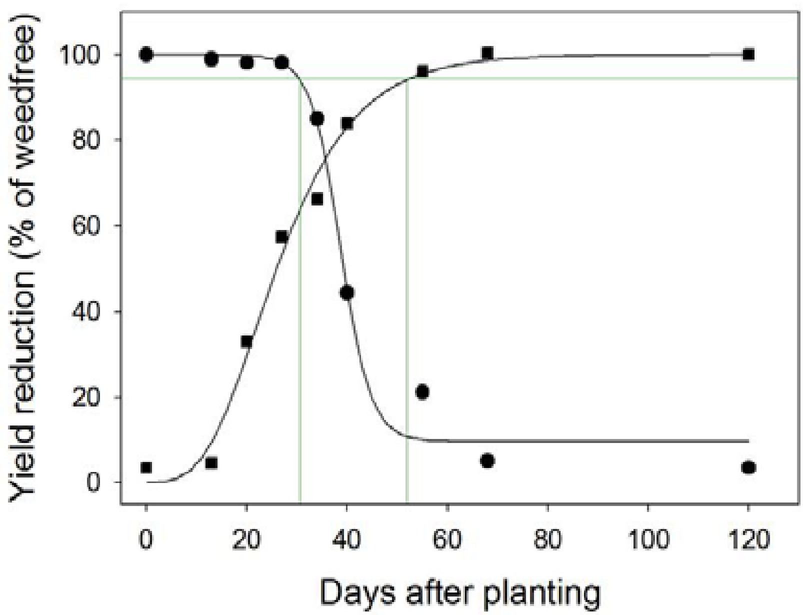

Fig. 1. The influence of various weed interference durations (●) and weed-free periods (■) on the critical period of weed control and relative yield of cotton in 2009, averaged over the presence and absence of a cover crop.

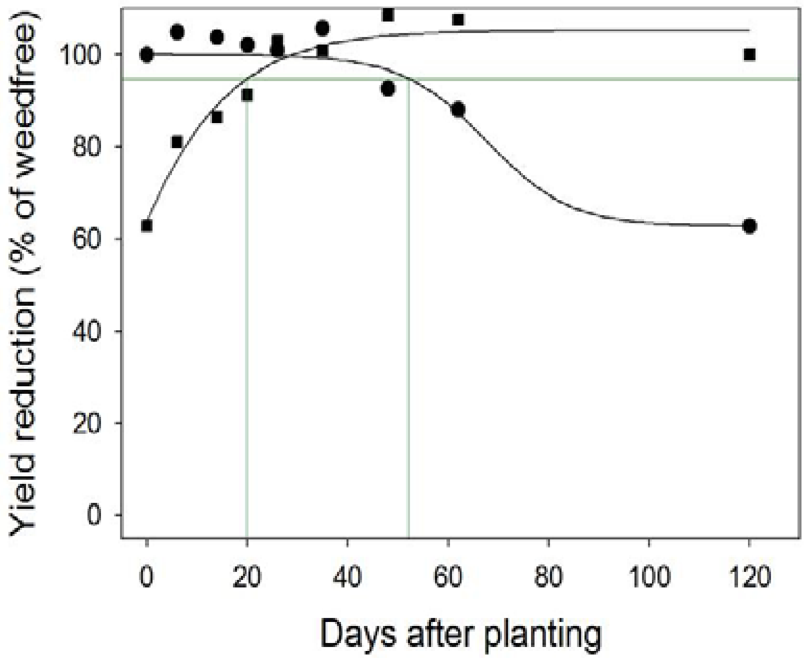

Fig. 2. The influence of various weed interference durations (●) and weed-free periods (■) on the critical period of weed control and relative yield of cotton in 2010, averaged over the presence and absence of a cover crop.

Studies on the Seedbank, Emergence, and Reproductive Ecology of Barnyardgrass in Arkansas Cotton

M.V. Bagavathiannan[1], J.K. Norsworthy[1], K.L. Smith[2], and N.R. Burgos[1]

RESEARCH PROBLEM

Knowledge on weed biology and ecology contributes greatly to designing effective weed management programs. Most importantly, our understanding of the ecology of weed species is critical in the context of herbicide resistance management. Barnyardgrass represents a significant problem in Arkansas cotton production (Norsworthy et al., 2007); yet, little is known about the ecology of this species in Mid-south cotton production systems. The objectives of this study were to characterize i) the seedbank, ii) emergence pattern, and iii) the reproductive ecology of barnyardgrass in cotton.

BACKGROUND INFORMATION

Currently, Roundup Ready Flex® cotton represents the majority of Arkansas cotton, with as many as five glyphosate applications per year being applied in some fields (Norsworthy et al., 2007). This exerts severe selection pressure for the evolution of glyphosate resistance in weed populations, and we have already witnessed glyphosate-resistant horseweed and Palmer amaranth in Arkansas cotton. It has been speculated that barnyardgrass has the potential to evolve resistance to glyphosate (Bagavathiannan et al., 2011), and the evidences of widespread barnyardgrass resistance to rice herbicides validate this concern (e.g., Malik et al., 2010). In this view, we have been developing a resistance simulation model for barnyardgrass, and the knowledge on seedbank, emergence pattern, and reproductive ecology of barnyardgrass is vital in parameterizing the model.

RESEARCH DESCRIPTION

Three different experiments were conducted to address each objective. Experiment I investigated the seedbank size of barnyardgrass through an extensive

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field survey. The survey was carried out in March 2008 across 12 cotton producing counties in Arkansas, including Arkansas, Chicot, Clay, Craighead, Crittenden, Desha, Jackson, Lawrence, Lee, Lincoln, Lonoke, and Mississippi. In each county, soil cores were collected from four fields (each 12 to 24 acres in size) with a history of cotton production in the immediate past season. In each survey field, ten soil cores were collected, each with a core area of 30 in^2, and a depth of 6 inches. The ten cores from each survey field were then bulked and a single sample was obtained. The soil samples were brought to the laboratory and the seed bank size was estimated by washing the samples.

Experiment II was conducted in 2008 and 2009 to determine the emergence pattern of barnyardgrass across different locations in Arkansas, including Rohwer (sites I, II, respectively in a Hebert silt loam and a Sharkey clay), Stuttgart (Dewitt silt loam), and Fayetteville (Taloka silt loam). The experiment was conducted in a completely randomized design with four replications. In each study site, barnyardgrass emergence from a naturally infested uncultivated field was monitored in a 10.9 ft^2 quadrat. The emergence was counted at weekly intervals from early April through late September each year.

Experiment III looked at the impact of relative time of emergence on the reproduction of barnyardgrass in cotton. The study was conducted in Fayetteville (Taloka silt loam) in 2008 and 2009 in a completely randomized design and four replications. Cotton (cultivar: Stoneville 4554 B2RF) was seeded during early May each year in 40-inch wide rows at a seeding rate of 4.5 seeds ft^{-1} of row. Barnyardgrass cohorts were established at about 2 inches from the row at weekly intervals from 0 to 7 weeks after cotton emergence (WAE). In each emergence timing, two barnyardgrass plants were established in a 10.9 ft^2 area and seed production was quantified from these plants. Standard production practices for the southern U.S. were used for cotton.

All data were analyzed using the Statistical Analysis Software (SAS) version 9.1 (SAS Institute, Cary, N.C.). The seedbank survey data (experiment I) were subjected to negative binomial regression analysis using PROC GENMOD. Cumulative emergence was calculated from the % emergence data (experiment II) and a logistic regression curve was fit to the data using PROC NLIN of SAS. Similarly, the NLIN procedure of SAS was used to fit exponential curves for the barnyardgrass seed production data obtained from the experiment III.

RESULTS AND DISCUSSION

Experiment I

The size of the barnyardgrass seedbank was highly dynamic across the fields, ranging from 0 to 10,200 seeds ft^{-2}, and an average size of 350 seeds ft^{-2}. This shows that barnyardgrass can form a persistent seed bank particularly in fields where weed and/or seedbank management is not adequate. As such, the variation in seedbank size may be attributed to the differences in the effectiveness of weed management programs implemented among the farms surveyed. This further suggests that effective management programs do prevent seedbank renewal and result in the exhaustion of the weed seedbank over time. Exhaustion of weed seedbank is the key to effective weed management.

Experiment II

Barnyardgrass exhibited a prolonged emergence period, with considerable variability in emergence among locations and years. In 2008, the first emergence ranged from 17 April (Rohwer-II) to 19 May (Stuttgart) and emergence continued until 12 August (Stuttgart), and 21 August (Rohwer-I, II). There was a considerable difference in the emergence window in 2009, with the first emergence ranging from 28 April (Rohwer-II) to 19 May (Stuttgart) and 100% emergence ranging from 18 August (Stuttgart) to 24 September (Rohwer-I, II) (Fig. 1). Prolonged emergence observed in barnyardgrass could greatly contribute to its success. Prolonged emergence can help the weeds escape control measures and can serve as a hedging strategy to ensure a successful seedbank renewal. Barnyardgrass cumulative emergence showed a strong sigmoidal shape relationship ($r^2 > 0.9$) with the majority of emergence occurring between mid-May and mid-June (Fig. 1). Efficient weed control could be achieved by targeting peak emergence periods.

Experiment III

Overall, reproductive success was observed when barnyardgrass emerged up to 7 WAE in cotton, although seed production declined exponentially over the period of emergence (Fig. 2). In general, seed production in barnyardgrass was significantly greater when the seedlings emerged with the crop (0 WAE) in comparison to the later-emerging cohorts and the decline in seed production was very prominent when the seedlings emerged after 3 WAE. In addition, there was a great variation in barnyardgrass seed production among the two study years. In 2008, seed production ranged from 5,037 (5 WAE) to 35,500 (0 WAE) seeds plant^{-1}, while it varied from 1,500 (7 WAE) to 16,500 (0 WAE) seeds plant^{-1} in 2009. The results show that barnyardgrass is a prolific seed producer and reproduction is possible even if it emerges weeks after crop emergence; however, the level of seed production can be severely affected by the crop canopy and by prevailing environmental conditions.

PRACTICAL APPLICATION

The findings obtained from this study expand our understanding of the ecology of barnyardgrass which will be vital in formulating suitable weed management programs. Further, the data will be used for parameterizing the herbicide resistance simulation model for barnyardgrass. The model will allow us to identify measures that will mitigate the evolution of glyphosate resistance in barnyardgrass. Ultimately such measures are critical in preserving the available herbicide modes of action.

ACKNOWLEDGMENTS

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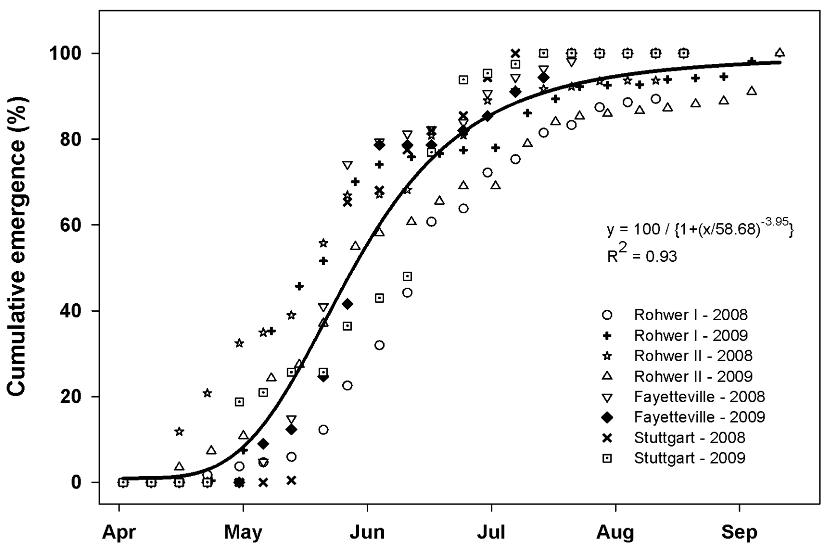

Fig. 1. Logistic regression model for barnyardgrass cumulative emergence across different locations in Arkansas in 2008 and 2009.

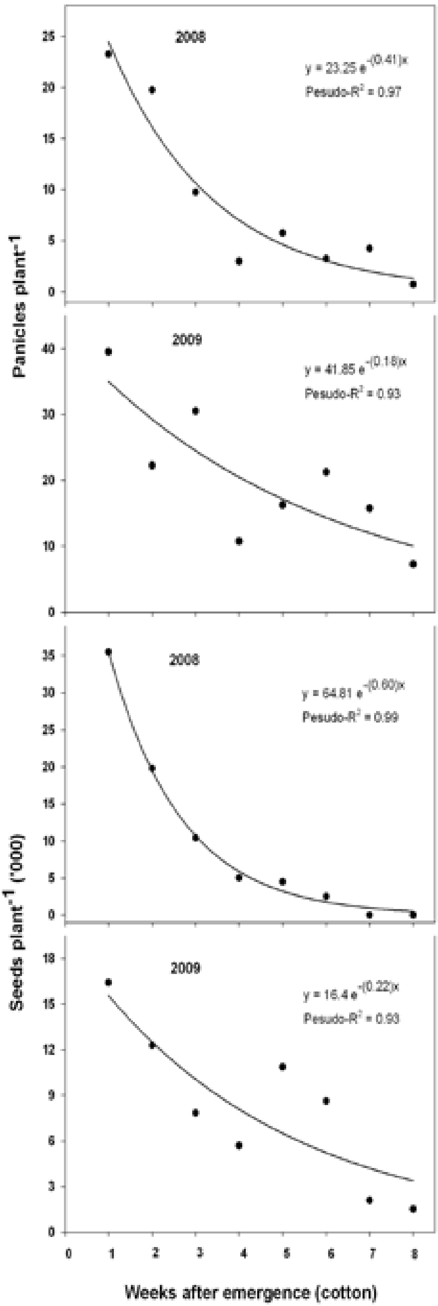

Fig. 2. Regression curves for barnyardgrass panicle and seed production at different times of emergence in cotton in 2008 and 2009. The data conformed to an exponential relationship ($Y = ae^{-bx}$), where "a" is the initial value, which starts the exponential function, and "b" is the fitted constant. The quality of the model fit was expressed using the pseudo-R2 value.

Regional Survey 2009-2010: Thrips Species Composition Across the Upland Cotton Belt

D.S. Akin[1], G.M. Lorenz III[2], G.E. Studebaker[3], and J.E. Howard[1]

BACKGROUND INFORMATION

Various species of thrips occurring on seedling cotton in the Mid-south have been identified in previous studies. Numerous pesticide evaluation publications have reported efficacy against thrips, but in general do not refer to species composition related to treatments unless a resistant species such as western flower thrips (*Frankliniella occidentalis* [Pergande]) is present. The objectives of this study were to (1) determine the composition of thrips species in cotton across the Mid-south and Southeast, and (2) to investigate differences in species across various at-plant insecticides.

RESEARCH DESCRIPTION

The effect of preventive, insecticidal/nematicidal seed treatments on thrips species composition is reported as part of a regional cotton project that was conducted in 2009 and 2010. Trials were established in 17 total locations within Arkansas, Georgia, Louisiana, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Randomized complete blocks were used in evaluating Aeris® seed treatment (imidacloprid [insecticide] + thiodicarb [nematicide]), Avicta Complete Cotton® seed treatment (optional) (thiamethoxam [insecticide] + abamectin [nematicide]), Temik® (aldicarb [insecticide/nematicide]) applied in-furrow, and an untreated control. Avicta was used in 10 locations in 2009 and 8 in 2010. All seed contained a fungicide package. For most locations, thrips were sampled on three sample dates by removing five plants from each plot beginning at the first-second true-leaf stage and placing them in containers. They were subsequently returned to the laboratory, and thrips were washed from the plants onto a filter paper or fine mesh screen. Adult thrips were then shipped to Starkville, Miss., where the species were identified.

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Data were summarized by year across sample dates and replicates within locations, and data were analyzed using locations as replicates with all variables fixed. The percentage of individual species relative to treatment was analyzed by using only locations where the species of interest was present based on the arcsin (sqrt(x)) transformation. The median test (Chi^2; $P = 0.05$) was the statistic used to evaluate differences of species percentages among treatments (Statsoft® Statistica, Tulsa, Okla., 74104).

RESULTS

Mean numbers of thrips per sample summarized across treatments and replicates is presented in Table 1. Thrips species composition varied considerably among locations within years and within some locations between years (Table 2), but were quite similar among treatments summarized across locations (Table 3). In 2009 and 2010 respectively, *Frankliniella fusca* (Hinds), tobacco thrips, was identified from 15 and 16 locations; *Thrips tabaci* Lindeman, onion thrips, was found at 6 and 8 locations; *F. occidentalis* (Pergande), western flower thrips, and *Neohydatothrips variabilis* (Beach), soybean thrips, were found at 11 and 11 locations; and *F. tritici* (Fitch), flower thrips, was identified from 13 and 12 locations (Table 1). Primary species composition was approximately reversed in two locations between years: *F. fusca* and *F. occidentalis* at the Lang Farm, Tift Co., Ga. location, and *F. occidentalis* and *N. variabilis* at the Dimmitt, Texas location. The Sunray, Texas study resulted in virtually 100% *F. occidentalis* in 2009, but had a high number of *T. tabaci* in 2010. These differences may well reflect the effect of other crops planted adjacent to or in the near vicinity of the cotton seed treatment plots, or the presence or absence of nearby wild hosts early in the season.

Results of percentage distribution of each common species among treatments based on analyses, excluding locations where the species of interest was not found, were similar for both years. Results of Chi^2 median test analysis ($P = 0.05$) were not statistically significant for any species for either year, indicating that the percentage of thrips of each of these species did not differ between treatments and that the systemic insecticides were not selective in this case.

PRACTICAL APPLICATION

Thrips species varied greatly among the 17 locations across the 10 states, but tobacco thrips was the dominant species at most locations. Overall composition of thrips species relative to preventive insecticide treatments did not appear to differ greatly among treatments. However, there was a slight trend towards a higher percentage of tobacco thrips in the untreated check plots and a higher percentage of western flower thrips in the aldicarb-treated plots, suggesting the possibility that western flower thrips may be less susceptible to the insecticides than tobacco thrips. No significant effects of insecticide treatment on thrips species composition based on identification of adults were noted.

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Table 1. Mean number of adult thrips averaged across treatments by species and year.

Locations	Tobacco Thrips		Flower Thrips		Western Flower Thrips		Soybean Thrips		Onion Thrips		Other*	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Keiser, Ark.	5.60	8.67	0.08	0.08	0.04	0.05	0.04	0.07	0.23	0.00	0.00	0.02
Marianna, Ark.	7.02	14.02	0.04	0.08	0.00	0.00	0.10	0.07	0.06	0.00	0.04	0.00
Rohwer, Ark.	10.2	19.44	0.02	3.64	0.00	0.00	0.02	0.00	0.00	0.00	0.02	0.00
ABAC Farm, Tift Co., Ga.	1.02		0.02		0.04		0.04		0.00		0.00	
Belflower Farm, Tift Co., Ga.		4.61		2.67		3.58		0.17		0.00		0.00
Lang Farm, Tift Co., Ga.	1.27	1.50	0.13	0.20	3.48	0.09	0.00	0.00	0.00	0.00	0.00	0.00
Winnsboro, La.	5.83	1.00	0.08	0.00	0.71	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Shreveport, La.	3.61	18.92	0.14	0.17	0.17	0.00	0.06	0.14	0.00	0.00	0.06	0.00
St. Joseph, La.		7.8		0.50		0.69		0.20		0.04		0.03
Portageville, Mo.	1.13		0.15		0.04		0.04		0.00		0.00	
Clarkton, Mo.		0.71		0.08		0.31		0.18		0.07		0.00
Raymond, Miss.	1.83		0.00		0.00		0.08		0.00		0.00	
Starkville, Miss.	1.15		0.13		0.00		0.00		0.00		0.00	
Stoneville, Miss.	0.94	5.90	0.04	0.03	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.02
Plymouth, N.C.		5.93		0.66		0.11		0.27		0.06		0.00
Raleigh, N.C.	7.08	4.54	0.53	0.23	1.25	1.74	0.11	2.55	1.58	0.27	0.03	0.00
Blackville, S.C.	1.33	3.83	0.00	0.06	0.00	0.00	0.10	0.22	0.00	0.00	0.00	0.00
Jackson, Tenn.	2.06	5.79	0.13	0.00	0.00	0.00	2.44	2.36	0.63	0.13	0.00	0.00
Dimmitt, Texas	0.00	0.00	0.00	0.00	10.25	1.36	0.00	0.00	2.83	3.45	0.00	0.00
Sunray, Texas	0.00	0.02	0.00	0.00	0.50	2.20	0.00	0.00	0.00	6.98	0.00	0.03
Suffolk, Va.	5.35	3.64	0.13	0.00	0.40	0.00	0.29	0.21	1.44	0.24	0.00	0.00
Number of locations where collected	15	16	13	12	11	11	11	11	6	8		

*Other thrips include: 2009-*Frankliniella williamsi* Hood, *Scolothrips paladus* (Beach), *Microcephalothrips abdominalis* (D.L. Crawford), or *Thrips nigripilosus* Uzel; 2010-*Frankliniella* sp., *Scirtothrips* sp., and *Thrips quinciensis.*

Table 2. Percentage composition of thrips species by location – years 2009 and 2010.

Location	Ff '09	Ff '10	Fo '09	Fo '10	Ft '09	Ft '10	Nv '09	Nv '10	Tt '09	Tt '10
Keiser, Ark.	93.4	97.7	0.7	0.5	1.4	0.5	0.7	1.3	3.8	1.3
Marianna, Ark.	97.1	95.9	0.0	0.0	0.6	0.3	1.4	3.7	0.9	0.0
Rohwer, Ark.	96.1	84.4	0.0	0.0	2.0	15.6	2.0	0.0	0.0	0.0
ABAC Farm , Ga.	90.7	53.5	3.7	31.4	1.9	13.7	3.7	1.4	0.0	0.0
Lang Farm, Ga.	26.1	85.7	71.4	9.7	2.6	4.7	0.0	0.0	0.0	0.0
Winnsboro, La.	88.1	84.6	10.7	15.4	1.3	0.0	0.0	0.0	0.0	0.0
Shreveport, La.	90.9	98.4	4.2	0.0	3.5	0.9	1.4	0.7	0.0	0.0
St. Joseph, La.	N/A	82.6	N/A	9.1	N/A	4.4	N/A	3.8	N/A	0.1
Portageville, Mo.	83.1	55.2	3.1	21.5	10.8	4.8	3.1	14.8	0.0	3.7
Raymond, Miss.	95.7	N/A	0.0	N/A	0.0	N/A	4.3	N/A	0.0	N/A
Starkville, Miss.	90.2	N/A	0.0	N/A	9.8	N/A	0.0	N/A	0.0	N/A
Stoneville, Miss.	93.8	97.4	2.1	0.5	4.2	2.1	0.0	0.0	0.0	0.0
Plymouth, N.C.	N/A	86.6	N/A	0.8	N/A	9.3	N/A	2.9	N/A	0.4
Raleigh, N.C.	67.1	55.8	11.8	22.4	5.0	1.4	1.1	2.2	15.0	2.2
Blackville, S.C.	92.8	91.5	0.0	0.0	0.0	2.3	7.2	6.2	0.0	0.0
Jackson, Tenn.	39.3	69.8	0.0	0.0	2.4	0.0	46.4	28.2	11.9	2.0
Dimmitt, Texas	0.0	0.0	78.3	34.6	0.0	0.0	0.0	0.0	21.7	34.6
Sunray, Texas	0.0	0.9	100.0	39.1	0.0	0.0	0.0	0.0	0.0	59.9
Suffolk, Va.	70.4	81.2	5.2	0.0	1.6	0.0	3.8	12.1	18.9	6.7

Table 3. Percentage composition of adult thrips related to treatments, 2009 and 2010.

Treatment	Ff '09	Ff '10	Fo '09	Fo '10	Ft '09	Ft '10	Nv '09	Nv '10	Tt '09	Tt '10	Other '09	Other '10
Aeris	70.0	68	9.3	10	7.2	3	5.4	9	7.7	9	0.4	0
Avicta	76.4	63	8.9	13	3.1	2	3	5	5.4	17	0.3	0
Temik	71.2	72	12.1	12	5.8	4	6.2	5	4.6	6	0.2	0
Untreated	84.7	76	6.3	10	2.1	6	4.1	3	2.7	9	0.1	0

Abbreviation guide:
Ff: *Frankliniella fusca,* tobacco thrips.
Fo: *Frankliniella occidentalis*, Western flower thrips.
Nv: *Neohydatothrips variabilis*, soybean thrips.
Tt: *Thrips tabaci*, onion thrips.

Thrips Control Using Selected Insecticides in Arkansas Cotton, 2010

C.K. Colwell[1], G.M. Lorenz III[1], J. Fortner[2], N. Taillon[2], and B. VonKanel[3]

RESEARCH PROBLEM

Thrips are a major pest in the early season in Arkansas cotton. Seed treatments as well as in-furrow and foliar applications have been the control options for growers to control thrips in Arkansas. Recently Temik has lost registration and will no longer be available for growers after 2013. There is a need to determine how these changes will impact thrips control and the efficacy of foliar applications for thrips needs to be examined. This study examined the efficacy of selected foliar and seed treatment insecticides for control of thrips in Arkansas Cotton.

BACKGROUND INFORMATION

Thrips are an early-season pest and feed on plant leaves and in terminals of developing seedlings. Thrips feeding on seedling cotton can cause delayed maturity and reduce yield potential. The cost of control and economic loss caused by thrips was more than $7.5 million for Arkansas cotton producers in the 2010 growing season. Seed treatments have become a standard with growers in Arkansas for thrips control in recent years. Seed treatments are effective for thrips control but usually only last 14-21 days after planting, depending on environmental conditions. Additional foliar applications may be needed if conditions result in delayed growth and development. With the deregulation of Temik and low residual control associated with seed treatments, additional foliar applications for thrips may be important for cotton producers. Efficacy data on new and currently labeled products can help in proper selection of foliar products for consultants and producers. Based on recent studies (Hopkin et al., 2002), economic damage from thrips declines when plants reach five true leaves and start growing rapidly, which makes it important to determine the most effective use of supplemental foliar applications for thrips control and help refine recommendations for when these products are

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needed. Early detection of thrips before they reach damaging levels and a timely insecticide application can result in earlier maturity and higher yields.

RESEARCH DESCRIPTION

The location for this trial was the Lonn Mann Cotton Branch Experiment Station, Lee County Ark. Plot size was 4 rows by 50 feet in a randomized complete block design with four replications. Treatment rates and application methods are listed in Table 1. All seed treatments were applied at the Lonoke Agriculture Research and Extension Center. The field was planted on 9 May 2010 and monitored weekly for thrips. When thrips levels reached the University of Arkansas Cooperative Extension Service threshold of 5 thrips per plant in the untreated control, the foliar insecticide treatments were made. Foliar applications were made on 24 May and 1 June 2010 with a 20-foot boom on a Mud Master spray tractor (cone jet TX-V6 tips at 40 PSI) at 10 gal/acre (GPA). Samples were taken 27 May, 1 and 7 June 2010. Thrips were counted by collecting 5 plants per plot and using an alcohol wash technique in the laboratory. Data were processed using Agriculture Research Manager Version 8 for analysis of variance and Duncan's New Multiple Range Test (P = 0.10) used to separate means.

RESULTS AND DISCUSSION

Thrip numbers were reduced in all treatments compared to the untreated control three days after application (Table 2). All seed treatments and foliar applications reduced populations except for the Cyazapyr treatment. At 8 days after first foliar application (8 DAT), Avicta/Cruiser provided better control of thrips than all foliar treatments. After the second foliar application (6 DAT2), thrips numbers began to increase in all treatments except foliar applications of Orthene, Bidrin, Dimethoate, and Cyazapyr. Also the in-furrow treatment of Temik and Aeris appeared to have lost control 26 Days after planting (DAP) compared to the foliar applications with the exception of Hachi. Seasonal totals indicated a trend of seed treatments to lower thrips populations better than most foliar applications. Seed treatments also provided numerically fewer thrips at 26 days after planting (8 DAT1) compared to foliar treatments. Hachi showed no significant control of thrips in this study based on seasonal total thrip numbers. No differences in yield were observed.

PRACTICAL APPLICATION

The results of these studies will provide growers and consultants with information on thrips control when current seed treatments and in-furrow residual control is lost. Additional trials will be conducted to evaluate the timing of foliar applications and their impact on yield.

ACKNOWLEDGMENTS

We thank the Lonn Mann Cotton Branch Experiment Station for their cooperation in this study. We also acknowledge Cheminova, Bayer, Syngenta, Dow, Nichino, AmVac, and DuPont for their support.

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Table 1. Treatment rates and application methods.

Treatment #	Common Name	Class of Chemistry	Rate	Unit/Acre	Application Method
1. UTC	--	--	--	--	--
2. Avicta	Abermectin	Avermectin B_{1+}			
(Complete Pack)	Thiamathoxam	Neonicotinoid	0.15	mg/ai/seed	Seed Treatment
Cruiser	Thiamathoxam	Neonicotinoid	0.34	mg/ai/seed	Seed Treatment
3. Aeris					
Gaucho	Imidacloprid	Neonicotinoid	0.375	mg/ai/seed	Seed Treatment
Thiodicarb	Thiodicarb	Carbamate	0.375	mg/ai/seed	Seed Treatment
4. Temik	Aldicarb	Carbamate	5	lb/acre	In-Furrow
5. Hachi	Tolfenpyrad	Pyrazole	14	oz/acre	Foliar
6. Orthene	Acephate	Organophosphate	0.2	lb/acre	Foliar
7. Bidrin	Dicrotophos	Organophosphate	0.2	lb ai/acre	Foliar
8. Dimethoate	Dimethoate	Organophosphate	0.25	lb ai/acre	Foliar
9. Cyazapyr	Cyazapyr	Chlorantraniliprole	0.08	lb ai/acre	Foliar

Table 2. Efficacy of selected insecticides for control of thrips in Arkansas (Total thrips by sample date)

	Total Thrips per 5 Plants		
Treatment Name	**3DAT1**[1]	**8DAT1**[1]	**6DAT2**[3]
UTC	58.8 a[2]	134.3 a	106.5 ab
Avicta/Cruiser	2.8 c	11.3 d	45.1 cd
Aeris	19.3 bc	20.5 cd	74.0 bc
Temik	5.3 c	23.8 cd	114.3 a
Hachi	32.5 b	157.8 a	98.9 ab
Orthene	18.3 bc	62.0 bc	39.6 cd
Bidrin	19.5 bc	63.0 bc	36.0 d
Dimethoate	14.5 bc	84.0 b	32.7 d
Cyazapyr	34.3 b	80.5 b	26.0 d

[1] DAT1 = days after first treatment.
[2] DAT2 = days after second treatment.
[3] Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 3. Efficacy of selected insecticides for control of thrips in Arkansas (seasonal totals)

Treatment Name	**Season Total Thrips**[1]
UTC	299.5 a
Avicta/Cruiser	60.2 c
Aeris	113.8 bc
Temik	143.3 b
Hachi	267.0 a
Orthene	116.5 bc
Bidrin	122.3 bc
Dimethoate	140.0 b
Cyazapyr	140.8 b

[1]Means within a column followed by the same letter are not significantly different.

Efficacy of Selected Insecticides for Control of Heliothines in Conventional Cotton in Arkansas, 2010

C.K. Colwell[1], G.M. Lorenz III[1], J. Fortner[2], N. Taillon[2], and B. VonKanel[3]

RESEARCH PROBLEM

Although dual gene transgenic cultivars provide a wide range of Lepidoptera control, supplemental foliar applications are often required when bollworm populations are high as in 2010. Higher technologies are leading growers to consider planting conventional cultivars. The purpose of this study was to determine the efficacy of new and current insecticides for control of heliothines in conventional cotton in Arkansas.

BACKGROUND INFORMATION

Arkansas cotton producers have relied on single and dual gene transgenic cotton cultivars to control both tobacco budworm and corn earworm in Arkansas cotton. In the last few years, new foliar insecticides have been released to control these pests. Belt (Bayer Crop Sciences) and Coragen (DuPont) are two new insecticides which have a wide range of Lepidoptera control and outstanding residual activity. The modes of action in both products is disruption of the calcium balance within insect muscle cells, leading to a rapid cessation in feeding as well as paralysis of target pests. These new compounds were evaluated compared to current insecticides to determine the efficacy of control of lepidopteron pests.

RESEARCH DESCRIPTION

The trial was located on Hooker Farms in Jefferson County Ark., 2010. Plot size was 25.3 ft. (8 rows) by 50 ft. Application was based on current University of Arkansas thresholds, and treatment and application information are given in Table 1. Insect density was determined by sampling 25 terminals, squares, blooms, and bolls per plot on 29 June, 8, 14, 20, 26 July 2010. Data was processed us-

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ing Agriculture Research Manager Version 8, AOV, and Duncan's New Multiple Range Test (P = 0.10) to separate means.

RESULTS AND DISCUSSION

Total damage by sample date indicated on 29 June that all treatments had less damage than the untreated control (UTC) except the Karate, Mustang Max, and Declare (1.54 oz/acre) treatments (Table 2). On 8 July, all treatments reduced damage compared to the UTC. The best control was shown with Belt, Coragen rates, bifinthrin +Tracer and Declare (1.54 oz/z). On 14 July, all pyrethroids did not decrease damage compared to the UTC probably because of a rise in tobacco bud worm numbers present in the field. Coragen at both rates appeared to show the least damage and had less damage compared to the UTC. On 20 July, all treatments reduced damage compared to the UTC, however Coragen and Belt had less damage than Declare (1.02 and 2.05 oz/acre), Karate, and Mustang Max. On 28 July, and 3 August, all treatments had significantly less damage compared to the UTC.

Total larvae by sample dates on 29 June and 28 July indicated all treatments reduced larval numbers compared to the UTC. No differences were observed on 8 July and 3 August, however on 20 July, when populations peaked, all treatments had fewer larvae than the UTC with Coragen (both rates) and Belt having fewer larvae than Declare and Karate (Table 3). Seasonal total damage and larval numbers indicated that all treatments reduced seasonal damage and larvae compared to the untreated check and showed the trend for improved control with Coragen (both rates) and Belt compared to all other treatments (Table 4).

Harvest date indicated yield reduction in the UTC compared to all treatments and Coragen (7 oz/acre) had a significantly higher yield than all other treatments except the Coragen (5 oz/acre) treatment (Table 5). This data indicated a superior level of reduced damage and larval numbers for the new insecticides.

PRACTICAL APPLICATION

The results of this study will provide growers and consultants with vital information for control of Lepidoptera pests in conventional cotton. Additional trials will be conducted to evaluate insecticides for their efficacy against tobacco budworms and cotton bollworms.

ACKNOWLEDGMENTS

We thank Chuck Hooker for his cooperation in this study. We also acknowledge the Arkansas Cotton State Support, Monsanto, Dow Agro Sciences, DuPont, and Bayer Crop Science for their support.

Table 1. Description of treatments, rates, and application dates.

Treatment	Common Name	Class of Chemistry	Rate	Unit/Acre	Application Dates
1. UTC	--	--	--	--	--
2. Declare	Gamma-cyhalothrin	Pyrethroid	1.02	oz/acre	26 June, 8, 16, 20 July
3. Declare	Gamma-cyhalothrin	Pyrethroid	1.54	oz/acre	26 June, 8, 16, 20 July
4. Declare	Gamma-cyhalothrin	Pyrethroid	2.05	oz/acre	26 June, 8, 16, 20 July
5. Karate Z	Lambda-cyhalothrin	Pyrethroid	2.46	oz/acre	26 June, 8, 16, 20 July
6. Mustang Max	Zeta-Cypermethrin	Pyrethroid	3.20	oz/acre	26 June, 8, 16, 20 July
7. Coragen	Chlorantraniliprole	Anthranilic diamide	5	oz/acre	26 June, 16 July
8. Coragen	Chlorantraniliprole	Anthranilic diamide	7	oz/acre	26 June, 16 July
9. Belt	Flubendiamide	Ryanodine inceptor	3	oz/acre	26 June, 16 July
10. Tracer + Bifinthrin	Spinosad A, D + Bifenthrin	Organophosphate	2 6	oz/acre oz/acre	26 June, 8, 16, 20 July

Table 2. Total damage by sample date.

Treatment	6/29 3DAT1[1]	7/8 12DAT1[1]	7/14 6DAT2[1]	7/20 4DAT3[1]	7/28 8DAT4[1]	8/3 14DAT4[1]
UTC	2.3 a[2]	.3 a	2.8 a	19.8 a	13.5 a	4.8 a
Declare 1.02 fl oz/acre	1.0 b	.3 a	3.3 a	12.3 b	3.5 b	0.5 a
Declare 1.54 fl oz/acre	0.8 b	.8 a	3.8 a	6.8 b-e	1.8 b	0.3 a
Declare 2.05 fl oz/acre	0.3 b	.8 a	3.8 a	9.3 bcd	1.0 b	0.3 a
Karate Z 2.46 fl oz/acre	0.8 b	.8 a	2.8 a	10.8 bc	5.5 b	0.0 a
Mustang Max 3.2 fl oz/acre	0.5 b	.8 a	2.8 a	4.5 cde	3.8 b	0.0
Coragen 5 fl oz/acre	0.3 b	.3 a	1.3 a	1.0 e	2.3 b	0.5 a
Coragen 7 fl oz/acre	0.0 b	.3 a	0.3 a	3.0 de	7.3 b	0.0 a
Belt 3 fl oz/acre	0.5 b	.0 a	1.3 a	3.3 de	4.3 b	0.8 a
Tracer 2 fl oz/acre + Bifinthrin 6.4 fl oz/acre	0.3 b	.3 a	4.0 a	6.0 b-e	1.5 b	0.0 a

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 3. Total larvae by sample date.

Treatment	6/29 3DAT1[1]	7/8 12DAT1[1]	7/14 6DAT2[1]	7/20 4DAT3[1]	7/28 8DAT4[1]	8/3 14DAT4[1]
UTC	2.3 a[2]	.3 a	2.8 a	19.8 a	13.5 a	4.8 a
Declare 1.02 fl oz/acre	1.0 b	.3 a	3.3 a	12.3 b	3.5 b	0.5 a
Declare 1.54 fl oz/acre	0.8 b	.8 a	3.8 a	6.8 b-e	1.8 b	0.3 a
Declare 2.05 fl oz/acre	0.3 b	.8 a	3.8 a	9.3 bcd	1.0 b	0.3 a
Karate Z 2.46 fl oz/acre	0.8 b	.8 a	2.8 a	10.8 bc	5.5 b	0.0 a
Mustang Max 3.2 fl oz/acre	0.5 b	.8 a	2.8 a	4.5 cde	3.8 b	0.0
Coragen 5 fl oz/acre	0.3 b	.3 a	1.3 a	1.0 e	2.3 b	0.5 a
Coragen 7 fl oz/acre	0.0 b	.3 a	0.3 a	3.0 de	7.3 b	0.0 a
Belt 3 fl oz/acre	0.5 b	.0 a	1.3 a	3.3 de	4.3 b	0.8 a
Tracer 2 fl oz/acre + Bifinthrin 6.4 fl oz/acre	0.3 b	.3 a	4.0 a	6.0 b-e	1.5 b	0.0 a

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 4. Season total damage and season total larvae.

Treatment	Season Total Damage[1]	Season Total Larvae[1]
UTC	151.3 a	43.3 a
Declare 1.02 fl oz/acre	64.5 bc	20.8 b
Declare 1.54 fl oz/acre	55.3 bcd	14.0 bc
Declare 2.05 fl oz/acre	55.3 bcd	15.3 bc
Karate Z 2.46 fl oz/acre	68.3 b	20.5 b
Mustang Max 3.2 fl oz/acre	60.8 bc	12.3 cd
Coragen 5 fl oz/acre	32.3 e	5.5 d
Coragen 7 fl oz/acre	35.3 e	10.8 cd
Belt 3 fl oz/acre	38.5 de	10.0 cd
Tracer 2 fl oz/acre + Bifinthrin 6.4 fl oz/acre	46.8 cde	12.0 cd

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

Table 5. Harvest data.

Treatment	Yield (lint lb/acre)[1]
UTC	323.9 d
Declare 1.02 fl oz/acre	874.3 c
Declare 1.54 fl oz/acre	948.7 bc
Declare 2.05 fl oz/acre	941.1 bc
Karate Z 2.46 fl oz/acre	880.9 c
Mustang Max 3.2 fl oz/acre	955.1 bc
Coragen 5 fl oz/acre	1009.8 ab
Coragen 7 fl oz/acre	1059.0 a
Belt 3 fl oz/acre	895.6 c
Tracer 2 fl oz/acre + Bifinthrin 6.4 fl oz/acre	947.4 bc

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

Efficacy of Selected Insecticides for Control of Plant Bugs in Arkansas, 2010

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RESEARCH PROBLEM

Insecticides are the primary method used for tarnished plant bug (*Lygus lineolaris*) control by Arkansas producers. Plant bug populations in 2009 and 2010 were extremely high and currently labeled insecticides are not providing the level of control that is needed to reduce plant bug numbers below economic thresholds with one application. Growers are currently shortening time intervals, using tank mixes and pre mixes of multiple chemistries of insecticides to effectively control this pest. This study was conducted to determine the efficacy of selected insecticides and tank mixes for control of plant bugs.

BACKGROUND INFORMATION

Tarnished plant bugs were the number one economic pest in cotton in 2010, and cost Arkansas producers over $25 million. Tarnished plant bugs puncture and feed on young terminals and squares on the plant. These pests can also feed on blooms and young bolls, resulting in "dirty blooms" and abortion of fruiting structures. It is important to investigate efficacy of labeled insecticides in order to make recommendations for achieving adequate control. This study was part of a regional efficacy trial conducted throughout the Mid-south to evaluate the efficacy of selected insecticides for control of plant bugs.

RESEARCH DESCRIPTION

The trial was located at the Lonn Mann Cotton Branch Experiment Station in Marianna, Ark. Treatments were not all single product applications, some were tank mixes and pre mixes (Table 1). Plot size was 12.5 ft × 50 ft in a randomized complete block design with four replications. Foliar applications were made on

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the following dates: 25 June; 6, 15, and 22 July 2010, with a 20-foot boom on a Mud Master spray tractor (cone jet TX-V6 tips at 40 PSI) at 10 gal/acre (GPA). Insect numbers were determined by taking two drop cloth samples per plot using a 2.5 ft. drop cloth. Samples were taken on 28 June 2010; 2, 6, 9, 15, 19, 26, 29 July 2010; and 5 August 2010. Data were processed using Agriculture Research Manager Version 8 (Gylling Data Management, Inc., Bookings, S.D.). Analysis of Variance was conducted and Duncan's New Multiple Range Test ($P = 0.10$) was used to separate means.

RESULTS AND DISCUSSION

Three days after the initial application (3 DAT1) all treatments had fewer plant bugs than the untreated control (UTC) except for Bidrin (Table 2). Endigo provided statistically better control of plant bugs than Diamond, Intruder, Carbine, Tri-Max, Vydate, Bidrin, and the UTC at 3 DAT1. No significant differences were observed at seven or eleven days after the first application. Populations were rapidly building and the overwhelming number of plant bugs may have contributed to the lack of mean separation at 7 and 11 DAT1. All treatments had fewer plant bugs than the UTC with the exception of Intruder at 3 DAT2 (Table 3). Acephate also had fewer plant bugs than Vydate, Centric, Trimax-Pro, Carbine, Leverage 360, and Brigade. All treatments reduced plant bug numbers below the UTC at 9 DAT2 while Acephate, Bidrin, Carbine, Endigo, and Diamond had significantly fewer plant bugs than Brigade and Diamond which had fewer plant bugs compared to Intruder. At 4 DAT3, all treatments reduced plant bug numbers compared to the UTC, and Tri Max-Pro had higher numbers of plant bugs compared to all other treatments (Table 4). Also, Acephate, Endigo, and Diamond had fewer plant bugs than Intruder. At 4 DAT4, all treatments had fewer plant bugs compared to the UTC; and, Endigo, Diamond, Brigade, Acephate, Leverage 360 and Bidrin had fewer plant bugs than Intruder (Table 5). At 7 DAT4, results showed the same trend of all treatments having fewer plant bugs than the UTC and Endigo had fewer plant bugs than Trimax-Pro and Vydate. At 14 DAT4 Acephate and Diamond were the only treatments that had significantly fewer plant bugs than the UTC. The UTC had the lowest yield compared to all other treatments (Table 6). Endigo, Diamond, Brigade, and Leverage had higher yields than Carbine. Endigo had the highest numerical yield and was significantly better than Acephate, Bidrin, Centric, Vydate, Trimax-Pro, Carbine, and Intruder. This data indicates that most single product applications of currently labeled and recommended products are inadequate for control and multiple applications are needed to control plant bugs in fields with high populations.

PRACTICAL APPLICATION

The results of these studies will provide growers and consultants with vital information for control of plant bugs in cotton. This data also shows the need for new insecticides for plant bug control. Additional trials will be conducted to evaluate insecticides for their efficacy against plant bugs.

ACKNOWLEDGMENTS

We thank the the Lonn Mann Cotton Branch Experiment Station for their support of this study. We also thank Cotton Incorporated, MANA, Gowan, Valent, AmVac, DuPont, Syngenta, Bayer, and FMC for their support.

Table 1. Treatment common names, class of chemistry and rate applied.

Treatment	Common Name	Class of Chemistry	Rate	Unit
1. UTC	--------	--------	------	-------
2. Acephate	Acephate	Organophosphate	0.75	lb/acre
3. Bidrin	Dicrotophos	Organophosphate	6.0	oz/acre
4. Vydate	Oxamyl	Carbamate	12.0	oz/acre
5. Centric	Thiomathoxam	Neonicotinoid	2.0	oz/acre
6. Tri-Max Pro	Imidacloprid	Neonicotinoid	1.5	oz/acre
7. Carbine	Flonicamid	Pyridinecarboxamide	2.5	oz/acre
8. Leverage 360	Cyfluthrin + Imidacloprid	Pyrethroid + Neonicotinoid	3.2	oz/acre
9. Intruder	Acetamiprid	Neonicotinoid	1.1	oz/acre
10. Endigo	Lambda-cyhalothrin + Thiomathoxam	Pyrethroid + Neonicotinoid	5.0	oz/acre
11. Diamond	Novaluron	Insect growth regulator	9.0	oz/acre
12. Brigade	Bifenthrin	Organophosphate	5.12	oz/acre

Table 2. Plant bugs at 3, 7, and 11 days after first application.

Treatment	6/28/2010 3 DAT-1[1]	7/2/2010 7 DAT-1[1]	7/6/2010 11 DAT-1[1]
1. UTC	11.3 a[2]	26.5 a	72.8 a
2. Acephate 0.75 lb/acre	3.0 cd	9.3 a	48.5 a
3. Bidrin 6 oz/acre	8.3 ab	26.5 a	62.3 a
4. Vydate 12 oz/acre	5.5 bc	25.8 a	64.0 a
5. Centric 2 oz/acre	2.5 cd	20.3 a	49.8 a
6. Tri-Max Pro 1.5 oz/acre	5.8 bc	15.0 a	55.8 a
7. Carbine 2.5 oz/acre	6.0 bc	17.3 a	53.8 a
8. Leverage 360 3.2 oz/acre	3.5 cd	17.5 a	66.3 a
9. Intruder 1.1 oz/acre	6.5 bc	22.8 a	63.0 a
10. Endigo 5 oz/acre	0.8 d	14.5 a	59.5 a
11. Diamond 9 oz/acre	8.0 ab	20.8 a	44.3 a
12. Brigade 5.12 oz/acre	4.0 cd	19.8 a	57.3 a

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 3. Plant bugs at 3and 9 days after second application.

Treatment	7/9/2010 3DAT2[1]	7/15/2010 9 DAT 2[1]
1. UTC	71.8 a[2]	65.8 a
2. Acephate 0.75 lb/acre	8.0 e	19.3 de
3. Bidrin 6 oz/acre	23.0 cde	25.8 cde
4. Vydate 12 oz/acre	29.8 cd	34.3 bcd
5. Centric 2 oz/acre	27.3 cd	28.0 b-e
6. Tri-Max Pro 1.5 oz/acre	42.0 bc	34.3 bcd
7. Carbine 2.5 oz/acre	31.3 cd	20.3 de
8. Leverage 360 3.2 oz/acre	37.5 cd	35.0 bcd
9. Intruder 1.1 oz/acre	56.5 ab	37.5 bc
10. Endigo 5 oz/acre	25.8 cde	21.5 de
11. Diamond 9 oz/acre	20.5 de	13.5 e
12. Brigade 5.12 oz/acre	27.8 cd	41.8 b

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 4. Plant bugs at 4 days after third application.

Treatment	7/19/2010 4 DAT 3[1]
1. UTC	60.5 a[2]
2. Acephate 0.75 lb/acre	9.0 d
3. Bidrin 6 oz/acre	12.5 cd
4. Vydate 12 oz/acre	23.3 bc
5. Centric 2 oz/acre	14.3 cd
6. Tri-Max Pro 1.5 oz/acre	32.8 b
7. Carbine 2.5 oz/acre	16.3 cd
8. Leverage 360 3.2 oz/acre	13.3 cd
9. Intruder 1.1 oz/acre	22.0 c
10. Endigo 5 oz/acre	8.5 d
11. Diamond 9 oz/acre	8.5 d
12. Brigade 5.12 oz/acre	14.0 cd

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 5. Plant bugs at 4, 7, and 14 days after fourth application.

Treatment	7/26/2010 4 DAT 4[1]	7/29/2010 7 DAT 4[1]	8/5/2010 14 DAT 4[1]
1. UTC	44.3 a[2]	43.5 a	53.0 ab
2. Acephate 0.75 lb/acre	7.0 cd	15.3 bc	16.0 c
3. Bidrin 6 oz/acre	7.7 cd	19.5 bc	36.0 bc
4. Vydate 12 oz/acre	11.0 bcd	24.8 b	67.0 a
5. Centric 2 oz/acre	10.8 bcd	17.0 bc	35.5 bc
6. Tri-Max Pro 1.5 oz/acre	12.3 bcd	25.0 b	57.5 ab
7. Carbine 2.5 oz/acre	16.5 bc	18.8 bc	44.3 ab
8. Leverage 360 3.2 oz/acre	7.8 cd	13.5 bc	44.5 ab
9. Intruder 1.1 oz/acre	20.3 b	23.0 bc	50.3 ab
10. Endigo 5 oz/acre	3.5 d	8.0 c	36.0 bc
11. Diamond 9 oz/acre	9.0 cd	21.3 bc	10.5 c
12. Brigade 5.12 oz/acre	5.5 d	11.0 bc	42.8 ab

[1]DAT = days after treatment.
[2]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Table 6. Treatment lint yields.

Treatment	Lint Yield lb/acre[1]
1. UTC	457.3 e
2. Acephate 0.75 lb/acre	1247.1 bcd
3. Bidrin 6 oz/acre	1260.6 bcd
4. Vydate 12 oz/acre	1133.2 cd
5. Centric 2 oz/acre	1162.7 bcd
6. Tri-Max Pro 1.5 oz/acre	1192.2 bcd
7. Carbine 2.5 oz/acre	1056.7 d
8. Leverage 360 3.2 oz/acre	1363.8 ab
9. Intruder 1.1 oz/acre	1174.7 bcd
10. Endigo 5 oz/acre	1488.5 a
11. Diamond 9 oz/acre	1350.4 abc
12. Brigade 5.12 oz/acre	1326.3 abc

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

Control of Spider Mites in Arkansas Cotton

C.K. Colwell[1], G.M. Lorenz III[1], J. Fortner[2], N. Taillon[2], B. VonKanel[3], and A. Vangilder[4]

RESEARCH PROBLEM

Spider mites are occasional pests that can cause serious damage to cotton in Arkansas. In 2010 spider mites cost Arkansas cotton producers $2.3 million. In hot dry years like we experienced in 2005, 2006, and 2007, Arkansas producers spent an average of $4 million to control spider mites (Williams, 2011). Miticides are expensive and the only means for control when populations reach damaging levels. This study was conducted to determine the most efficacious miticides for growers to control spider mites.

BACKGROUND INFORMATION

Spider mites (*Tetranychus urticae*) are occasional pests in Arkansas cotton (Studebaker, 1997). Infestations are often most severe during hot and dry weather. Spider mite symptoms in cotton usually show on the leaf surface as a speckled appearance. As infestations become heavier, symptoms may turn leaves red in color and result in defoliation of the plant. Damage in fields usually occurs in spots upon initial infestation and as populations increase, damage can become field wide. Miticide applications are usually required to control this pest when populations reach damaging levels and can be very expensive for growers. University of Arkansas data indicates economic impact of this pest can occur when 50% of plants are infested and populations are building. As with other insect pests, early detection of spider mites at damaging levels and a timely application can result in higher yields.

RESEARCH DESCRIPTION

The location for this trial was Clay County Ark. Plot size was 4 rows by 50 feet in a randomized complete block design with four replications. The selected

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[4]County extension agent staff chair, Clay County Extension Services, Piggot.

miticides used in this trial are listed in Table 1. Spider mite density was determined by choosing five randomly selected plants per plot and counting all spider mites on five main stem leaves located at the third node down from the terminal of infested plants using a 1 in. × 1 in. square linen tester. Foliar applications were made on 17 June 2010 with a 20 foot boom on a Mud Master spray tractor (cone jet TX-V6 tips at 40 PSI) at 10 GPA. Samples were taken on 21, 24, and 30 June 2010. Data were 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 used to separate means.

RESULTS AND DISCUSSION

At 3 days after application (3 DAT) all treatments provided control of spider mites compared to the untreated control (UTC) (Table 2). At 7 and 13 days after application, all treatments except Dicipline had fewer spider mites than the UTC. Seasonal totals also indicated the level of control was better with all treatments compared to Discipline (bifinthrin) in control of spider mites.

PRACTICAL APPLICATION

The results of this trial will help growers and consultants make better decisions in controlling spider mites in Arkansas cotton. Spider mites can be difficult to control and miticide efficacy can be affected by crop stage, environmental conditions and population densities. Additional trials will be conducted to evaluate new and current miticides for their control of spider mites in Arkansas.

ACKNOWLEDGMENTS

We thank the Dale Vangilder for his cooperation in this study. We also acknowledge Bayer Crop Science, Dow Agrosciences, FMC, Syngenta Crop Protection, Valent, and AmVac for their support.

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Table 1. Treatment common name, class of chemistry, and rate of applications.

Treatment	Common Name	Class of Chemistry	Rate	Unit/ acre
1. UTC	----	----	----	----
2. Kelthane MF	Dicofol	Organo chlorine	24	oz/acre
3. Agri-Mek	Abamecton	Glycoside	6	oz/acre
4. Athena	Bifenthrin, Abamectin	Pyrethroid, Glycoside	8	oz/acre
5. Discipline	Bifenthrin	Pyrethroid	6.4	oz/acre
6. Zeal	Etoxazole	Diphenyl Oxazoline	0.75	oz/acre
7. Oberon	Spiromesifan,	Tetronic acid	8	oz/acre
8. Oberon	Spiromesifan,	Tetronic acid	4	oz/acre
NIS [1]			0.25	% v/v
9. Oberon	Spiromesifan,	Tetronic acid	8	oz/acre
NIS[1]			0.25	% v/v
10. Oberon	Spiromesifan,	Tetronic acid	4	oz/acre
NIS[1]			0.25	% v/v
UAN [2]			1.5	qt/acre

[1]NIS is a Non-Ionic Surfactant.
[2]UAN is a solution of urea and ammonium nitrate used as fertilizer.

Table 2. Spider mites at 3, 7, 13 days after treatment and seasonal totals.

Treatment	Spider Mite 3 DAT[3]	Spider Mite 7 DAT[3]	Spider Mite 13 DAT[3]	TOTAL Spider Mites[3]
1. UTC	133.8 a[4]	98.0 a	67.0 a	298.8 a
2. Kelthane MF	2.3 b	1.8 c	5.3 c	9.3 c
3. Agri-Mek	17.8 b	7.8 c	2.0 c	27.5 c
4. Athena	12.3 b	6.5 c	1.0 c	19.8 c
5. Discipline	15.0 b	30.3 b	45.0 b	90.3 b
6. Zeal	13.0 b	2.3 c	5.0 c	20.3 c
7. Oberon	8.3 b	1.3 c	2.3 c	11.8 c
8. Oberon + NIS[1]	4.8 b	1.3 c	4.8 c	10.8 c
9. Oberon + NIS[1]	3.8 b	0.8 c	3.0 c	7.5 c
Oberon + NIS[1] + UAN[2]	3.5 b	2.5 c	6.5 c	12.5 c
10. Oberon + NIS[1] + UAN[2]	5.3 b	1.8 c	3.0 c	10.0 c

[1]NIS is a Non-Ionic Surfactant.
[2]UAN is a solution of urea and ammonium nitrate used as fertilizer.
[3]DAT = days after treatment.
[4]Means within a column followed by the same letter are not significantly different (*P* = 0.05).

Tarnished Plant Bug and the Plant Growth Regulator, Mepiquat Chloride-Influence on Cotton Fruiting Dynamics and Yield

T.G. Teague[1], K. Neele[1], A. Flanders[2], and L. Fowler[2]

RESEARCH PROBLEM AND BACKGROUND INFORMATION

Crop management practices that emphasize early maturity are an important component for integrated pest management (IPM) programs in Arkansas cotton. Managing for early and high yields involves the appropriate mix of cultivar selection, seeding rates, tillage system, fertility, irrigation timing, and use of the plant growth regulator, mepiquat chloride. Effective use of mepiquat chloride can lead not only to improved height management of cotton but also increased small boll retention (through reduced physiological shed) and improved earliness (fewer total days from planting to physiological cutout nodes above white flower (NAWF) = 5) (Kerby et al., 2010). Mepiquat chloride can reduce late season rank terminal growth which provides an attractive and a high quality food source for tarnished plant bugs *Lygus lineolaris* (Palisot de Beauvois). Such rank growth does not contribute to economic yield and can lead to reduced efficiencies in defoliation and harvest.

In efforts to improve fuel and labor efficiency and to increase use of their on-farm mechanization and technology investments, cotton producers often tank-mix insecticides with their scheduled herbicide, mepiquat chloride and/or fertilizer applications. In early season, the insecticide applications typically are directed at *preventing* infestations and feeding injury from mirid insect pests including the tarnished plant bug. Early season damage by plant bugs can result in crop delay and reduced yield. Regrettably, a preventative approach to cotton insect pest control historically has resulted in secondary pest outbreaks as well as selection for insecticide-resistant pest populations. Compared to a preventative approach, an IPM strategy requires scouting and crop monitoring. Insecticides are applied only when pest numbers are sufficiently high to cause economic damage. Integrated pest management has been considered a more sustainable production option.

This report presents results from a 2010 field study to examine how yield and crop maturity were impacted in response to automatic compared to scouting-

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based insecticide applications for control of tarnished plant bug when made in a program approach that includes mepiquat chloride.

PROCEDURES

The experiment was installed at the Cooperative University Research Station on the Judd Hill Foundation Farm near Trumann, Ark. Cruiser treated (thiamethoxam) cotton (*Gossypium hirsutum* L.) cultivar Stoneville 4554 B2RF was planted on 7 May 2010 in the Dundee silt loam soil at 3 to 4 seeds/ft. Production practices were similar across all treatments in-season except for application timing for insecticides and mepiquat chloride. Row middles (water furrows) were cleared with sweep plows prior to first furrow irrigation; no further cultivations were made in any treatments. Weekly irrigation began during the second week of squaring and extended (as needed) until the third week after physiological cutout. Plots were 8 rows wide and 45 ft long with 10 ft alleys.

Program treatment combinations of insecticide and/or plant growth regulator (PGR) included automatic applications of insecticide (weekly after first squares through cutout, rain permitting), insecticide applications prompted if plant bug counts exceeded Extension action thresholds (3 plant bugs per drop cloth sample), or no insecticides. Mepiquat chloride applications were made in the second week of squaring (mean number of squaring nodes = 5.7), at first flowers (mean number of squaring nodes = 9.5) and/or just after physiological cutout (mean number squaring nodes = 4.4). Program treatment combinations including rates, product, and timing are listed in Tables 1 and 2.

The Squaremap procedure in the COTMAN crop monitoring system (Oosterhuis and Bourland, 2008) was used to document differences in crop development and square and boll retention among program treatments from squaring until physiological cutout. Plant bug monitoring included use of weekly drop cloth sampling in each plot. The trial was harvested using a 2-row research cotton picker positioned in 2 center rows, 50 boll samples were hand-picked from each plot for fiber quality and yield component determinations. 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 testing. Costs for program treatments were estimated using the University of Arkansas Crop Enterprise Budget Calculator (http://www.uaex.edu/depts/ag_economics/farm_management.htm). All plant monitoring, yield and fiber quality data were analyzed using ANOVA with mean separation using protected LSD.

RESULTS

The 2010 production season featured hot, dry conditions with low to moderate insect pest pressure. Crop growth curves from plant monitoring with COTMAN showed early commencement of squaring in 2010 when compared to the COT-

MAN standard target development curve (Fig. 1). There were no significant differences in pace of pre-flower nodal development among treatments. By the time of physiological cutout, a significant maturity delay was observed in the untreated control (Fig. 2). Physiological cutout was earlier among program treatments that included a mid-season application of mepiquat chloride.

Square retention (first position squares on main-stem sympodia) was at high levels much of the season and was similar among program treatments until the final week of Squaremap sampling at 84 days after planting—just after physiological cutout for most treatments (Fig. 3). First position boll retention was lowest in those treatments that did not receive insecticide (Table 3). Highest boll retention levels were observed where protection was coupled with mid-season use of mepiquat chloride. Plant height tended to be lower in program treatments that included early and mid season applications of mepiquat chloride; however, there were no significant differences among treatment means. Plant bug numbers did exceed action thresholds after flowering (Fig. 4); but overall numbers were moderately low until the week of cutout.

Significantly lower yields were observed in the untreated check compared to program treatments receiving insecticide or mepiquat chloride. Highest mean yields were associated with automatic insecticide applications, but these values were *not* significantly different ($P = 0.05$) from threshold based management—particularly if mepiquat chloride was included in the program at mid-season (Fig. 5).

Costs for program treatments, estimated using the University of Arkansas Crop Enterprise Budget Calculator, indicate application + product costs ranged from $2.31/acre to $74.31/acre (Fig. 6). Net profit estimates based on mean lint yields and assuming $0.81/lb. price for lint was ca. $18/acre higher for the threshold + OMO (single mepiquat chloride application at first flower) treatment compared to the highest yielding automatic insecticide spray approach.

Results from HVI analyses showed no differences in fiber quality or yield components (fibers per seed and fiber density) associated with insecticide or plant growth regulator program treatments (Table 4).

CONCLUSIONS

In this 2010 NE Arkansas field trial, it is notable that in a system with moderately low numbers of plant bugs, use of the plant growth regulator mepiquat chloride alone and no insecticide resulted in higher yield compared to the untreated check. The threshold based program (insecticides applied only when insect pest numbers exceeded the action threshold) coupled with a midseason application mepiquat chloride resulted in that highly desirable combination of high and early yield as well as highest economic return among programs.

Crop management decisions that include appropriate choices for crop cultivar selection, irrigation timing, fertilizers, and use of mepiquat chloride are important components of cotton IPM systems in the Mid-south. Management mistakes with any of these components can result in delayed maturity which can lead to prolonged vulnerability to losses from late season infestations of pests.

There are relatively few insecticides available to control tarnished plant bug in Mid-south cotton. To maintain their effective use, insecticide resistance management should be an important consideration in the overall production system. This includes avoiding unnecessary sprays that help to select for resistant populations. An IPM strategy requires crop monitoring and scouting. Chemical control options are implemented only when needed. Such an approach is a distinguishing characteristic of the cotton culture of Arkansas where IPM has a long and prominent history.

ACKNOWLEDGMENTS

This project is a part of a Cotton Sustainability Project supported through Cotton Incorporated in cooperation with the University of Arkansas Division of Agriculture, Arkansas State University and the Judd Hill Foundation.

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Table 1. Designations and timing (days after planting) of different insecticide and mepiquat chloride spray treatments at Judd Hill, 2010.

Treatment Designation	Treatment Application Timing (days after planting)		
	Pre-flower	Mid-season	Cutout
Control +OOO[1]	None + None	None + None	None + None
Control +MMM	None + 16 June (40)	None + 29 June (53)	None + 30 July (84)
Automatics[2] +OOO	10, 15, 22, 29 June (34, 39, 46, 53) + None	6, 21,July (60, 75) + None	30 July (84) + None
Automatics +MMM	10, 15, 22, 29 June (34, 39, 46, 53) + 16 June (40)	6, 21,July (60, 75) + 29 June (53)	30 July (84) + 30 July (84)
Threshold[3] +OOO	None	6 July (60) + None	30 July (84) + None
Threshold +OMO	None	6 July (60) + 29 June (53)	30 July (84) + None
Threshold +OOM	None	6 July (60) + None	30 July (84) + 30 July (84)
Threshold +OMM	None	6 July (60) + 29 June (53)	30 July (84) + 30 July (84)

[1] Treatments received separate applications of mepiquat chloride sprays (“M”) or were untreated (“O”). OOO = untreated, OMO = single mepiquat chloride application at first flower, MMM = three mepiquat chloride sprays.

[2] Automatic insecticide applications were directed at preventing tarnished plant bug infestations. All applications were made with a tractor mounted high clearance sprayer equipped with 8 row boom.

[3] Threshold based insecticide applications were applied for plant bug control using the University of Arkansas MP144 recommended action threshold of a mean 3 bugs per drop cloth sample.

Table 2. Pesticide application descriptions including product, rate, and timings for the insecticide and mepiquat chloride treatments in 2010 Judd Hill trial.

Treatment Description	Insecticide or Mepiquat Chloride (rate/acre) Application Date
Automatic Insecticides[1]	Centric (2oz/acre) 10, 15, 22, 29 June, 6, 21,July & Bidrin (6oz/acre) 30 July
Threshold based Insecticide[2]	Centric (2oz/acre) 6 July & Bidrin (6 oz/acre) 30 July
Mepiquat chloride	Early (8 oz/acre) 16 June; Mid (16 oz/acre) 29 June; Late (16 oz/acre) 30 July
Untreated Check	None

[1] Treatments received separate applications of mepiquat chloride sprays (“M”) or were untreated (“O”).
[2] Automatic insecticide applications were directed at preventing tarnished plant bug infestations. All applications were made with a tractor mounted high clearance sprayer equipped with 8 row boom.
[3] Threshold based insecticide applications were applied for plant bug control using the University of Arkansas MP144 recommended action threshold of a mean 3 bugs per drop cloth sample.

Table 3. COTMAN Squaremap results from samples made on 84 days after planting, the approximate time of physiological cutout for most treatments.

Treatment Description[1]	Mean no. first position bolls	Mean shed[1] of first position fruiting forms[2] (%)	Mean plant height (inches)	Mean no. main stem sympodia	Mean no. main stem squaring nodes[3]
Check + OOO	5.7 d[4]	33.3 a	61	14.5	5.4 a
Check + MMM	6.1 cd	31.2 ab	52	15.0	4.9 ab
Automatics + OOO	6.9 abc	25.9 c	52	14.5	4.4 bc
Automatics + MMM	7.3 ab	23.5 c	50	15.7	4.1 bc
Threshold + OOO	6.6 abcd	27.0 c	57	14.9	4.7 abc
Threshold + OMO	7.5 a	25.9 c	49	14.8	3.7 c
Threshold + OOM	6.4 bcd	24.7 c	56	14.3	4.7 abc
Threshold + OMM	7.1 ab	24.7 c	51	14.8	3.9 bc
P > F	0.02	0.01	0.73	0.54	0.04
LSD_{05}	1.0	5.2			1.0

[1] Treatments received separate applications of mepiquat chloride sprays ("M") or were untreated ("O"). OOO = untreated, OMO = single mepiquat chloride application at first flower, MMM = three mepiquat chloride sprays.
[2] Total first position % shed reflects both square shed likely related to plant bug feeding injury as well as small boll shed resulting from physiological boll shed.
[3] Squaring nodes are main stem sympodia on which there has not been a flower; after the crop begins to flower, these values are comparable to "nodes above white flower" (NAWF) except that a white flower does not have to be present on the sampled plant.
[4] Values within a column followed by the same number are not significantly different (*P* = 0.05).

Table 4. Means for HVI classing data and yield component information for 50 boll samples hand-harvested throughout consecutive plants, Judd Hill 2010[1].

Insecticide PGR treatment[2]	Lint fraction (%)	Boll weight (g)	Micronaire	Length	Uniformity index %	Strength (g/tex)	Elongation (%)	No. seed per acre (mil.)	Fibers per seed	Fiber density (no. per mm^2)
Check + OOO	41.0	4.6	4.8	1.15	83.8	33.4	7.3	8.6	15968	154
Check + MMM	40.7	4.8	4.9	1.19	84.9	34.2	7.4	9.9	15570	147
Automatics +OOO	40.8	5.2	5.0	1.16	84.1	33.1	7.5	10.6	15767	148
Automatics +MMM	39.0	5.1	4.9	1.20	84.2	33.8	7.2	10.6	15086	140
Threshold +OOO	39.9	5.0	4.9	1.15	83.9	34.4	7.6	9.8	15875	149
Threshold +OMO	41.0	4.9	4.9	1.17	84.5	33.7	7.4	10.3	16003	150
Threshold +OOM	41.0	4.9	5.0	1.14	83.9	32.8	7.7	9.6	15941	152
Threshold +OMM	41.1	5.3	4.9	1.17	83.7	33.1	7.7	10.1	16109	151
P > F	0.48	0.27	0.60	0.32	0.86	0. 79	0.58	0.01	0.92	0.72
LSD_{05}								0.82		

[1]Determinations made at International Fiber and Biopolymer Research Institute at Texas Tech University, Lubbock.
[2]Treatments received separate applications of mepiquat chloride sprays ("M") or were untreated ("O"). OOO = untreated, OMO = single mepiquat chloride application at first flower, MMM = three mepiquat chloride sprays.

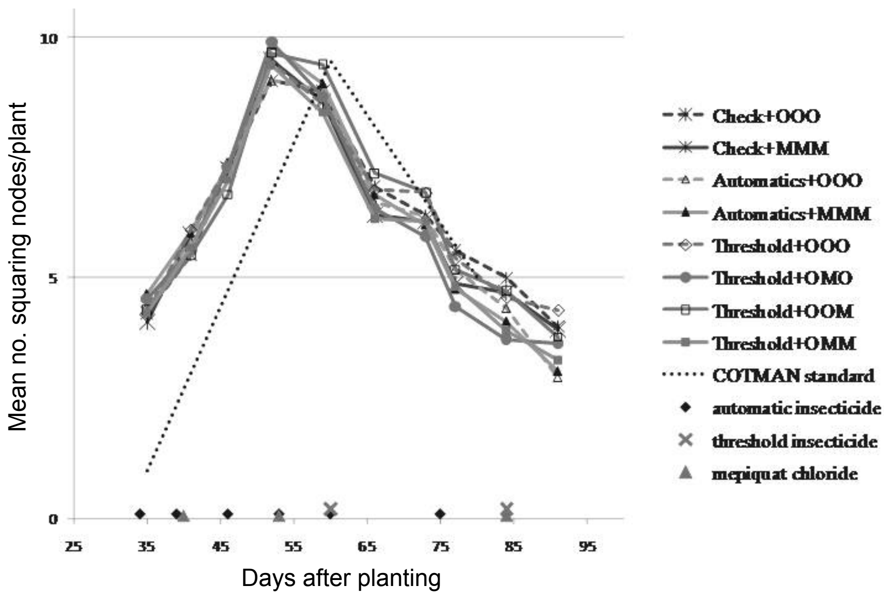

Fig. 1. COTMAN growth curves for program treatments indicate similar main stem nodal development among program treatments until the time of first flowers (52 days after planting). As plants approached physiological cutout (squaring nodes = 5), crop delay was apparent for the check + OOO treatment. Application dates for insecticides and mepiquat chloride are indicated on the x-axis.

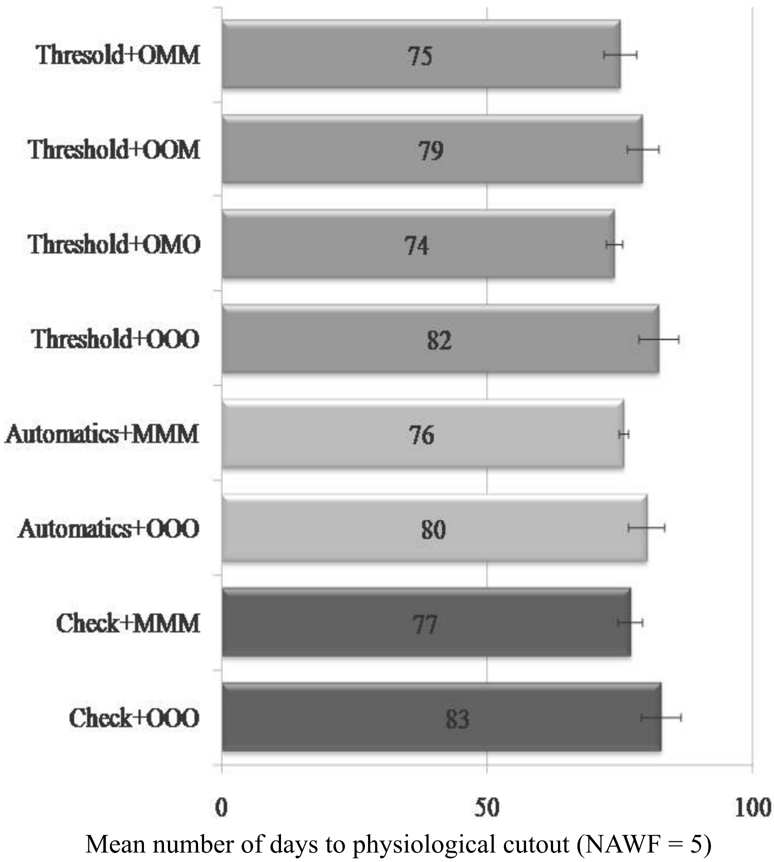

Fig. 2. Mean number of days until physiological cutout (node above white flower (NAWF) = 5) for insecticide and mepiquat chloride program treatments; an earlier cutout generally was associated with program treatments that included mepiquat chloride (P = 0.04; LSD_{05} = 6.3).

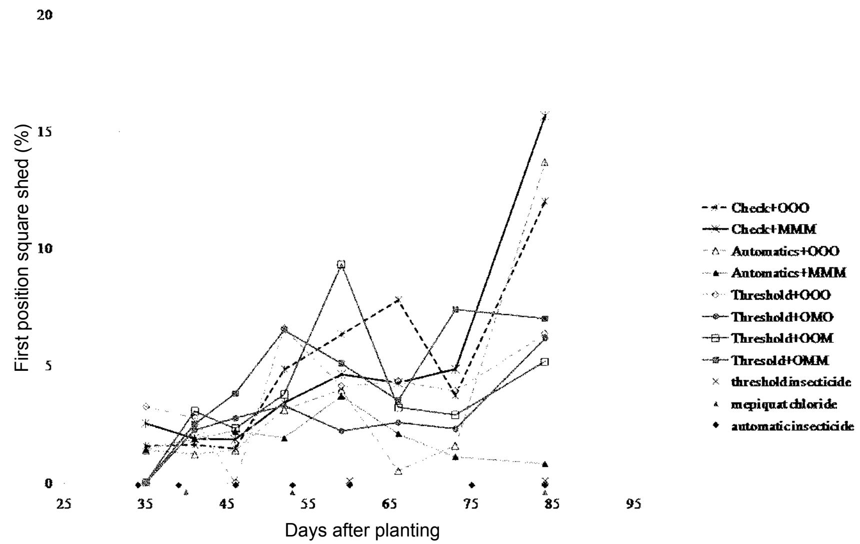

Fig. 3. Mean first position square shed determined from weekly COTMAN Squaremap sampling. No differences among treatments were apparent until the final sampling period.

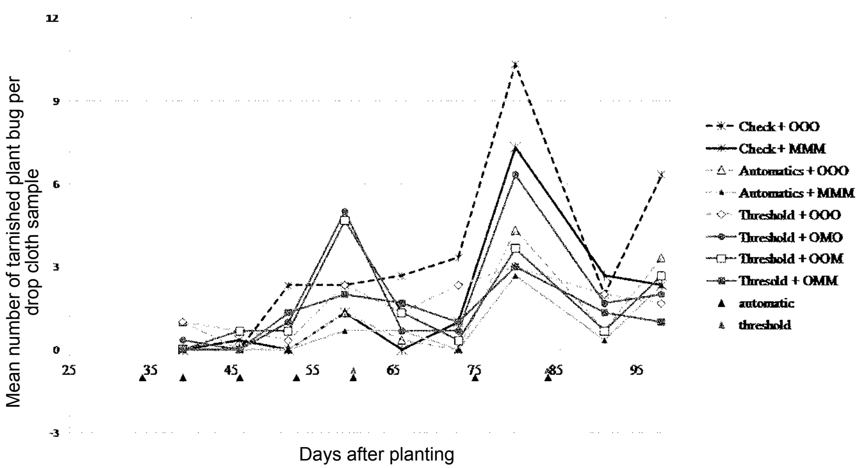

Fig. 4. Plant bug field population densities were moderately low much of the season with numbers exceeding action thresholds (mean = 3 bugs per sample) just after first flowers at around 60 days after planting and at the time of physiological cutout. Insecticide application dates are indicated on the x-axis.

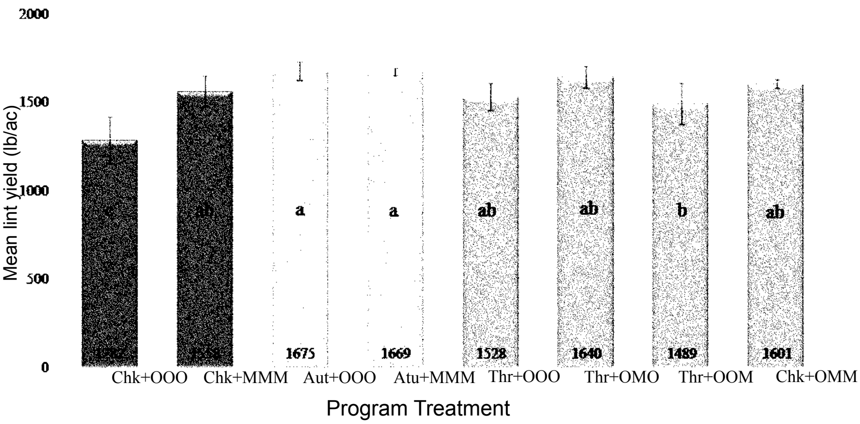

Fig. 5. Mean lint yield (±SEM) for 2010 mepiquat chloride/insecticide program treatments; lowest mean yields were harvested from plots that received neither insecticide nor mepiquat chloride applications (*P* = 0.001; LSD_{05} = 154).

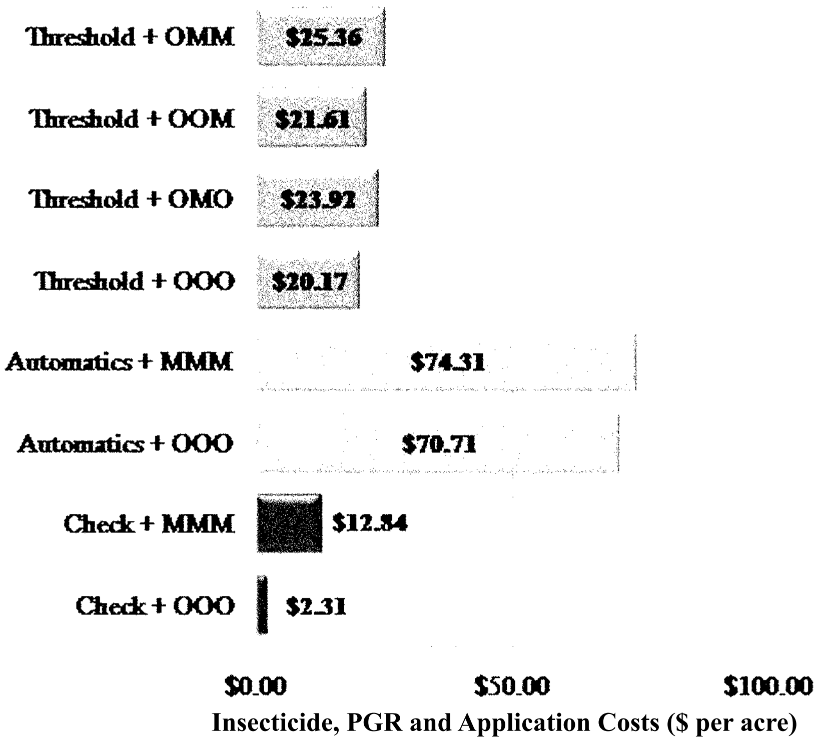

Fig. 6. Cost comparison of program treatments including product and application charges. If application timing coincided with an early season herbicide or plant growth regulator application, only one application charge (cost for the trip) was included. The baseline costs included for the untreated check reflect the equivalent of the one spray trip with a self propelled sprayer to apply an herbicide. No further applications were made in this program treatment.

Varietal Selection as a Management Tool for Tarnished Plant Bugs in Cotton

G.E. Studebaker and F.M. Bourland[1]

RESEARCH PROBLEM

Applying recommended insecticides for tarnished plant bug (TPB) when they reach treatment threshold is the most commonly used option to manage this pest in cotton in Arkansas (Studebaker, 2010). However, increasing levels of resistance to insecticides are beginning to make some chemistries less effective. Therefore, it is important to evaluate other options for TPB management, such as host-plant resistance.

BACKGROUND INFORMATION

The TPB is one of the most important pests of cotton in Arkansas. From 2003 to 2009 it caused more yield losses than any other pest averaging a loss of over 50,000 bales in Arkansas (Williams, 2009). Recent data from small plot studies has indicated that some commercially grown varieties may be less attractive or exhibit some level of resistance to TPB. A large block study was conducted in 2010 to evaluate the resistance of several varieties that exhibited low damage from TPB in small plot studies in previous years.

RESEARCH DESCRIPTION

Trials were conducted at the Northeast Research and Extension Center, Keiser, Ark. Plots were 24-rows by 90-ft long arranged in a randomized complete block design with 3 replications. Varieties showing low damage in small plots that were evaluated included; ST4554B2RF, ST5458B2RF, ST4498B2RF, PHY-375WRF and DP0935B2RF. One variety exhibiting high damage in small plots, FM1740B2RF, was also evaluated as a control. Each variety had two treatment regimes; an untreated control and treated when TPB numbers reached 3/5 row-ft. Plots were sampled weekly. When TPB reached the treatment level of 3 bugs per 5-row feet, treatments were applied with a high clearance sprayer calibrated to

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deliver 10 gal/acre through two hollow cone nozzles per row. Acephate at 0.75 lbs ai/acre was applied when threshold was reached. Plots did not reach treatment level until after bloom. Yields were taken from the center 4-rows of each plot at the end of the season. All data were analyzed using Agriculture Research Manager (ARM) version 8 software (Gylling Data Management, Inc., Brookings, S.D., 2009). Treatment means were separated at the $P = 0.05$ alpha level.

RESULTS AND DISSCUSSION

The TPB numbers throughout the season are shown in Fig. 1. The number of times each variety reached a treatment threshold of 3 TPB/5 row-ft are shown in Fig. 2. Yields from treated and untreated plots are shown in Fig. 3. Differences in TPB populations were detected between varieties in large plots (Fig. 1). These differences in TPB densities did correlate with previous years' small plot measurements (Fig. 4). Five of the varieties tested exhibited lower TPB damage to blooms in 2009 and also had lower populations in the large plot study in 2010. The variety with the highest amount of damage in 2009 also had higher levels of TPB earlier in the season in 2010. This variety also reached the treatment threshold of 3 TPB per 5 row-ft 4 times in 2010, while the other varieties reached threshold 1 to 2 times (Fig. 2).

PRACTICAL APPLICATION

Reduced TPB populations in certain varieties implies that they are less attractive to this pest until very late in the season. The small plot data correlates well with the large plot studies. This should also translate to the field, giving growers and pest managers another option for managing TPB. By utilizing these varieties, growers could potentially reduce insecticide applications for TPB in half.

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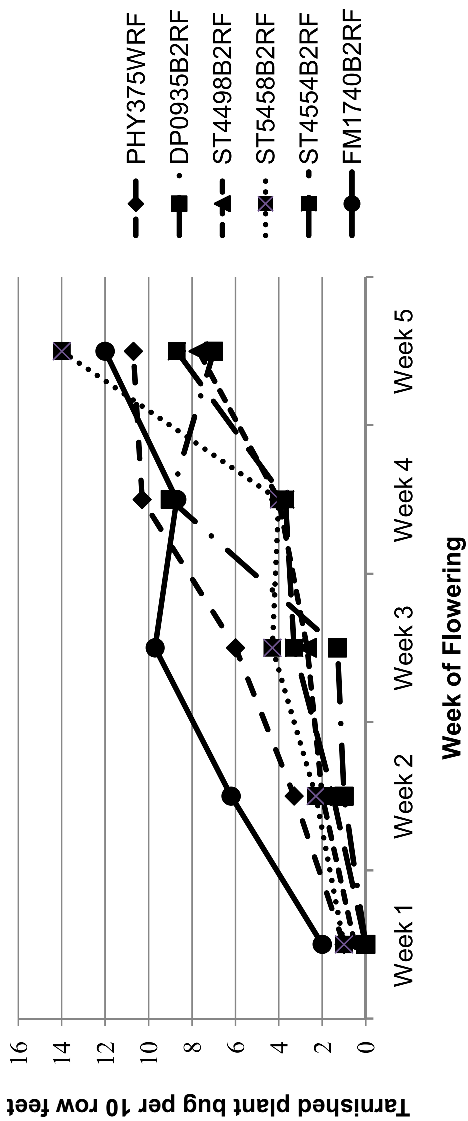

Fig. 1. Tarnished plant bug density in untreated plots throughout 2010 growing season.

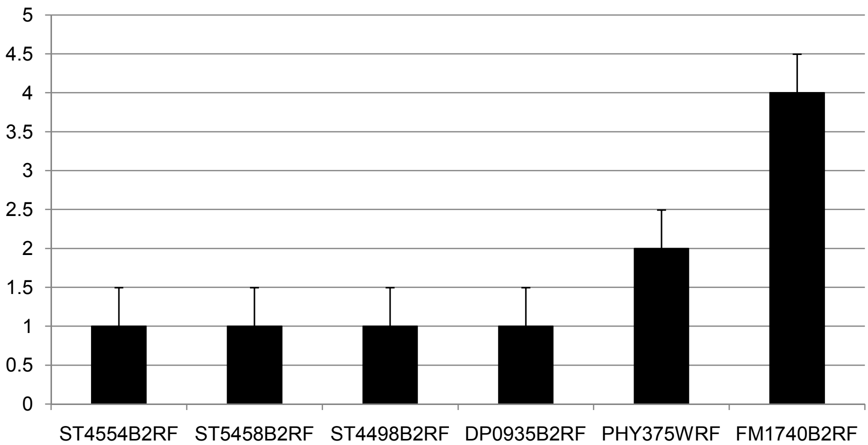

Fig. 2. Frequency of reaching tarnished plant bug treatment threshold of 3 TPB per 5 row-ft.

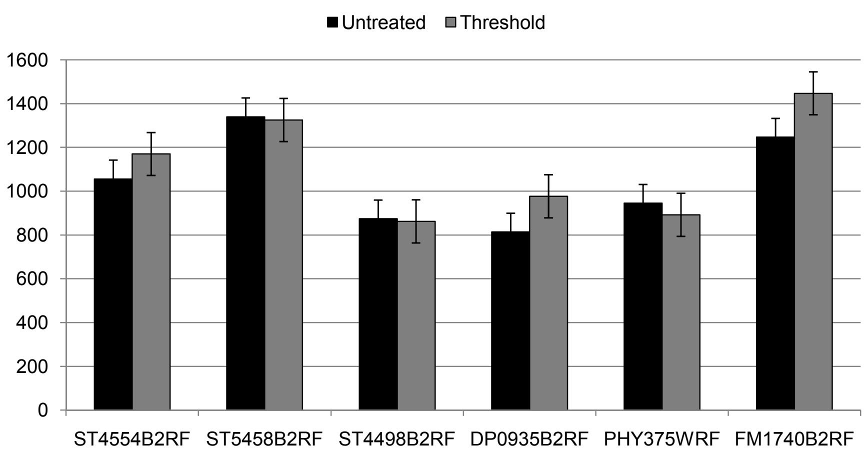

Fig. 3. Lint yield for each variety in 2010.

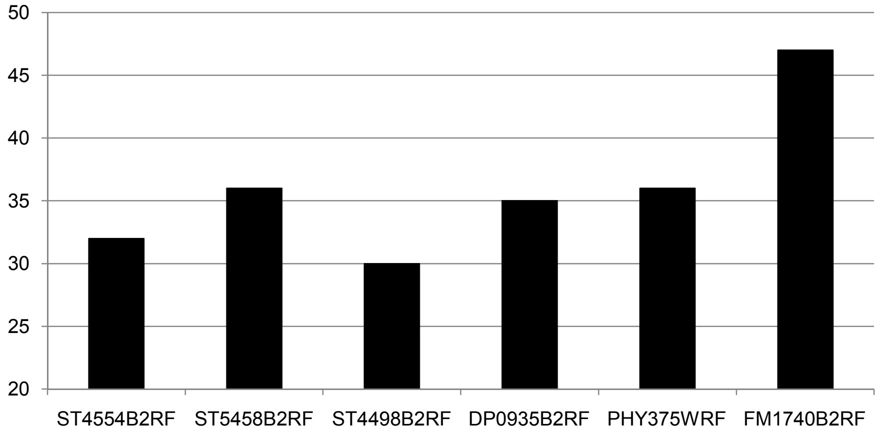

Fig. 4. Percent tarnished plant bug damaged blooms in 2-row plots in 2009.

Effects of Eastern Arkansas Production Systems on Soil Strength and Electrical Conductivity

R.L. Raper[1], J.L. Snider[1], T.G.Teague[2], and S.S. Kulkarni[3]

RESEARCH PROBLEM

Eastern Arkansas soils present specific soil management problems exacerbated by the large percentage of clay content present in these soils. Traditional management of eastern Arkansas soils has been to use extensive tillage systems that require large equipment and frequent field trips, thereby increasing soil susceptibility to compaction, increasing soil losses due to runoff, and accelerating organic matter decomposition. Soil conservation management systems currently under development include reduced tillage systems with cover crops.

BACKGROUND INFORMATION

Despite potential benefits derived from conservation tillage systems, conversion to conservation systems has been partially stymied by the excessive amounts of soil compaction found in these soils that limits root development and reduces crop yields. For example, previous research results indicate that a cone index (CI) of 2 MPa restricts root growth and reduces cotton yield (Raper, 2005, Taylor et al., 1966). Frequent tillage has been used to manage soil compaction, but with reduced tillage systems these extra tillage opportunities are not possible.

RESEARCH DESCRIPTION

An experiment has been in place at Judd Hill Plantation in eastern Arkansas for three years that has compared three tillage systems: (1) a conventional tillage system, (2) a reduced-tillage system, and (3) a reduced-tillage system with a cover crop. A Veris Technologies P4000T VIS-NIR-EC-Force Probe (Salina, Kan.) was used to obtain a full set of cone index (CI) and electrical conductivity (EC) data for this experiment. Unfortunately, the NIR (Near Infrared) sensor was not opera-

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[3]Program associate, Cooperative Extension Services, Little Rock.

tional and only CI and EC data were obtained. Five separate locations across the row were sampled; (1) untrafficked row middle, (2) midway between untrafficked row middle and row, (3) in the row, (4) midway between row and trafficked row middle, and (5) trafficked row middle. Three sets of data were obtained at each location at opposite ends of the plot on 6 December 2010.

RESULTS AND DISCUSSION

Previous research results indicate that a CI of 2 MPa restricts root growth and reduces cotton yield (Raper, 2005, Taylor et al., 1966). Using these criteria illustrates that the CI data obtained at the Judd Hill Plantation achieved a root-limiting condition at all five positions across the row and at relatively shallow depths of 0.3-0.35 m (Fig. 1). A potential fix for this condition is to conduct in-row subsoiling down to a depth where rooting is desired. However, the soil compaction condition that is indicated by these graphs does not tend to support this management practice. No reduction in CI is noted until depths of at least 0.5-0.6 m, which would require excessive amounts of energy for any tillage practice. However, the practice of in-row subsoiling may provide some additional benefits including increased infiltration that may be beneficial to overall crop production.

Another possible method of reducing CI is to incorporate a cover crop which can contribute to reduced soil compaction by increasing infiltration, increasing soil organic matter, and increasing water holding capacity of the soil. According to Fig. 1, this scenario may be taking place with a cover crop providing some assistance by increasing the depth to the root-limiting condition of 2 MPa CI. Increased depths of up to 0.05 m are noted on the graphs for the conservation tillage treatment that has a cover crop present in all row positions except for the row middle. No differences in treatments were found at this location.

Also noted in the management treatments are the reductions in overall CI caused by conventional tillage. This is frequently found when converting fields over to conservation tillage practices. In some situations, this is a temporary condition that changes over time to a somewhat softer soil condition with overall lower CI. In other soil conditions, a physical change in soil leading to reduced CI is not found and conservation tillage soils continue to exhibit excessive values of CI (Wilkins et al., 1999). However, improvements in overall productivity are often found with these soils, thus contributing to enhanced adoption of conservation tillage systems (Raper et al., 2000).

There are no apparent differences in EC across the row positions that are evident from the graphs. In some graphs, it appears that EC for the no-till treatment is slightly greater than either conventional or no-till with a cover crop. However, these differences don't typically occur within the rooting depth and are probably not connected with recent management practices.

PRACTICAL APPLICATION

Root-limiting conditions were found with the CI data at depths of 0.3-0.35 m. However, in-row subsoiling tillage is not a viable option to decrease CI due to fuel costs and the required depth of operation. However, the practice may have other benefits that should be examined. Cover crops provide a slight benefit by increasing the depth to the root-impeding layer at most row positions, except immediately beneath the row.

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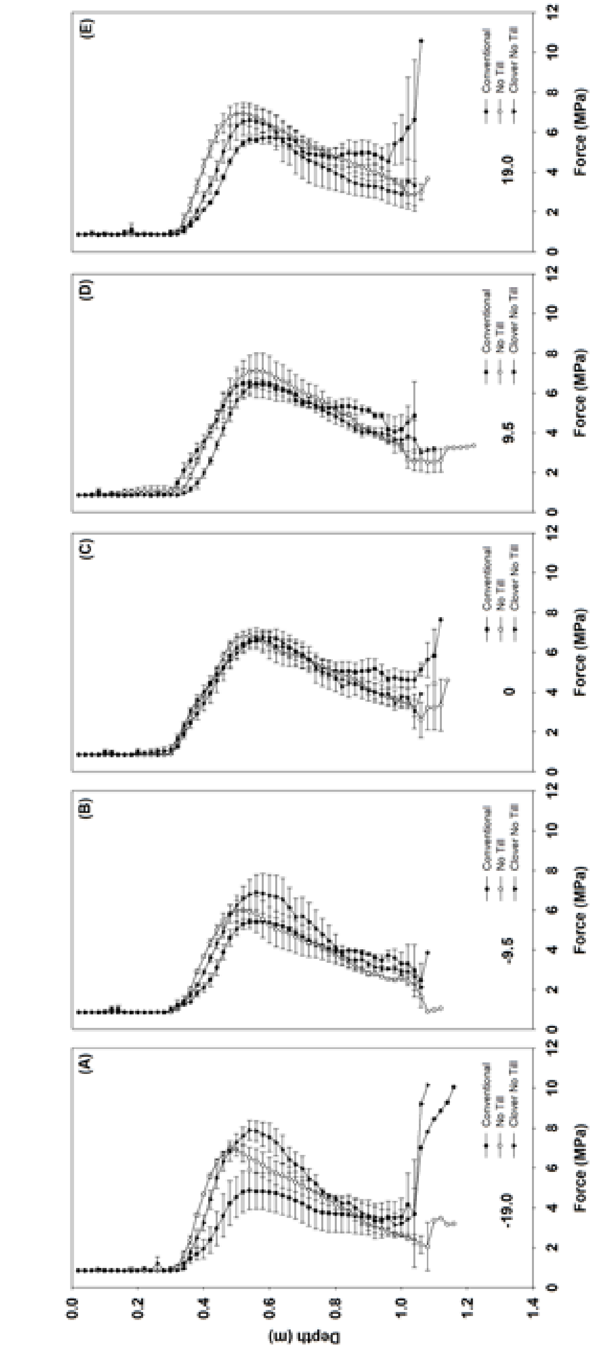

Fig. 1. Cone index (MPa) taken across the row from -19 cm (A), -9.5 cm (B), 0 cm (C), 9.5 cm (D), and 19.0 cm (E). Error bars (0.05) are shown for each depth data was obtained. Sampling was performed on 6 Dec. 2010.

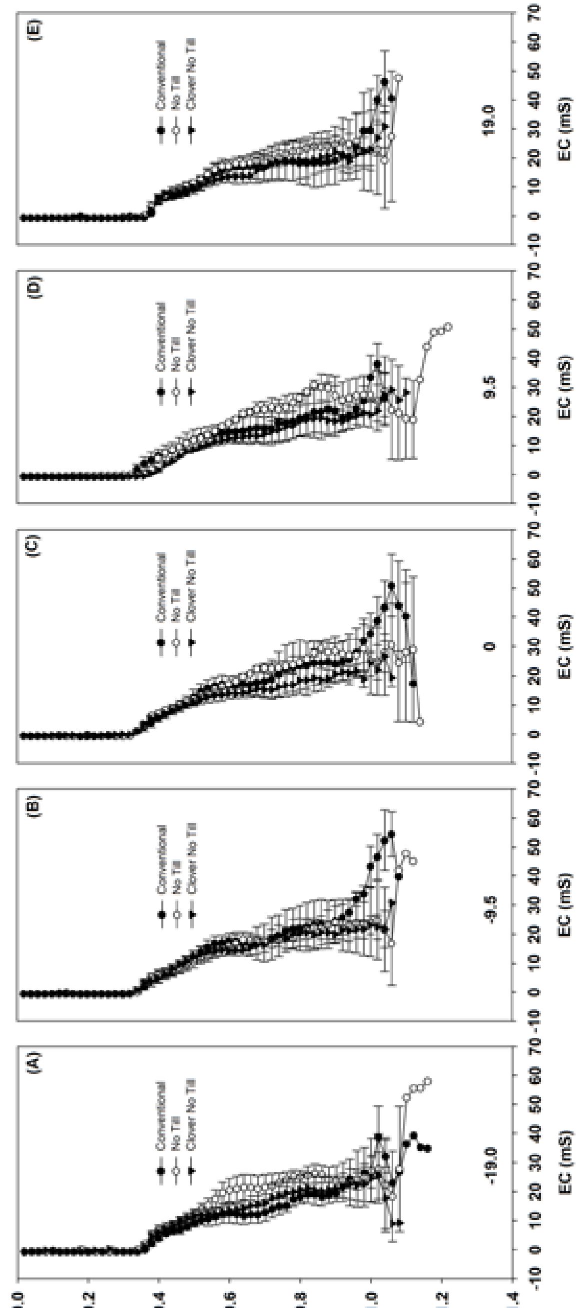

Fig. 2. Electrical conductivity (mS) taken across the row from -19 cm (A), -9.5 cm (B), 0 cm (C), 9.5 cm (D), and 19.0 cm (E). Error bars (0.05) are shown for each depth data was obtained. Sampling was performed on 6 Dec. 2010.

Two Undescribed Cotton Species from Western Australia and Southern Mexico

J.M. Stewart[1]

RESEARCH PROBLEM

Two new cotton species have been discovered from western Australia and southern Mexico. The current research problem is to determine the germplasm-pool to which these two new species belong.

RESEARCH DESCRIPTION

The first species is *Gossypium annapoides* and occurs in the Kimberley region of western Australia and it belongs to grandi calyx. It has a record pedicel and a woody lignotuber and unlike other species it grows in sandy soil. Most of the species of this subsection grow in lateralic soil. The specific name is made up of Greek words which mean that the top and the bottom of the leaves are similar.

The second species is *Gossypium nahuatlum* and occurs in eastern Guerrero in southern Mexico and specifically in the water shed of the Rio Balsas of eastern Guerrero. It occurs on rocky hill sides in a sclerophyllous forest and it belongs to the subsection erioxylum and gets the specific name from an Indian tribe which occupies the area.

RESULTS AND DISCUSSION

The species description has been determined and they belong to the subsection previously described; the first belonging to grandi calyx and the second to erioxylum. The species of this subsection belong to the tertiary and the secondary germplasm-pools. The secondary germplasm-pool recombines with the (D) genome of cotton, whereas the tertiary germplasm-pool does not recombine readily.

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PRACTICAL APPLICATIONS

The germplasm-pool to which these two new species from western Australia and southern Mexico belong has been determined. This is important for the continuing understanding and identification of the cotton D genome and for future introgression of traits.

Cotton Yield Components

H. Lewis[1] *and D.M. Oosterhuis*[2]

INTRODUCTION

Cotton is like most of the important field crops in that a major component of yield is the reproductive potential, or the number of seeds produced per unit of land surface. However, it differs from most of the other field crops, where seed yield is the prime determinant of economic yield, in that if no fiber or a reduced amount of fiber is produced on the seed surface, the lint yield may be severely reduced.

Cotton lint yield is probably best understood in terms of the components which make it up. Fiber or lint yield in cotton is determined by two major components, i.e., the number of seeds produced per acre and the weight of fiber produced on the seed. Cotton fibers are elongated epidermal cells of the outer integument of the seed coat. If there is no seed, there can be no fiber. The structure and dimensions of the fibers determine their quality.

COMPONENTS OF YIELD

Classically, the yield components of cotton in its simplest form consist of two main components: the number of bolls per unit area and the weight of the bolls. However, because the lint (fiber) is produced on the seed and is the main component of interest and harvested for profit, the components of yield can be further considered as number of seeds/acre multiplied by the weight of fiber/seed:

Lint yield = [(No. of Seeds/Acre)(Weight of Fiber/Seed)]

Cotton seed is still of commercial interest for oil and cattle feed, and the seed yield can be expressed as:

Seed Yield = [(No. of Seeds/Acre)(Weight/Seed)]

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The number of seeds per acre is determined by the number of plants per acre, the number of bolls per plant and the number of seeds per boll. This suggests that the number of seeds produced per acre is influenced to a high degree by management and environmental factors and to a lesser extent by genetic considerations.

Seeds per acre = [(Plants/Acre)(Bolls/Plant)(Seeds/Boll)]

The weight of fibers per seed is a function of the number of fibers per seed and the average weight per fiber.

Weight of fiber per seed = [(Number of fibers per seed)(Average weight/fiber)]

From a cell physiology perspective, the number of fibers per seed is determined by the number of epidermal cells in the outer epidermis of the seed coat which initiate elongation and develop into lint fibers. Physically, the number of fibers per seed is a function of the weight of fiber per seed divided by the mean weight per fiber.

Number of Fibers/Seed = Weight of fiber per seed/Mean weight per fiber

The mean weight per fiber is a function of the mean length of the fibers on the seed multiplied by the mean linear density of the fibers.

Average weight per fiber = (Mean fiber length)(Mean linear density of fibers on the seed)

Physiologically, the average weight per fiber is determined by the degree and extent of primary and secondary cell wall growth. Primary wall growth is equivalent to fiber elongation. As long as a plant cell is increasing in volume it is considered to be producing primary cell wall. After a plant cell stops increasing in volume but continues to increase in weight it has entered the secondary cell wall phase of growth. Secondary wall growth is equivalent to an increase in the linear density (micronaire tex, etc.) of the fiber or the thickness and, perhaps, the density of the secondary cell wall. Thus, the mean weight per fiber is a function, physiologically speaking, of both primary and secondary cell wall growth. This constitutes strong evidence that the weight of fiber per seed is heavily influenced by genetic considerations, especially in so far as the number of fibers per seed is concerned.

A relatively small increase in the weight of fiber per seed may have a highly significant impact on lint yield. For example, in the south central and southeastern U.S. cotton belt, the long term average number of seeds per acre produced is approximately 7 million. Thus, if the weight of fiber per seed were increased by only 5 milligrams, this could result in a yield increase of a little more than 75 pounds of lint per acre.

CONCLUSIONS

A knowledge of the components of yield of cotton is important in understanding how yield is produced and what influences yield and fiber quality. This description explains what makes up the main components of yield and provides an explanation of each component. Lint is produced on the seed and is the main component of interest and harvested for profit, and therefore the main components of yield are the number of seeds/acre multiplied by the weight of fiber/seed. However, the weight of fiber/seed and the number of fibers/seed, and the average weight per fiber are integral aspects of these components.

APPENDIX I

STUDENT THESES AND DISSERTATIONS RELATED TO COTTON RESEARCH IN PROGRESS IN 2010

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

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

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

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

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)

Phillips, 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)

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

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

A P P E N D I X I I

RESEARCH AND EXTENSION 2010
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