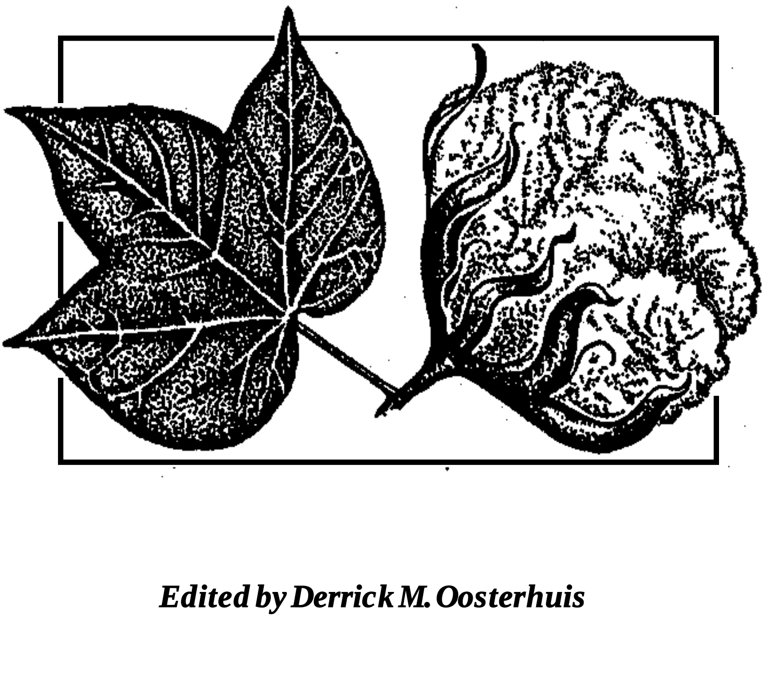
Proceedings of the 1999 Cotton Research Meeting

and

Summaries of Cotton Research in Progress



Edited by Derrick M. Oosterhuis

ARKANSAS AGRICULTURAL EXPERIMENT STATION

Division of Agriculture — University of Arkansas

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PROCEEDINGS OF THE 1999 COTTON RESEARCH MEETING

AND

SUMMARIES OF COTTON RESEARCH IN PROGRESS

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PREFACE

Cotton yields in Arkansas increased steadily during the 1980s, but in recent years there has been a leveling off of this upward trend. Furthermore, the last five years have provided extreme year-to-year variability in yields, which is a major point of concern with cotton producers. The 1998 crop was one of the poorest in recent history due to extreme weather conditions as well as insect infestations. The average state yield was 651 lb lint per acre from 920,000 acres, and the lint quality was disappointing.

The crop started slowly with poor, uneven stands due to drier and warmer conditions than normal at planting. However, crop development up to flowering was reasonably good despite lower than average rainfall. Extremely hot and dry conditions during July and early August affected boll growth, seed and fiber development in particular, which resulted in low yields despite good management efforts. Irrigation could only partially offset the extreme heat and excessively dry conditions. High temperatures reduced fertilization and available carbohydrates. Consequently, poor seed and boll development resulted in low boll weights and poor yields. There is no obvious immediate remedy to the problems associated with high temperature.

Although cotton originates from hot climates, it does not necessarily grow best at excessively high temperatures. The ideal temperature range for cotton is reported to be from 68 to 86°F. Average daily maximum temperatures in August in the Delta *are invariably above 90°F.* There is a report in Arkansas (this issue) of a negative correlation between cotton yield and temperature in August, with high daytime temperatures being associated with low yields and low daytime temperatures being associated with high yields. Even with the best management efforts, the occurrence of untimely adverse weather and insect attacks can still affect cotton growth and yield. A concerted effort in future research is needed to address this problem.

ARKANSAS COTTON RESEARCH GROUP
1998/99

The University of Arkansas Cotton Group is composed of a steering committee and three sub-committees representing production, genetics, and pest management. The group contains the appropriate representatives in all the major disciplines as well as representatives from the Cooperative Extension Service, the Farm Bureau, the Agricultural Council of Arkansas, and the State Cotton Support Committee.

The objective of the Arkansas Cotton Group is to coordinate efforts to improve cotton production and keep Arkansas producers abreast of all new developments in research.

Steering Committee: Gus Lorenz, Gene Martin, Keith Martin, Robert McGinnis, Derrick Oosterhuis (Chm.), Don Plunkett, Bill Robertson, Craig Rothrock, Mac Stewart, Cecil Williams, David Wildy

Pest Management: Charles Allen, Ford Baldwin, Gary Felton, Bob Frans (emeritus), Don Johnson, Terry Kirkpatrick, Tim Kring, Gus Lorenz, Jake Phillips (emeritus), Bill Robertson, Craig Rothrock (Chm.), Don Steinkraus, Glen Studebaker, Tina Teague, Phil Tugwell, Seth Young

Production: Bill Baker, Ray Benson, Mark Cochran, Dennis Gardisser, Terry Keisling, Gus Lorenz, Scott McConnell, Derrick Oosterhuis (Chm.), Lucas Parsch, Don Plunkett, Bill Robertson, Cal Shumway, Phil Tacker, Earl Vories

Genetics: Fred Bourland, Hal Lewis, Bill Robertson, Mac Stewart (Chm.)

ACKNOWLEDGMENTS

The organizing committee would like to express its appreciation to all who helped with the arrangements for the 1999 Arkansas Cotton Research Meeting, particularly Keith Martin and Bill Robertson, and the companies who sponsored the continental breakfast and coffee breaks: Bayer and Dow AgroSciences. We also extend our gratitude to Marci Milus for help in typing this Special Report and getting it ready for production.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The 1999 Proceedings of the Arkansas Cotton Research Meeting has been published with funds supplied by the Arkansas State Support Committee of Cotton Incorporated.

The principal purpose of Cotton Incorporated is to increase the profitability of cotton production by building demand for U.S. cotton. The Arkansas State Support Committee of Cotton Incorporated is a board whose voting members are cotton growers from Arkansas. Advisory members include representatives of Arkansas' certified producer organizations, the University of Arkansas, the Cotton Board, and Cotton Incorporated. Five percent of Cotton Incorporated's total budget is allocated for research and promotion activities, as determined by the State Support Committees of the cotton producing states. The sum allotted to Arkansas' State Support Committee is proportional to Arkansas' contribution to the total U.S. cotton fiber production and value in the five years previous to the budget.

The Cotton Research and Promotion Act is a federal marketing law. The objective of the act is to develop a program for building demand and markets for cotton. The Cotton Board, based in Memphis, Tennessee, was created to administer the act and empowered to contract with an organization with the capacity to develop such a program. Cotton Incorporated, with its main offices in New York, New York, the center of the U.S. clothing merchandising industry, and its research offices in Raleigh, North Carolina, the center of the U.S. textile industry, is the contracting agency. Cotton Incorporated also maintains offices in Basel, Switzerland; Osaka, Japan; Mexico City, Mexico; Shanghai, China; and Singapore to foster international sales. Both the Cotton Board and Cotton Incorporated are non-profit entities with governing boards comprised of cotton growers and cotton importers. The budgets of both organizations are annually reviewed and approved by the U.S. Secretary of Agriculture.

Cotton production research is supported in Arkansas both by Cotton Incorporated directly from its national budget and by the Arkansas State Support Committee from its formula funds. Several of the projects described in these proceedings, including the publication of these proceedings, are supported wholly or in part by these means.

Arkansas Cotton State Support Committee / Cotton Incorporated Funding 1993-1999

Project	Principal investigator	Amount Funded ($)						
		1993	1994	1995	1996	1997	1998	1999
Harvest aid decisions based on NAWF	Bonner	17,000	17,000	——	——	——	——	——
Characterization of cotton root growth	Oosterhuis	28,000	28,000	——	——	——	——	——
Row-spacing effects on management options	Vories	27,000	30,000	——	——	——	——	——
Manipulation of the effective fruiting window	Bourland	27,000	27,000	25,550	24,550	24,550	——	——
Conservation tillage for Arkansas cotton	McClelland	28,000	28,000	18,190	——	——	——	——
Boll weevil survey and eradication research	Johnson	6,000	36,000	45,000	——	——	——	——
Proceedings annual Arkansas research meeting	Oosterhuis	4,000	4,000	6,000	6,000	6,000	5,000	5,000
Cottonseed pool — Arkansas	Cotton Inc.	8,000	9,000	10,000	11,000	10,000	14,200	14,200
Conditions for successful use of foliar nitrogen	Baker	——	——	21,410	21,400	21,400	——	——
Integration of boll weevil control technology	Teague	——	——	20,000	——	——	——	——
Weed control in conservation tillage	McClelland	——	——	6,975	7,000	7,000	——	——
Harvest aid performance and fiber quality	Guy	——	3,000	3,621	——	——	——	——
Evaluations of cotton defoliants	Shumway	——	3,000	3,000	——	——	——	——
Early irrigation management	McConnell	——	——	19,616	19,500	19,500	——	——
Petiole monitoring sampling evaluation	Oosterhuis	——	——	8,099	8,100	8,100	——	——
Management of early season pest damage	Rothrock	——	——	23,539	22,000	22,000	——	——
Coordination of boll weevil eradication in Arkansas	Alexander	——	——	——	15,000	15,000	10,000	10,000
Boll weevil eradication: implementation and evaluation	Yearian	——	——	——	123,450	123,450	89,800	89,800
Research on the cotton aphid fungus	Steinkraus	——	——	——	8,000	11,000	13,800	——
Integration of weed control programs	Baldwin	——	——	——	10,000	10,000	10,000	——
Terminating squares after physiological cutout	Bourland	——	——	——	——	——	3,500	3,500
Control of reniform nematodes	Kirkpatrick	——	——	——	——	——	16,300	16,300
COTMAN: Economics	Cochran	——	——	——	——	——	16,000	16,000
Validation of COTMAN termination	Allen	——	——	——	——	——	10,000	10,000
Plant growth regulator evaluation	Oosterhuis	——	——	——	——	——	16,000	16,000
Breeding and evaluation of host plant resistance	Bourland	——	——	——	——	——	20,000	20,000
Control of spider mite	Steinkraus	——	——	——	——	——	13,700	13,700
Boll weevil overwintering sites	Johnson	——	——	——	——	——	30,200	30,200
Roundup Ready and Bt evaluation	Allen	——	——	——	——	——	15,000	15,000
Cotton graduate student award	Oosterhuis	——	——	——	——	——	500	500
Natural enemies	Kring	——	——	——	——	——	——	6,800
Totals:		145,000	185,000	211,000	276,000	278,000	284,000	267,000

PROCEEDINGS OF THE 1999 COTTON RESEARCH MEETING

Arkansas Cotton Research/Extension/Production and Marketing Group
University of Arkansas

Theme: Research for Efficient and Profitable Cotton Production

Proceedings of a Conference held at the
Mississippi County Community College, Blytheville
February 9, 1999

WELCOME
Your University System

Milo J. Shult[1]

Welcome to the 1999 Cotton Research meeting. We hope you will enjoy today's agenda and take something home with you that will improve your productivity. I am pleased to have the opportunity to be a part of the program today. It is always satisfying for me to have the opportunity to see and hear the results of our research work.

The Arkansas Cotton Research Group is the best of its kind in the country. It is composed of a steering committee and three sub-committees representing production, genetics, and pest management. All major disciplines as well as the Cooperative Extension Service, the Farm Bureau, the Agricultural Council of Arkansas, and the State Cotton Support Committee are represented. This group does an outstanding job coordinating efforts to improve cotton production and keeping Arkansas producers abreast of new developments in research.

The University of Arkansas Division of Agriculture is a statewide effort encompassing research and extension programs. Our "campus" extends to every corner of the state. Our research and extension programs are conducted at the University of Arkansas at Fayetteville, University of Arkansas at Monticello, Arkansas State University, Cooperative Extension Service headquarters in Little Rock, at four Research and Extension Centers, and at branch stations throughout the state. In every county of the state you can find us at your county's Cooperative Extension Service office.

Accessibility and relevancy are two of our primary goals. We strive to be both accessible to Arkansans and relevant to their needs. We also know we have to be accountable for the trust the people have placed in us, which includes knowledge of, and sensitivity to, the needs of stakeholders. Instead of having a laundry list of issues to address, we intend to go beyond outreach and service to what the Kellogg Commission calls an engaged institution. In a published report earlier this year, the Commission portrayed the engaged institutions as those that have "redesigned their teaching, research, and extension and service functions to become even more sympathetically and productively involved with their communities." I would like to share some of their insights with you today.

The seven guiding characteristics of an engaged institution are:

1. Responsiveness. Is our communication with the communities clear? Are we asking the right questions at the right time in the right way? Do we encourage community-university discussions of public problems? Are we collecting the information we need to assist the community?

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[1] Vice President for Agriculture, University of Arkansas Division of Agriculture.

2. Respect for partners. Our purpose is not only to provide superior expertise to the community, but also to encourage joint academic-community definitions of problems, solutions, and successes. We must recognize that we have as much to learn in these efforts as we have to offer.

3. Academic neutrality. Some of our activities unavoidably involve controversial issues such as pesticide use, waste management, and others. Are we maintaining the role of neutral facilitator and source of information on these issues, especially the contentious ones?

4. Accessibility. We need to be certain we help potential partners navigate the complex network of the university system that may be confusing. Are we making every effort to increase awareness of our resources and programs to everyone in the community?

5. Integration. We need to integrate our extension mission with our responsibilities for developing intellectual capital and trained intelligence. Does the university climate foster outreach, service, and engagement?

6. Coordination. Our right hand needs to know what our left hand is doing. The task of coordinating activities between extension and research takes time and commitment. Are we developing the skill to translate expert knowledge into something the public can appreciate?

7. Resource partnerships. Engagement is not free. Besides the obvious costs of the time and effort of staff, faculty, and students, we have to be aware of the costs of program, curriculum, and possible limitation of choices. Can we depend solely on state and federal funds or corporate investments? Successful engagements are those with strong and healthy relationships with partners in government, business, and the nonprofit world.

Becoming an engaged institution requires system-wide participation. Each administrator, faculty, staff member, and student has a part in the land-grant philosophy of knowledge harnessed to responsibility. The challenge is not an easy one, but the whole community benefits from an informed citizenry who are prepared to take up the complex problems of our society.

We are proposing to reshape the land-grant concept of a new kind of university that would create open access to knowledge. If we are successful, we will celebrate because we insisted that we could do more -- and we could do it better.

THE ECONOMIC OUTLOOK FOR U.S. COTTON

Mark Lang[1]

Despite a surprisingly strong performance by the U.S. economy, the farm sector is suffering one of the harshest periods since World War II. The combination of poor yields, low commodity prices, and weak export demand has pushed down net farm income even as Congress allocated some $3 billion in supplemental AMTA payments. With U.S. commodity futures markets indicating harvest prices for 1999 crops at or below the damaging prices present during 1998, most producers are taking stock of their operating alternatives as well as the overall package of farm legislation known as the FAIR Act.

The U.S. cotton industry is now in the midst of a market that is digesting the full impact of the exhaustion of Step 2 funding and the imminent availability of foreign cotton under the Step 3 import quotas. While the United States goes through the exercise of adjusting to policy implementation, the world cotton market is suffering from a lack of demand, uncertainty of actions by Chinese authorities, and an over-capacity of polyester production.

With the conclusion of the National Cotton Council's annual meeting, a unanimous industry position seeking reestablishment of the funding of cotton's competitiveness provisions will be sought. Some modifications to current regulations regarding the operation of the provisions are also desired. However, the fundamental message is that U.S. cotton must be competitive, and, because of who the principal players are in the world market and how they operate, the type of competitiveness provisions we seek are crucial to protecting U.S. producer income and the investments in our infrastructure associated with cotton processing and flow.

The World Cotton Market for 1998/99

The world began the year with stocks of 41.1 million bales, capping four consecutive years of stock accumulation. The USDA estimates that the Chinese held 16.9 million bales of the total stock. Production in 1998/99 is pegged at 84.9 million bales, down more than 5 million bales from the previous year. The decline in U.S. production accounts for most of the reduction.

Mill use of cotton is now projected at 84.6 million bales, the lowest level since 1987/88. The continuing economic crisis in Asia, the Brazilian currency problem, and the latest round of Russian difficulties combine to reduce worldwide retail purchases of cotton some 4 to 5 million bales annually. In a picture completely different than that of the United States, polyester continues to gain market share in the total world fiber

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[1] Economist, National Cotton Council, Memphis, Tennessee.

market. Expectations for any real turnaround in world cotton mill use within the next 12 to 18 months are slim.

With the world cotton demand problem bearing down on the market, current low commodity prices are not sufficient to bring support to mill use and the world is expected to finish the crop year with 41.6 million bales of carryover. China is pegged at holding some 16.6 million bales of stocks by year-end. This has a corresponding stock to use ratio of 49.2%.

In addition to the economic conditions affecting demand, the world raw cotton market is coping with the uncertainty of actions by Chinese authorities in regard to imports and exports. By February 1998, China effectively ceased imports of raw cotton. For the previous four years, China had been the world's largest importer of raw cotton – drawing an annual average of 3 million bales from the world market. In April 1998, the Chinese announced an export tender of 1 million bales and followed that announcement in May with discussions of perhaps as much as another 1.5 million bales being offered to the world market. Ultimately, the April tender was the only formal tender made by China in 1998. Rumors persisted throughout the year of new tenders that never appeared.

However, several Chinese cotton authorities now offer Xinjiang province 129 and 229 cotton for delivery on a vessel in a Chinese harbor at 60 to 61 cents per pound. Xinjiang 129 and 229 cottons are considered higher grade than "A Index" or 3135 cottons. The first digits of 1 and 2 refer to color and are generally comparable to U.S. standards of Good Middling and Strict Middling, respectively. The second and third digits, 29, refer to staple length in millimeters. This is essentially one inch and 3/32. Until these prices move higher or this supply is exhausted it will be extremely difficult for world cotton prices to move higher than the current 56-cent level.

The World Cotton Market in 1999/2000

The world will begin the new marketing year with virtually the same stock level as the previous year, now estimated at 41.6 million bales. The following estimates were derived by Economic Services of the National Cotton Council and released in the council's annual outlook publication. Despite the lowest prices for cotton since 1993, world acreage devoted to cotton is not expected to decline. Prices of competing crops have generally suffered as much or more of a decline than cotton prices. World production is expected to reach 87.6 million bales.

World mill use is pegged at 85 million bales as economic conditions prevent any likely resurgence in use until midcalendar year 2000. The projected inability of mill use to recover in 1999/2000 results in an estimated ending stock on 31 July 2000 of 44.2 million bales. This has a corresponding ending stocks to use ratio of 52%. This will be the first time since 1985 that the world's stocks to use ratio exceeds 50%.

If, as forecast, world mill use is unable to rebound and the Chinese continue to export raw cotton, world raw cotton trade in 1999 will be as competitive as any raw cotton export market in the past decade. These expected market conditions make the proposed changes to the U.S. cotton competitiveness provisions all the more crucial for this industry.

The U.S. Cotton Market in 1998/99

The United States began the year with stocks of 3.9 million bales. Production was only 14 million bales as virtually every part of the U.S. Cotton Belt fought adverse conditions at some point in the production process. Ultimately, Texas abandoned some 2.2 million acres as drought and heat damaged the crop beyond recovery. The same factors that reduced yields and increased abandonment across the Cotton Belt also contributed to quality losses. Staple length and strength were below average and a smaller than average percentage of the crop classed grade 41 or better.

U.S. mill use has been under pressure from textile imports since early in calendar 1998. Mill use is projected by USDA at 10.4 million bales, but this expectation may be optimistic. Cotton mill use at annualized rates ran at 10.2 million bales in November and December 1998. These rates are down from 11.8 million bales annualized rates in November and December 1997.

U.S. cotton textile imports for calendar 1998 were 12.3 million bale equivalents, up from 10.5 million bale equivalents in 1997. For the first three quarters of calendar 1998, cotton textile imports were running at pace equal to 13 million bale equivalents. U.S. consumers increased their purchases of cotton at the retail level in 1998, but not by the full increase in imports. U.S. textile production is suffering from the surge in cotton textile imports. Hopefully, the surge is reaching a plateau and 1999 will not witness a similar increase. The loss of the Step 2 user certificate has further disadvantaged U.S. textile mills in the competitive market for textiles.

The loss of the Step 2 certificate has also reduced U.S. export competitiveness. Since the last export shipment of raw cotton to receive the certificate on 15 December 1998 the United States has experienced cancellations of raw cotton exports totaling over 226,000 bales. USDA forecasts exports at 4.2 million bales, but many U.S. cotton merchants expect shipments to have difficulty reaching 4 million bales.

Based on USDA's February estimates, ending stocks will be 3.4 million bales with a stocks to use ratio of 23%. However, the larger crop and weakened mill use and exports could produce an ending stock level of 3.8 to 3.9 million bales. This would be an ending stocks to use ratio of 26.8%.

The U.S. Cotton Market for 1999/2000

The National Cotton Council conducted its annual early season planting intentions survey in late December 1998 and early January 1999. Producers indicated they would increase their upland cotton area 1.2% to 13.246 million acres. The largest acreage increase was expected in Texas where an additional 200,000 acres could be planted. Acreage reductions indicated by the survey for the states of Louisiana, Arkansas, and California were unexpected. Using five-year average yields and abandonment, the expected crop based on the survey results is 17.040 million bales.

While price conditions could be such that by new crop no new Step 3 import quotas are triggered on a weekly basis, any Step 3 import quotas opened in May 1999 will remain open well into the harvest period. Raw cotton imports during early season 1999 could reach 200,000 bales. Combining the estimated stocks, production, and imports result in a total U.S. supply of 21 million bales.

Assuming an effective competitiveness program is in operation for the 1999/2000 crop year, mill use is expected to rebound modestly to 10.8 million bales. With the availability of an export user certificate, U.S. exports could grow to 6 million bales despite the tremendous competitive pressures in the world market for raw cotton.

Subtracting these offtake estimates from the expected available supply results in a projected U.S. ending stock on 31 July 2000 of 4.2 million bales and a stocks to use ratio of 25%.

CONCLUSION

The U.S. farm sector is essentially being pummeled by forces beyond the control of U.S. policy makers. Commodity prices in agriculture, energy, metals, and other products are at new lows in recent history. The disastrous declines in the exchange rates of many export oriented Asian economies and Brazil, as well as the severe contraction in gross domestic product for these nations, have rendered a situation where most international commodity prices are well below the cost of production.

However, while legislators may be unable to influence events in foreign nations and international markets, the impacts of those events on U.S. farmers and the agribusiness sector can be mitigated with sound U.S. farm policy. The supplemental AMTA payment in 1998 was undoubtedly beneficial to growers, however, we are now going into the 1999 crop year with commodity futures prices some 12% to 20% lower than one year ago. The farm safety net is not adequate and most lawmakers are aware that problems persist in U.S. agricultural policy.

The U.S. cotton industry's top priority is to reestablish an effective competitiveness program for the coming crop year. All seven segments of the industry stand united in seeking funding for cotton competitiveness provisions as modified at our 1999 annual meeting. The domestic and export demands for U.S. cotton will be vital to maintinaing the economic health of our industry.

USING OPTIONS TO MANAGE PRICE RISK

Tony E. Windham[1]

INTRODUCTION

There are many marketing strategies available to farmers that can minimize the risk associated with pricing a cotton crop. Forward pricing is one of the most common price risk management strategies used to price a percentage of expected production. The disadvantage of this strategy is that delivery is usually required and the farmer will not benefit if cotton prices should increase later. This paper discusses the use of options on commodity futures contracts as a tool that can provide a price floor, while allowing the producer to profit if prices increase.

Options on Commodity Futures Contracts

An option simply gives a producer the right but not the obligation to buy or sell a commodity futures contract at a specific price before a specific time expires. Agricultural options simply provide price insurance against declines for producers while taking advantage of price increases.

Buyers in the option markets have the right but not the obligation to exercise their option. One of the unique attributes of options is that the buyer has the legal right to use (exercise) the option but is not obligated to do so.

Types of Options

There are two different types of options. The two types are "calls" and "puts" and they offer opposite pricing alternatives. A put option gives the buyer the right to sell a futures contract at a given price level (strike price) on or before the expiration date. The call option gives the buyer the right to buy a futures contract at a given price level (strike price), on or before the expiration date.

Puts and calls are separate option contracts. They are not the opposite sides of the same transaction. For every buyer of a put option, there is a seller (or writer) of the same put option. The same is true for call options.

The buyer of a put or call option has three possible alternatives after the option has been purchased. The buyer's alternatives are:

(1) let the option expire (do nothing);
(2) offset the option at the current premium value; or
(3) exercise the option.

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[1] Extension Section Leader–Agricultural Economics, Little Rock.

The majority of option buyers will offset the option at expiration, or prior to expiration, and receive the current premium value. Exercising the option (alternative 3), would be used if the buyer of the option wanted a position in the underlying futures market.

There are also three alternatives for the individual (writer) who sells the option. The option may:

(1) expire;

(2) be offset at the current premium value; or

(3) be exercised by the buyer, which causes the writer to accept a futures position at the specified (strike) price.

The buyer of an option is the only person who can choose to exercise the option.

Option Premiums

The major cost associated with purchasing an option is the premium. The premium is known when the option is purchased. The buyer of an option has no margin calls as occurs in the futures markets to hedge commodities. Supply and demand in the marketplace will ultimately determine option premiums. Option buyers will be willing to pay premiums to acquire the rights associated with the particular option. Option sellers (writers) receive those premiums as compensation for the risk associated with writing the option.

Several factors interact to affect the premium levels. The first factor is the difference between the strike price of the option and the price of the underlying commodity. The second factor is the length of time before the option expires. A third factor is volatility in the futures market.

The portion of the premium attributed to the difference between the strike price and the price of the underlying commodity is called intrinsic value. As long as the market price is below the strike price of a put option, the option will have intrinsic value. A call option has intrinsic value as long as the underlying commodity is priced above the strike price of the option.

Another factor that influences option premiums is the length of time before the option expires. Option premiums will usually decrease as the length of time until expiration decreases. The longer the time period until expiration, the option seller (writer) demands a greater premium to assume the larger risk of writing a longer term option.

Using Put Options to Set a Price Floor

The buyer of a put option can set a minimum price for his crop and still take advantage of a large increase in price. As an example, assume December cotton futures prices are trading at 62 cents. A cotton producer purchases a put option for a December futures contract at a strike price of 62 cents and a premium of 4 cents. This gives the producer the right, but not the obligation, to sell a December futures contract at 62 cents if the market falls under the strike price before the expiration date. The farmer has set a minimum selling price of 62 cents minus the 4-cent premium and plus or minus the basis and other charges. Assuming the basis is a minus 4 cents, the minimum selling price would be 54 cents per pound regardless of how low cotton prices fall.

On the other hand, assume futures prices increase at harvest to 72 cents per pound. The producer would let the option expire and do nothing. The net selling price would be 72 cents minus the 4-cent premium minus the 4-cent basis resulting in a final price of 64 cents per pound.

Using Call Options

Call options give the buyer the right, but not the obligation, to buy a futures contract at a given price level (strike price), on or before the expiration date. One strategy for using call options is to forward price the crop and then buy a call option in case prices increase. Another strategy is to sell the crop at harvest and purchase call options when there is some expectation that prices may increase. This is sometimes referred to as storing the crop on paper. This marketing strategy eliminates storage costs and provides immediate cash for repaying operating loans.

As an example, assume a producer sells his cotton crop at harvest for 62 cents per pound. The producer believes prices may go up and therefore purchases a March call option with a 62-cent strike price for a premium of 3 cents. If prices remain stable or decline, the call option will expire without any action being taken. The net selling price will be 59 cents per pound (62-cent cash price minus the 3-cent premium).

On the other hand, if futures prices were to increase to 70 cents, the producer would offset the option at the current premium value or exercise the option. The producer would have made 5 cents per pound by purchasing the call option (70-cent futures price minus 62-cent strike price minus 3-cent premium). Under this scenario, the producers net selling price would be 67 cents per pound (62-cent cash price plus 5-cent gain on the call option).

SUMMARY

Options on commodity futures contracts offer advantages to cotton producers over other marketing strategies. Options offer a form of price insurance at a predetermined cost (premium) that will not change regardless of changes in the futures market. Options also allow producers to lock in a price and still take advantage of changes in the market.

YIELD RESPONSE TO ENVIRONMENTAL EXTREMES IN COTTON

Derrick M. Oosterhuis[1]

INTRODUCTION

Before getting into what environmental extremes can do to plant growth and how to counteract them, it needs to be stated that the cotton crop is reputed to be the most complicated of all the major row crops grown in the United States (Oosterhuis, 1990). Cotton is a perennial with an indeterminate growth habit and a complicated fruiting pattern. Of particular importance is that the cotton plant has a very dynamic response to management and changes in the environment. There are effectively three major components influencing yield: variety, cultural inputs including management, and environment. The first two can be greatly influenced by us, but we have only very limited control over the environment of the cotton crop. In recent years, cotton yields in the Mid-South have varied dramatically and unpredictably from one year to the next. The following provides a discussion of some of the major factors involved.

COTTON YIELD TRENDS

According to the National Cotton Council, the average cotton yield in the United States is increasing at about 12 pounds per acre per year. Cotton yields in Arkansas increased steadily during the 1980s, but in recent years there has been a leveling off of this upward trend (Fig. 1). Of more concern is the extreme year-to-year variability of having record yields one year and disastrous results the next. Three out of the last six seasons (1993-1998) have been extremely disappointing with unusually low yields (Oosterhuis, 1995; 1996). The 1998 crop was one of the poorest in recent history and much of this was related to extreme weather conditions as well as insect infestations. Generally, each year the cotton crop appears to have good potential at midseason, but this potential is not always achieved at harvest due to combinations of moisture stress, high temperatures, and insects.

REASONS FOR THE LOW AND VARIABLE YIELDS

No season is ever perfect and there are always periods of adverse weather or insect attacks. The main deterrents to high yields are environmental stress (particularly temperature and drought) and high insect infestations associated with timing of the stress, i.e. in relation to the development of the boll load.

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We like to blame pests, and they are definitely a cause, however, environmental stresses are the real culprits. We don't fully understand these effects or how to control them. Genetics are also a favorite place to point a finger, and there is a need for a research effort investigating germplasm for tolerance to stressful extremes.

In the environment there are a few things to focus on. Water stress, usually too little, but sometimes too much, causes problems. Temperature stresses, again both extremes with cool temperatures at the beginning of the season and high temperatures later in the season during boll development, decrease yield. Soil disorders include acidity and salinity. Environmental effects cause numerous plant disorders (Oosterhuis and Hake, 1999). Cloudy weather in the Mississippi River Delta also is a problem causing adverse plant growth due to insufficient light for photosynthesis. The one thing to remember is that rarely do you get one of these environmental stresses operating at a time; it's usually an interaction of two or more factors. For example, cool, wet weather promotes seedling disease, but you cannot study one without the other. An example from last season would be high temperatures coupled with low water availability. The effect of two stresses together can be devastating causing poor plant growth and low yields. Since temperature and water are such critical factors for plant growth, they need major emphasis.

LONG-TERM WEATHER PATTERNS

The long-term weather pattern for the Delta Branch Station in Clarkedale (Fig. 2) shows maximum temperatures of about 75°F at planting, increasing steadily to near 90°F in late July, and then decreasing below 60°F in late October. However, minimum temperatures averaged just below 60°F at the beginning of May, increased to about 70°F in late July and then fell steadily to about 40°F in late October. This pattern varies tremendously each year, and these extreme variations (usually cold weather at germination during early seedling root development, and periods of excessively high temperature during fertilization and boll development) contribute to poor yields.

TEMPERATURE AND COTTON GROWTH

Root Growth and Temperature

Cotton roots can grow down 1 to 2 inches per day during the early season if soil conditions are right. However, when growing in cool conditions, the roots do not like to penetrate too deeply, because it's below their minimum for growing, and therefore don't develop a deep, branched system (Oosterhuis, 1990). In addition, high water tables at planting often prevent roots from growing down into the soil profile. Hard pans have the same effect.

Data from Texas have shown that the optimum soil temperatures for cotton root growth is 95°F, compared to 86°F for sunflower (McMichael and Burke, 1996). In contrast, farmers in Arkansas plant when soil temperatures at a 2 in. depth are at least 68°F (current recommendations), which is well below the optimum for cotton growth. As a result, the cotton root system develops poorly early in the season. The effect of a poorly developed root system is manifested later in the season during July and August when the boll load is developing, temperatures are at a maximum, and the plant requires large amounts of water for cooling the plant and nourishing the boll load. This is compounded by the fact that the root system effectively stops growing once flowering and boll development begins because carbohydrates are preferentially partitioned to the bolls at the expense of the roots. The poor early root development coupled with less root growth after flowering is a serious problem for Arkansas cotton farmers. These conditions result in poor yields, which was clearly evident in the disappointing 1995 and 1998 seasons.

Photosynthesis and Temperature

Although cotton originates from hot climates, it does not necessarily grow best at excessively high temperatures. The ideal temperature range for cotton is reported to be from 68 to 86°F (Reddy *et al.*, 1991). Once temperatures reach about 95°F, growth begins to decrease. However, from a physiological point of view, the ideal temperature range for cotton for optimal metabolic activity (also known as the thermal kinetic window) is 74 to 90°F with the optimum temperature for photosynthesis being 82°F (Burke *et al.*, 1988). However, average daily maximum temperatures in August (and July in 1998) in the Mid-South *are always at or above 90°F*, well above the optimum for photosynthesis.

We have found a strong negative correlation between yield and temperature in August when boll development occurs (Oosterhuis, 1997), with high daytime temperatures being associated with low yield and low daytime temperatures being associated with high yields (Fig. 3). This correlation was strongest in August but also applied to a lesser extent in July (data not shown). Although cotton is reputed to like high temperatures, it obviously does not necessarily grow best at high temperatures. The availability of water can modulate the effect of high temperatures by cooling the plant below air temperature, or alternatively, drought stress can greatly exacerbate the adverse effect of high temperature.

High *Day* and High *Night* Temperatures

Above average temperatures during the *day* can increase photorespiration and decrease photosynthesis and carbohydrate production. Our research indicates that there is no sharp threshold but rather a gradual decline to more than 50% decrease at about 90 to 95°F. On the other hand, hot *night* temperatures, i.e above 68°F, can significantly increase respiration. This occurs only during daylight with an additional loss in carbohydrates. Research is needed to better understand and quantify these losses in carbohydrate.

The overall result of high temperatures is insufficient carbohydrate production to satisfy the plant's needs. This insufficiency will be reflected in increased boll shedding, malformed bolls (e.g. parrot beak), smaller boll size, decreased lint percent, and lower yields (as in 1995 and 1998). This is particularly important in August when the size of the boll load increases the most (i.e. in its maximum phase of development). Excessively high temperatures will also cause increased shedding of young bolls.

Cotton fiber consists predominantly of carbohydrate. Therefore, decreased availability of carbohydrate can also be manifested in less fiber and lower gin turnout. Under normal conditions, a cotton seed properly fertilized with adequate water produces about 12,000 to 21,000 fibers per seed. Excessively high temperatures can decrease seed size, fibers per seed, and fiber length. High temperatures can also lead to decreased pollen viability and fertilization. This effect usually occurs approximately 17 days before flowering. The end result of high temperatures and decreased carbohydrate is reduced number of seeds, lower fibers per seed, and a smaller boll size. This situation was evident in Arkansas in 1995 and 1998.

THE INFLUENCE OF DROUGHT

Drought will compound the adverse influence of excessively high temperatures. Normally, the cotton crop attempts to regulate plant tissue temperatures by the cooling process of evaporation of water through the numerous small pores, called stomates, on the leaves. Stomates are also important for permitting the entry of carbon dioxide for photosynthesis. When water is available to the plant, the evaporative process (540 cal/cc water) can keep the leaves a few degrees below air temperature and the leaves "feel" cool to the touch. However, when drought persists, the stomates close, evaporative cooling stops, and the leaf heats up above the optimum temperature range suitable for photosynthesis and carbohydrate production. Dryland cotton production is, therefore, more sensitive to high temperatures when water is in short supply than irrigated cotton.

Yield formation may be considered as the production of dry matter by photosynthesis. This has two major components: production of carbohydrates by photosynthesis in the leaves, and the partitioning (translocation) of the resultant carbohydrate to the fruit. Both these components are adversely affected during extended hot dry spells, resulting in less carbohydrate, smaller bolls, reduced gin turnout, and lower yields.

HEAT UNITS

Heat units (HU) are a method of quantifying a biological organism's thermal environment. We use heat units as a means of predicting the growth and development of crops and pests. However, they have not always been reliable for some of the reasons already discussed. Heat units are calculated as: (maximum + minimum temperature)/2 minus the base temperature of 60°F. Although we take the lower threshold temperature for growth of 60°F into consideration, we do not take the upper threshold temperature into consideration. One exception to this is in Arizona (Brown, 1989) where an upper threshold of 86°F is used. Arizona also uses a lower threshold (55°F rather than 60°F). Research is needed in the Mid-South to address this issue. It may be of particular importance in the COTMAN crop monitoring system where numerous predictions are based on HU estimates.

REMEDIES

There is no obvious immediate remedy to the problems associated with high temperature. Possible solutions include genetic selection for varieties more tolerant to high temperatures during boll development, possibly through less temperature sensitivity of photosynthesis or carbohydrate translocation. In the area of management, attention should focus on producing an early crop (e.g. effective and timely insect and weed control, promotion of root growth through tillage and seed treatments, attention to water availability, judicious use of fertilizer, early square set, and high early boll retention) to ensure a decent yield, e.g. using COTMAN. Plant growth regulators should be used to enhance early fruit set and early maturity, e.g., Mepiquat chloride. Also, there is some recent evidence (Zhao and Oosterhuis, 1994) that plant growth regulators such as PGR-IV may help under *mild* stress conditions (low temperature, water stress, and shading) through improved translocation of carbohydrates to the developing bolls. However, in spite of best management efforts, the occurrence of untimely and severe weather and/or insect attacks can still adversely affect cotton growth and yield.

FUTURE RESEARCH

In the future, efforts need to be focused on following fruit numbers (e.g. in COTMAN) in addition to addressing boll weight components. The upper and lower limits of photosynthesis, translocation, and growth also need to be determined. The current heat unit formula needs to be reevaluated for both upper and lower (night) thresholds.

CONCLUSIONS

The main reasons for the poor yields in recent years were the extremely hot temperatures in August combined with moisture stress and high insect infestations. High day temperatures resulted in poor fertilization and smaller bolls. High night temperatures resulted in much of the carbohydrate formed in photosynthesis being "burned off," which contributed to low boll weights and poor yields.

Cotton can usually withstand limited periods of mild stress, however, severe stresses, extended periods of stress, or more than one stress at a time (e.g. high temperature and drought) usually prove to be highly detrimental to yield.

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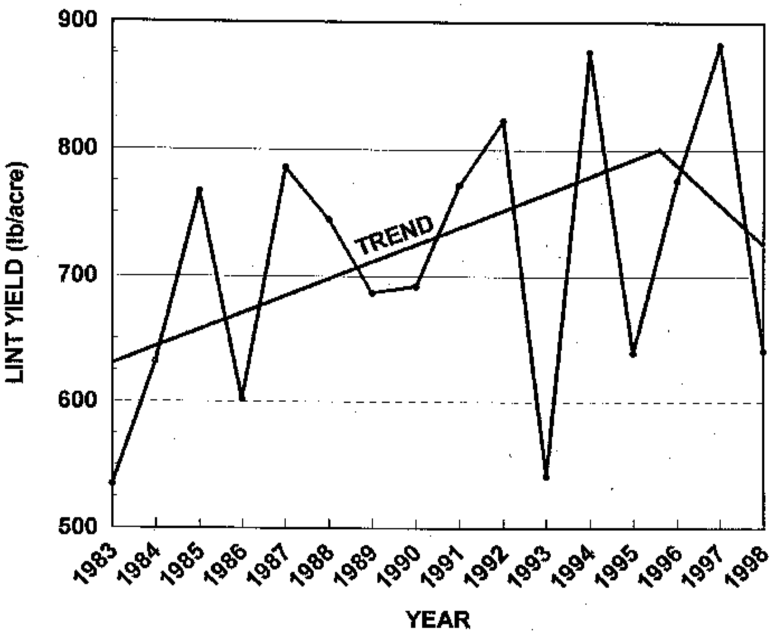

Fig. 1. Cotton lint yield in Arkansas, 1983 to 1998.

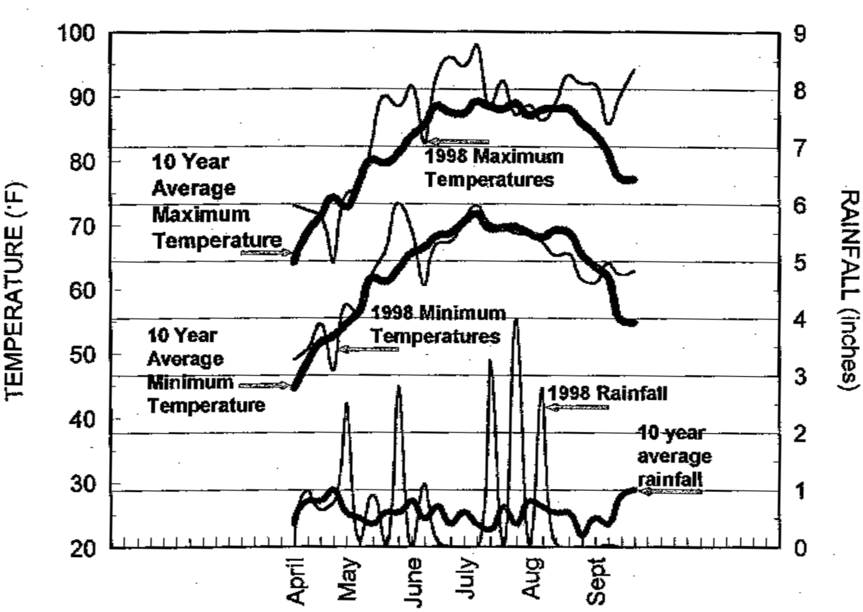

Fig. 2. Weekly maximum and minimum temperatures and rainfall compared with 10-year averages, 1 April to 30 September 1998, Delta Branch Station, Clarkedale.

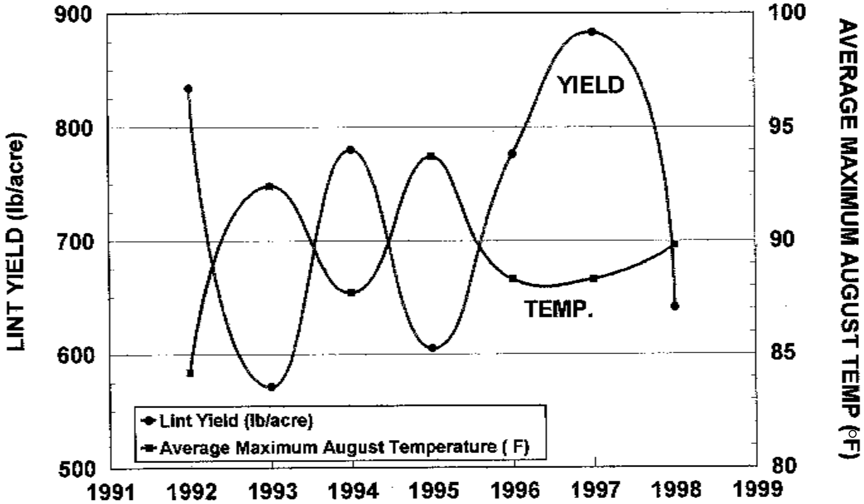

Fig. 3. Relationship between yield and temperature.

LET THE COTTON PLANT TELL YOU WHEN TO STOP SPENDING MONEY

N. Ray Benson, William C. Robertson, Gus M. Lorenz, and Kelly J. Bryant[1]

INTRODUCTION

Inconsistent cotton yields and low prices have increased the importance of eliminating unnecessary crop production costs. Knowing when expensive late-season insecticide applications can be terminated without negatively impacting yield or fiber quality can insure more profitable cotton production. Accurately identifying crop maturity is required if improvements to late-season management are to be made.

"Blooming-out-the-top" has long been identified as crop cutout. However, the position of white flowers relative to the plant terminal used to more accurately define crop maturity (i.e., cutout). Bourland *et al.* (1992) defined the flowering date of the last effective boll population using numbers of nodes above the uppermost first position white flower (NAWF). They found that NAWF = 5 represented the last flower population that significantly contributed to yield, and was the basis for re-defining cutout. From establishing growth patterns, they suggested that cotton should have 8 to 10 NAWF at first flower and decline to cutout (NAWF = 5) by approximately 80 days after planting.

Zhang *et al.* (1994a; 1994b) refined the definition of cutout by indicating that NAWF = 5 could be used to identify cutout only if there is a sufficient probability of that flower population developing into a harvestable boll of adequate quality. Recognition of weather restraints resulted in cutout being categorized as physiological, seasonal, or premature (Oosterhuis *et al.*, 1996). The authors defined physiological cutout as plants attaining an average of NAWF = 5 before end-of-season weather restricts plant development. Seasonal cutout occurs when the flowering date of the last effective boll population is determined by end-of-season weather constraints rather than by crop maturity. Premature cutout is defined as physiological cutout due to excessive stress.

Arkansas research has shown that bolls begin to resist bollworm, budworm, and boll weevil damage at 350 heat units (DD60s) after anthesis (Bagwell and Tugwell, 1992; Bagwell, 1994). Therefore, producers should be able to terminate the use of insecticides for the control of bollworms, budworms, and boll weevils based on crop cutout + 350 DD60s.

COTMAN, a cotton management program, allows producers to monitor crop development until cutout (NAWF = 5 or the latest possible cutout date). The program

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then tracks heat unit accumulation and recommends when insect control is no longer economical. Preliminary testing of the insecticide termination rules of COTMAN has shown the potential for increasing farm profitability (Cochran *et al.*, 1994). The objectives of this study were 1) to validate the insecticide termination component of COTMAN, and 2) to determine the effects on fiber quality of insecticide termination based on COTMAN recommendations.

MATERIALS AND METHODS

In 1998, COTMAN test fields were established on producer farms in six counties in Arkansas: three fields in Mississippi County, one field in Poinsett County, one field in Crittenden County, one field in St. Francis County, one field in Jefferson County, and two fields in Lincoln County. Tests at each location were arranged in a randomized complete block with plots running the length of the field. Cultivar and date of planting were based on individual producer preferences and varied across locations (Table 1). All crop production practices were consistent within a field and were implemented independently by producers based on their normal production practices. Measurements of NAWF were made as described by Bourland *et al.* (1992). Weekly NAWF measurements began at approximately first flower and continued once per week until NAWF = 5. Once a field reached cutout, heat unit accumulation was initiated using the following equation:

$$[(\text{Daily high temp.} + \text{Daily low temp.})/2] - 60°F$$

where 60°F is the lower threshold for growth. Treatments were established after the accumulation of 350 DD60s beyond cutout (NAWF=5), and included treated and untreated plots at each location. Untreated plots received no insecticide applications after cutout + 350 DD60s. Insect control continued on treated plots after 350 DD60s had been accumulated beyond cutout. Insecticide applications in treated plots were based on producer and consultant prescribed thresholds, and were applied as often as the producer deemed necessary. Plot size was not consistent within locations and varied greatly across locations (Table 2). All other production practices were consistent across treatments within a location.

Harvest

Timing of defoliation and harvest initiation were determined by the producer and were consistent across plots within a location. Across locations, harvest area ranged from 0.25 acres to greater than seven acres per plot (Table 2). All plots were machine spindle-picker harvested using producer equipment. Seedcotton weights were recorded. Data were converted to pounds of seedcotton per acre with lint yields calculated based on an assumption of 33.3% turnout. Fiber samples were collected from five of the locations and analyzed for fiber micronaire, length, and strength. Yield data were analyzed over locations and within locations using analysis of variance statistical procedures. Mean yields of treated and untreated plots were compared and separated using Fisher's Protected LSD test at (P<0.05).

RESULTS AND DISCUSSION

Date of cutout (NAWF = 5), days from planting to cutout, and date of cutout + 350 DD60s varied across locations (Table 3). Cutout at the Finch, Stuckey, and Wildy 15 locations occurred 70, 49, and 64 days after planting, respectively, and represented extreme challenges to the COTMAN rules. Extremely hot dry weather, in conjunction with possible delays in irrigation, caused crops at these locations to cutout much earlier than would be desired. This "stress induced" cutout was followed by a resurgence of crop growth and provided extreme tests to the COTMAN program. COTMAN-defined cutout for these fields occurred on dates that first flower is normally expected in Arkansas. The three locations having extremely early cutout were grouped as fields expressing premature cutout. The six remaining locations reached cutout near 80 days after planting, prior to historical weather restrictions, and were therefore categorized as fields having physiological cutout (Table 3). No field in this study expressed weather determined cutout.

Premature Cutout

Yields for treated and untreated plots at the Stuckey, Finch, and Wildy 89 locations are reported in Table 4. No yield advantage was observed in plots where insect control continued after cutout + 350 DD60s. Although not statistically different, yields tended to be slightly lower where insect control was terminated at cutout + 350 DD60s. Average yields of locations having premature cutout were significantly lower than yields of locations expressing physiological cutout. Reduced yields associated with premature cutout indicate that severe early-season stress cannot not be overcome.

Physiological Cutout

Insecticide applications after cutout + 350 DD60s did not increase yields in fields having physiological cutout (Table 4). The untreated plots yielded significantly more cotton than the treated plots at the Kimbrell location (south central Arkansas). Across locations, plots receiving no insecticide after cutout + 350 DD60s yielded 21 pounds more lint than did the plots sprayed full-season. These data support results obtained by Ungar *et al.* (1987). In their study, removal of large squares late in the season provided a 12% increase in seedcotton / m^2 over control plots. Results of these studies support the report by Kim and Oosterhuis (1998) that late-season removal of fruit which are not likely to be harvested, may allow more carbohydrates for more economically important bolls.

Fiber Quality

Fiber samples were collected from treated and untreated plots at the Edwards, Wildy 15, Gandy, Mizell 3, and Tarlton locations. Across the five locations, no significant differences in fiber micronaire, fiber length, or fiber strength were observed between treatments. Values for micronaire, strength, and length averaged 4.6, 30.2, and 1.1, respectively, where insecticide applications were terminated at cutout + 350 DD60s and 4.7, 29.7, and 1.1, respectively, where insects were controlled after cutout + 350 DD60s.

Cost of Control

As is typical from north to south Arkansas, cost of late-season insect control varied across locations (Table 4). Cost of insect control after cutout + 350 DD60s ranged from a low of $5.34 at the Kimbrell location (central Arkansas) to a high of $27.46 at the Tarlton location (southeast Arkansas). Across locations, insecticides applied after cutout + 350 DD60s resulted in an increased production cost of $15.38 per acre with no additional yield.

CONCLUSIONS

These data support the use of COTMAN rules for timing insecticide termination late in the season. Even under conditions of premature cutout, control of fruit feeding insects after cutout + 350 DD60s did not improve farm profitability. Significant yield responses should not be expected as a result of controlling fruit feeding insects beyond cutout + 350 DD60s. Results of this study showed an average of $15.38 per acre was spent for late-season insect control on plots treated after cutout + 360 DD60s. These plots however, had no statistical yield or fiber quality advantage over the untreated plots.

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Table 1. Cultivars and planting dates used in 1998 test sites.

Location[z]	County	Cultivar	Planting date
Edwards	Mississippi	Stoneville BXN 47	24 April
Wildy 15	Mississippi	Deltapine 5111	6 May
Wildy 89	Mississippi	Stoneville BXN 47	17 May
Finch	Poinsett	Stoneville BXN 47	25 April
Stuckey	Crittenden	Stoneville BXN 47	14 May
Gandy	St. Francis	Stoneville 474	7 May
Kimbrell	Jefferson	Stoneville BXN 47	8 May
Tarlton	Lincoln	Deltapine NuCOTN 33B	5 May
Mizell #3	Lincoln	Stoneville 474	9 May

[z]Arranged from north to south Arkansas.

Table 2. Plot size, harvest area, and number of replications in 1998 test sites.

Location	Treated[z]	Untreated[y]	Harvested	Replications
	-------------------- (acre)	----------------------		(no.)
Edwards	7.40	7.40	7.40	2
Wildy 15	6.75	6.75	6.75	3
Wildy 89	2.25	2.25	2.25	7
Finch	8.85	4.40	1.47	5
Stuckey	8.00	8.00	1.60	3
Gandy	2.50	2.50	0.20	3
Kimbrell	3.00	1.80	0.40	4
Tarlton	2.50	2.50	0.25	4
Mizell #3	2.00	2.00	0.40	4

[z] Plots where insects were controlled after cutout + 350 DD60s.
[y] Plots where insect control was terminated at cutout + 350 DD60s.

Table 3. Date of cutout, days from planting to cutout, and date of cutout + 350 DD60s for all locations.

Location	Cutout date	Days to cutout	Date of 350 DD60s
Premature cutout[1]			
Wildy 89	20 July	64	5 August
Finch	4 July	70	22 July
Stuckey	1 July	49	17 July
Physiological cutout[2]			
Edwards	22 Jul	89	8 August
Wildy 15	25 July	80	11 August
Gandy	9 August	88	20 August
Kimbrell	30 July	83	14 August
Tarlton	21 July	73	6 August
Mizell #3	23 July	79	8 August

[z] Premature cutout defined as early cutout due to excess stress.
[y] Physiological cutout defined as crop reaching NAWF = 5 without end of season weather restraints (NAWF = 5 prior to the latest possible cutout date).

Table 4. Yield of treatments and cost of applications made after cutout + 350 DD60s.

	Lint yield			Late insecticide	
Location	NAWF + 350[z]	Full-season[y]	LSD	No.[x]	Cost[w]
Premature[v] cutout					
Wildy 89	437	450	50	2	$16.15
Finch	486	494	11	2	$12.29
Stuckey	499	508	84	1	$12.33
Average	474	484			$13.59
Physiological cutout					
Edwards	768	739	639	2	$13.95
Wildy 15	896	866	103	2	$16.15
Gandy	788	793	322	1	$10.30
Kimbrell	938*	854*	56	1	$ 5.34
Tarlton	735	747	41	2	$27.46
Mizell #3	1,028	904	251	2	$24.46
Average	859	817			$16.28
Avg. all locations	696	675		27.9	$15.38

[z] Insect control terminated at cutout + 350 DD60s.
[y] Insect control applied full-season.
[x] Number of insecticide treatments made after cutout + 350 DD60s.
[w] Total cost of insecticide (including cost of application) applied after cutout + 350 DD60s.
[v] When averaged across treatments, means for premature cutout fields (479 lb) were significantly less than physiological cutout fields (838 lb).
*Significantly different ($P < 0.05$).

USING THE COTMAN SYSTEM FOR EARLY DETECTION OF STRESS: TRIGGERING IRRIGATION BASED ON SQUARE RETENTION AND CROP GROWTH

Tina G. Teague, Earl D. Vories, N. Philip Tugwell, and Diana M. Danforth[1]

INTRODUCTION

Cotton growers commonly call for insecticide applications for tarnished plant bugs, bollworms, or boll weevils in order to maintain a high square set in preflowering cotton. Unfortunately, they may see the majority of those same fruiting forms shed as bolls if irrigation is poorly timed. When boll shed occurs, it is reasonable to question whether the early insect control was excessive for that system. A major crop management dilemma ensues. It appears that excessive insect control may be as detrimental as poor insect control if a balance is not achieved between square retention and growth. Researchers in Israel have addressed this problem and concluded that "irrigation scheduling and control of pests that damage squares and bolls cannot be optimized independently" (Ungar *et al.*, 1992). We agree.

Better methods are needed to monitor the balance between crop growth and square retention to enable decision-makers to use this important crop information to foresee and avoid stress. We have initiated research focused on 1) practical sampling methods that will allow crop managers to anticipate and detect emerging crop stress, and 2) decision aids that allow them to use field data to manage the crop to maintain the appropriate balance between retention and growth.

This work is a continuation of crop monitoring research using the cotton information management system, COTMAN (Danforth and O'Leary, 1998). Data collection in pre-flowering cotton using COTMAN allows calculation of a plant-based economic injury level (Mi *et al.*, 1998). These data also may be used to provide timely information on crop stresses including information on the changes in the balance between square retention and plant growth. In COTMAN, the change in number of square sheds for every new fruiting node added between two sampling dates is calculated to measure the *aggregate* change in square retention and plant growth, i.e., changes in retention-growth balance. This is called COTMAN Cue-*A* or the "aggregate change in the Robertson / Growth Balance" (ARGB). The formula to calculate Cue-*A* or ARGB is the following:

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$$Cue\text{-}A = \frac{X2 * Y2 - X1 * Y1}{X2 - X1}$$

Where: X2 is actual number of squaring nodes on sampling date two; Y2 is actual square shed rate on date two; X1 is actual number of squaring nodes on date one; and Y1 is actual square shed rate on date one.

This report summarizes one season of research using the COTMAN Cue-*A* as an early indicator of stress and the cue to trigger irrigation.

MATERIALS AND METHODS

The irrigation trial was conducted on cotton 'SureGrow 125' planted 6 May 1998 in a Calloway silt loam soil at the University of Arkansas Cotton Branch Experiment Station in Marianna. The 0.14 acre plots were 4 rows (38 in. centers) wide and bordered by 4 non-irrigated rows. The five irrigation treatments were arranged in a randomized complete design with three replications. Furrow irrigation treatments were initiated on [1] Flower, timed using the Irrigation Scheduler Program with estimated soil water deficit 2 in.; this occurred the first week of flowering; [2] COTMAN Cue-*A* <0.3; [3] Early, one week before soil water deficit = 2 in.; timing based on Dr. Vories' judgement; [4] Late, after layby weed control which occurred two weeks after first flower; or [5] Dryland, rainfall only.

Plants were monitored weekly from early squaring until cutout using COTMAN. Changes in crop development resulting from irrigation treatments were tracked using the COTMAN Target Development Curve (Fig. 1). Square and boll retention in the first fruiting position were monitored post-flower using the experimental *Scoutmap* version of COTMAN (Tugwell *et al*., 1999). End-of-season management decisions (i.e. crop protection and defoliation) were based on the condition of the latest plots (e.g. insecticides were still applied in plots that were well past spray termination dates). Our season-long insect control program kept insect-induced square and boll shed at extremely low levels.

RESULTS

Rainfall levels in the Marianna area in June and July were below normal in 1998, providing excellent conditions for the irrigation initiation comparison. For May, June, July, and August, rainfall amounts recorded at the Cotton Branch Station were 1.4, 1.6, 2.6, and 1.7 in., respectively. No rainfall was recorded between 16 June and 11 July. Visible signs of water-deficit stress were apparent in non-irrigated plots during this period; this stress is shown clearly in the COTMAN crop development curve for the dryland treatment (Fig. 2).

The first irrigation was applied 23 June with Treatments 2 and 3 receiving water (Table 1). For Treatment 2, COTMAN Cue-*A* values less than 0.3 (an arbitrarily selected value) prompted initiation of irrigation; the mean value for *A* for Treatment 2 plots on 23 June was 0.0445. The Irrigation Scheduler program (Treatment 1) did not call for irrigation until 30 June; plants began flowering during that week. Irrigation in

Treatment 3 was skipped on 30 June. On 8 July all treatment plots except the dryland treatment received water.

Slower and reduced nodal development resulting from water stress was tracked using the Crop Development Curves for each treatment compared to the COTMAN Target Development Curve (Fig. 3). Changes in nodal development in response to irrigation were conspicuous with each treatment where irrigation was delayed or skipped. The first separation of the growth curves occurred immediately after the first irrigation with the slope of curves for Treatments 2 and 3 showing little change compared to the obvious decline in slope of curves for Treatments 1, 4, and 5. Growth curves separated again in the next week when Treatments 1 and 2 received water. The third sample period occurred during the first week of flowering, and the typical decline in squaring nodes was apparent for all curves at that point as boll filling began. By the fourth sampling date, growth curves indicated that Treatments 1, 4, and 5 had reached physiological cutout (Nodes Above White Flower = 5). In the week of 12 July all treatments showed an increase in nodal accumulation following aproximately 2 in. of rain. Plant monitoring was suspended in Treatments 4 and 5 after that date because of low plant numbers with first position white flowers (plants with white flowers selected for sampling under such conditions likely are unrepresentative of the dominant plant population). The crop development curve for Treatment 1 indicated that terminal growth for those plants increased; NAWF values once again were above 5 after the mid-July rain.

This reinitiating of terminal growth is most likely related to the extremely high levels (> 70%) of small boll shed noted in the first two weeks of flowering in Treatment 1 (Fig. 4). Physiological shed of <10 day old bolls was highest for this treatment. Lowest physiological shed was observed in Treatment 2 where irrigation was initiated using COTMAN Cue-*A*.

Yield data indicate significant crop response to irrigation (Table 2). Highest total yields were observed in plots that received the earliest irrigation, Treatments 2 and 3. Lowest yields were observed in Treatments 4 and 5, the late and dryland treatments. The proportion of lint harvested at first picking was highest for Treatments 2 and 5. Well-timed irrigation did not delay crop maturity; crop delay was associated with treatments in which irrigation was delayed or skipped. No statistical differences in lint quality measures (strength, length, and micronaire) were observed between treatments.

PRACTICAL APPLICATION

Currently, Arkansas Cooperative Extension Service recommendations for irrigation scheduling in cotton suggest that irrigation should be applied any time the soil moisture status is low, regardless of the crop growth stage, until open bolls are observed. We believe that crop monitoring using the COTMAN system will help us improve this recommendation by incorporating plant cues into the decision-making process.

In the COTMAN treatment in this study, a value of 0.3 or less for Cue-*A* (retention-growth balance) triggered irrigation. Values less than 0.3 indicated that the number of squares shed between the latest two sampling dates was less than a third of the number of new main-stem squaring nodes added during that time period. This translates as good square retention and good growth; therefore, high crop demand for water was anticipated and irrigation was triggered.

Our reasoning was fairly simple. We assume that rapidly growing cotton plants with many fruiting forms will demand more water than slow growing plants with few fruiting forms. It is also likely that if plant demands are not met, young bolls will be aborted and/or final boll size will be reduced. A low value for Cue-*A* reflects high fruit set and steady growth. On receiving such data, a crop manager should prepare for the imminent high water and nutrient demands that will be required by his crop. Management would then focus on irrigation scheduling and fertilizer inputs. If fruit set was low, but nodal development maintained at a steady pace, the resulting higher Cue-*A* value would alert the crop manager to expect reduced crop demands. Using this information, the crop manager would initiate management practices that would discourage excessive vegetative growth and check on his/her insect management options.

The methodology outlined in this paper shows promise as a tool for making integrated decisions in a cotton management system, but we will make no recommendations based on one season of research. Our work with COTMAN as a monitor for crop stress will continue and include expanded investigations with irrigation, plant growth regulators, and insect interactions. A related report in this publication uses the same retention-growth balance relationship to detect plant stress from high plant populations and insect infestations (Oosterhuis *et al.*, 1999).

ACKNOWLEDGMENTS

We thank Mr. Bob Turner and his staff at the Cotton Branch Experiment Station for their excellent assistance in conducting this experiment. We also thank Sha Mi, Stephen Bradshaw, and Dr. Mark Cochran, University of Arkansas Department of Agricultural Economics and Agribusiness for their COTMAN support. Funding from the University of Arkansas Division of Agriculture and Cotton Incorporated also is gratefully acknowledged.

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Table 1. Timing of irrigation for each of five treatments in 1998 irrigation trial.

Irrigation Timing	23 June	30 June	8 July	21 July	28 July	5 August
1) 1st Flower	–[z]	x[y]	x	x	x	x
2) COTMAN Cue-*A*	x	x	x	x	x	x
3) Early	x	--	x	x	x	x
4) Late	–	--	x	x	x	x
5) Dryland	–	–	–	–	–	–

[z]– = no irrigation applied.
[y]X = irrigation applied.

Table 2. Mean lint yield from each irrigation treatment.

Irrigation timing	First pick lint yield	Total lint yield	First pick as percentage of total yield
	------------ (lb/acre)	-------------	(%)
1) 1st Flower	849 b	983 b	86.4 b
2) COTMAN Cue-*A*	994 a	1166 a	93.2 a
3) Early	914 b	1029 a	88.8 b
4) Late	671 c	818 c	82.0 c
5) Dryland	571 d	602 d	94.7 a

[z]Yields followed by the same letter do not differ significantly (AOV, LSD 0.05).

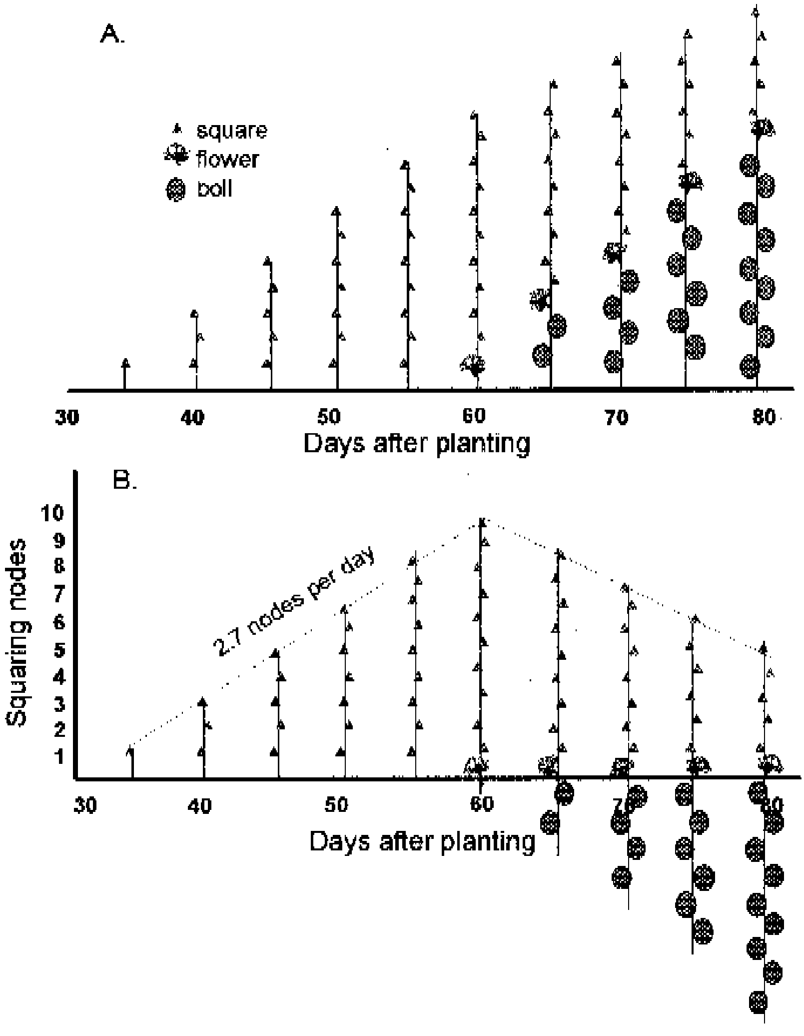

Fig. 1. Main-stem nodal development of cotton is simple to monitor by tracking the number of fruiting branches that have not yet flowered (A). When these squaring nodes are plotted against days, there is an abrupt downturn at first flower associated with good stress from boll loading (B). The resulting curve is the basis of the COTMAN Target Development Curve (TDC). In the COTMAN TDC, squaring nodes are replaced with Nodes Above First Square and Nodes Above White Flower (NAFS/NAWF).

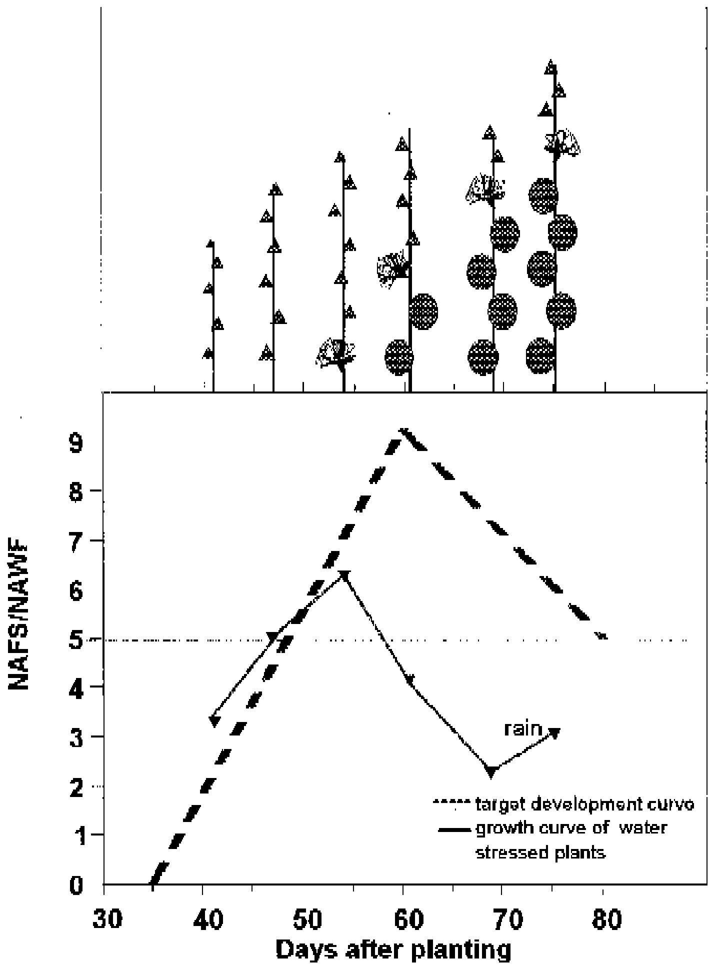

Fig. 2. Mean main-stem nodal development observed in the non-irrigated cotton depicted as stick figures (above) and in the COTMAN drop development curve for these plants shown (below) in relation to the COTMAN Target Development Curve (TDC).

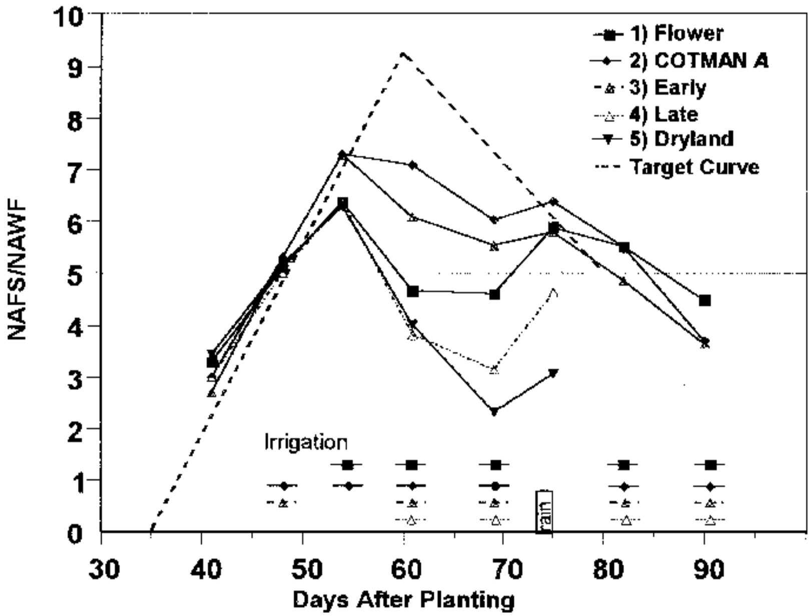

Fig. 3. The COTMAN Target Development Curve (TDC) and crop development curves for the five irrigation treatments in the 1998 irrigation initiation trial. Irrigation timing for each treatment is indicated by symbols at the bottom of the graph.

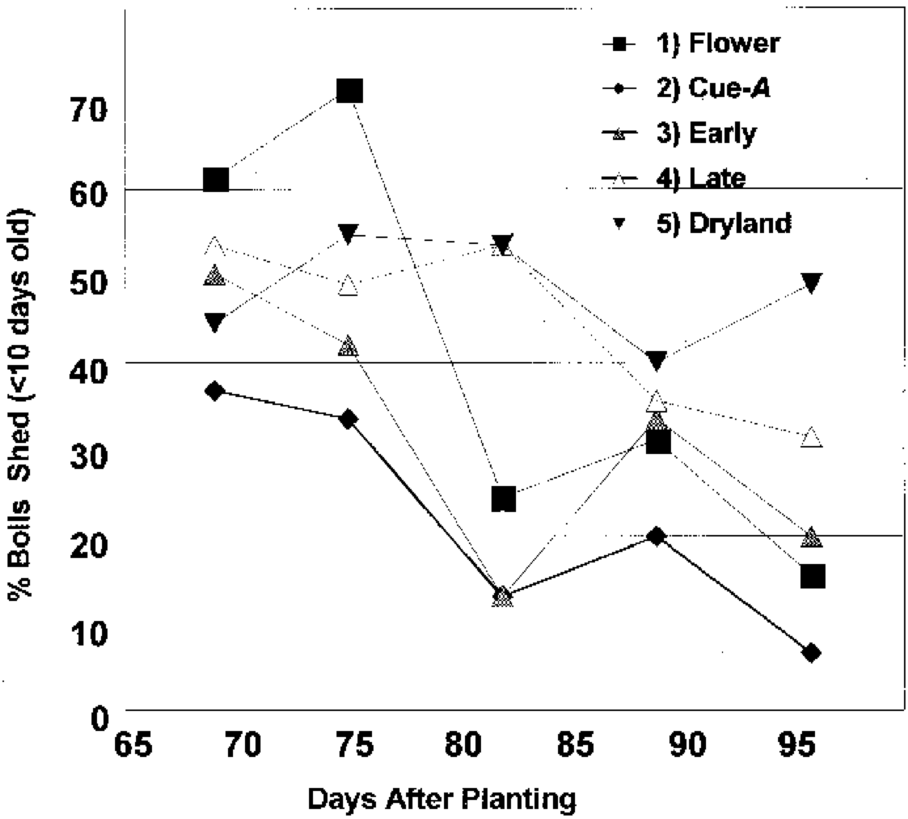

Fig. 4. Mean percent physiological small boll (<10 days old) shed observed in 1998 irrigation initiation trial.

STEWARD®: NEW INSECTICIDE FOR THE NEW MILLENNIUM

Charles T. Allen, Marwan S. Kharboutli, Charles Capps, Jr., and Larry Earnest[1]

INTRODUCTION

Tobacco budworm has historically been able to develop resistance to insecticides after just a few years of use. Bollworm has also developed insecticide resistance to many products, but more slowly. The availability and use of products and technologies with several modes of action during a production season helps slow down resistance development in these pests. In addition to slowing resistance, the availability of several effective insecticides with different modes of action provides competition in the marketplace thereby lowering the cost of these products. In addition, insecticides which are effective against a broader spectrum of the pests of cotton (plant bugs, beet armyworms, etc.) may lower the total cost of insect control in cotton.

Steward® is a new insecticide with a unique mode of action which is scheduled to be available to producers by the summer of 2000. It is reported to have activity against bollworm, tobacco budworm, and plant bugs (Bierman, 1998) and has been reported to be relatively safe on beneficial insects (Tillman *et al.*, 1998). It has low mammalian toxicity and has been shown to pose only low level threats to non-target organisms (Hammes *et al.*, 1998). This paper is a report of studies on the performance of Steward in southeast Arkansas.

MATERIALS AND METHODS

Five small-plot replicated tests were run on the Southeast Research and Extesion Center, Rohwer Division, in 1998. Plots were 40 ft long by 4 rows wide with a 2-row skip between plots. Insecticides were applied in 10 gallons total spray per acre. Randomized complete block designs were used in these tests. Insect counts were taken 3 days after each treatment application by counting worms and damage on 25 terminals, 25 squares, and 25 bolls or 6-foot beat sheet samples, or 15-sweep net samples. Plots were maintained using standard irrigated production practices. Worm tests were run on cultivar ‘Suregrow 125’, while plant bug tests were run on ‘Paymaster 1220 BgxRR’ cotton. The two middle rows of plots were processed using Pesticide Research Manager 5 (PRM) and CoStat statistical software. Analysis of variance and least significant difference were the statistical techniques used to test for and separate differences.

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RESULTS AND DISCUSSION

Bollworm Control

In Test 1, Steward reduced bollworm numbers and damage below the levels seen in untreated check plots (Table 1). However, worm pressure was not high enough to separate differences in worms or damage between insecticide treatments. Approximately 92% of the worms in this test were bollworms. Steward-treated plots were similar to Tracer®-treated plots in worm numbers damage and yield, but were numerically (not statistically) higher in worms and damage compared with some of the pyrethroid and pyrethroid combination treatments.

Tobacco Budworm Control

In Test 2, tobacco budworm numbers and damage were numerically but not significantly lower in plots treated with Steward than those in the check plots (Table 2). In Test 3, worm counts in plots treated with Steward were similar to that in the check but square damage was lower (Table 3). The efficacy of Steward on tobacco budworm in both tests was not statistically different from that of Tracer, which produced the lowest numerical worm count among all treatments used. In both budworm tests (Tests 2 & 3), Steward exhibited a trend, though not always significant, toward suppression of tobacco budworm populations and damage. Worm counts and damage in plots treated with Steward were numerically lower than many of the other comparitive treatments.

Beet Armyworm Control

In the two tests that generated beet armyworm efficacy data, Test 2 and Test 3, Steward effectively minimized damage. Steward reduced defoliation by beet armyworm compared to that of the check treatment (Tables 2 and 3). Steward was as effective on beet armyworm as Pirate® and resulted in defoliation rates similar to those obtained with Tracer (Tables 2 and 3).

Plant Bug Control

In all the tests where plant bugs were monitored, Steward provided strong reductions in plant bugs. Steward-treated plots had plant bug populations at levels similar to the most highly effective plant bug compounds available (Orthene®, Provado®, and Regent®) (Table 2 through Table 5). Steward's efficacy on plant bugs was consistent in each of the tests reported here. In view of the development of insecticide resistance in populations of plant bugs in the Mid-South (Snodgrass, 1996; Pankey *et al.*, 1996), the development of new chemistries for plant bug control is a high priority.

Beneficial Insects

Steward-treated plots tended to have high numbers of beneficial arthropods compared with other treatments (Table 5). However, these were not statistically significant differences.

Lint Yield

Neither Steward nor other insecticides tested in the bollworm trial (Test 1), with the exception of a combination treatment of Baythroid® and Tracer, provided a significant increase in lint yield compared to the check (Table 1). However, Steward-treated plots yielded numerically approximately 150 lb / acre more cotton lint than the check plots.

In Test 2 and Test 3, where tobacco budworm was the dominant worm pest and lint yields may have also been affected by plant bugs and beet armyworms, lint yield in plots treated with Steward ranked among the highest among all treatments used (Table 2 and 3). Steward did not produce significantly higher lint yields in plant bug tests (Tables 4 and 5). However, these were single application tests.

PRACTICAL APPLICATION

Our data indicated that Steward is an effective insecticide against beet armyworm and plant bugs. Yield advantages (numerical trends and statistically significant differences) were seen in Steward-treated plots compared with treatments. These advantages were most appearant in tests in which multiple applications and heavier insect pressures were experienced. The efficacy of Steward on bollworm and tobacco budworm was less apparent. Trends toward control of larvae and damage were seen, but Steward tended to allow somewhat more worm survival and damage than did Tracer. Steward appears to have little or no activity on boll weevil. Steward appeared to have little negative effect on beneficial arthropods.

Steward is a new insecticide with a novel mode of action which should be helpful in slowing the development of insecticide resistance in pests. As Arkansas enters boll weevil eradication in 1999, compounds such as Steward that can provide yield protection from bollworm / budworm, plant bug, and beet armyworm damage will be important. These features along with Steward's apparent "softness" to predaceous beneficial arthropods will be helpful in the pest management programs that will evolve (in the natural enemy intensive, reduced insecticide environment) after boll weevil eradication.

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Table 1. Efficacy of insecticides[z] against bollworms[y] and effects on lint yield (Test 1). Rohwer.

Treatment	Rate	Bollworm count	Bollworm damage	Lint yield
	(lb ai/acre)	(#/25 square)		(lb/acre)
Check		0.88 a[z]	4.38 a	648 b
Steward 1.25SC	0.09	0.25 b	0.38 b	798 ab
Steward 1.25SC	0.11	0.13 b	0.63 b	817 ab
Tracer 4SC	0.067	0.13 b	0.75 b	800 ab
Pirate 3SC +	0.2 +			
Baythroid 2EC	0.028	0 b	0 b	713 ab
Pirate 3SC +	0.25 +			
Baythroid 2EC	0.028	0 b	0.63 b	834 ab
Tracer 4SC +	0.031 +			
Baythroid 2EC	0.028	0 b	0 b	847 a
Baythroid 2EC	0.033	0 b	0.50 b	742 ab

[z] Means in columns followed by the same letter(s) are not significantly different at ($P < 0.05$).
[y] Insect and damage data are seasonal means three days after treatment (spray dates 17 July and 27 July 1998) of 25 squares inspected/plot.

Table 2. Efficacy of insecticides against tobacco budworms, boll weevils, plantbugs, and beet armyworms; and effects on lint yield (Test 2). Rohwer.

Treatment	Rate	Tobacco budworm Count[z]	Tobacco budworm Damage[z]	Boll weevil damage[z]	Plant bug count[z]	Beet armyworm	Lint yield
	(lb ai/acre)	------------------------	(no./25 squares)	------------------------		(% Def.)[y]	(lb/acre)
Check		2.25 a[x]	3.7 a	1.7 ab	6.3 abc	6.9 a	708 de
Baythroid 2EC +	0.03 +						
Orthene 90S	0.5	2.10 ab	3.3 a	1.9 a	0.7 f	5.8 ab	920 abc
Baythroid 2EC	0.03	1.75 abc	2.8 ab	1.4 ab	4.8 bcd	5.8 ab	808 cde
Pirate 3SC +	0.2 +						
Curacron 8L	0.5	1.75 abc	3.1 ab	1.4 ab	4.0 cde	3.3 c	718 de
Baythroid 2EC +	0.03 +						
Pirate 3SC	0.35	1.58 abc	2.6 ab	1.5 ab	4.4 bcd	3.0 c	894 abc
Pirate 3SC +	0.25 +						
Curacron 8L	0.5	1.17 abc	3.4 a	1.9 a	5.0 bcd	3.1 c	770 cde
Baythroid 2EC +	0.03 +						
Steward 1.25SC	0.09	1.17 abc	1.8 ab	1.5 ab	1.2 ef	2.6 c	1048 a
Steward 1.25SC	0.09	1.00 abc	1.5 ab	1.7 ab	1.0 ef	3.4 c	1011 ab
Steward 1.25SC	0.11	0.83 abc	1.7 ab	0.8 ab	1.1 ef	2.8 c	1041 a
Pirate 3SC	0.35	0.58 bc	1.8 ab	1.2 ab	8.7 a	2.6 c	673 e
Tracer 4SC	0.063	0.33 c	1.5 ab	0.7 b	7.3 ab	3.3 c	728 de
Baythroid 2EC +	0.03 +						
Tracer 4SC	0.031	0.33 c	1.1 b	1.1 ab	2.5 def	5.0 b	870 bcd

[z] Seasonal means of counts three days after treatments (spray dates 10 August, 17 August, and 24 August 1998) 25 squares inspected/plot.
[y] Rating was taken on 2 September 1998 on a scale of 0 to10 (where 0 = no defoliation and 10 = complete defoliation).
[x] Means in columns followed by the same letter(s) are not significantly different at (P<0.05).

Table 3. Efficacy of insecticides against tobacco budworms, boll weevils, plantbugs, and beet armyworms; and effects on lint yield (Test 3). Rohwer.

Treatment	Rate	Tobacco budworm Count[z]	Tobacco budworm Damage[z]	Boll weevil damage[z]	Plant bug count[z]	Beet armyworm	Lint yield
	(lb ai/acre)	(no./25 squares)				(% Def.)[y]	(lb/acre)
Legend	3.75[x]	4.6 a[w]	6.7 a	1.2 bc	0.75 ef	7.4 a	784 ab
Provado 1.6F	0.047	2.7 b	3.7 b	2.7 ab	2.4 cd	6.1 ab	687 b
Baythroid 2EC	0.03	2.1 bc	4.0 b	1.5 abc	2.1 de	5.4 bc	626 b
Check		1.5 bcd	3.4 a	2.0 abc	3.7 bc	4.3 c	648 b
Karate 1EC	0.03	1.5 bcd	3.2 b	1.1 c	4.7 b	5.7 bc	689 b
Steward 1.25SC	0.09	1.2 cd	2.1 bc	2.8 a	0.58 g	1.9 d	781 ab
Steward 1.25SC	0.11	0.92 cd	2.7 bc	2.3 abc	0.50 f	2.2 d	996 a
Tracer 4SC	0.067	0.33 d	0.67 c	2.8 a	6.7 a	2.1 d	821 ab

[z] Seasonal means of counts three days after treatments (spray dates 15 August, 21 May, and 29 August 1998) 25 squares inspected/plot.
[y] Rating was taken on 2 September 1998 on a scale of 0 to10 (where 0 = no defoliation and 10 = complete defoliation).
[x] Oz product per acre.
[w] Means in columns followed by the same letter(s) are not significantly different at ($P<0.05$).

Table 4. Efficacy of insecticides[z] against plant bugs, effects on beneficial arthropods and effects on lint yields (Test 4). Rohwer.

Treatment	Rate	Plant bugs	Lint yield	
	(lb ai/acre)	(no./15 sweeps)[z]	(no./25 squares)[y]	(lb/acre)
Check		3.2 a[x]	2.8 ab	961 a
Naturalis L	16.00[w]	2.3 ab	3.8 a	1020 a
Orthene AG 97SP	0.50	1.4 bc	1.0 bc	1014 a
Naturalis L	10.00[w]	1.2 bc	1.3 bc	965 a
Regent 2.5EC	0.05	1.0 c	0.5 c	1011 a
Steward 1.25SC	0.11	0.88 c	1.3 bc	1051 a
Steward 1.25SC	0.09	0.38 c	1.0 bc	945 a

[z] Sweep net samples were taken on 13 August and 14 August 1998, two and three days after a single application.
[y] Squares were inspected on 18 August 1998, seven days after a single application.
[x] Means in columns followed by the same letter(s) are not significantly different at ($P < 0.05$).
[w] Oz product per acre.

Table 5. Efficacy of insecticides against plant bugs, effects on beneficial arthropods, and effects on lint yields (Test 5). Rohwer.

Treatment	Rate	Plant bugs	Beneficials	Lint yield
	(lb ai/acre)	---------- (no./6 row ft)[z] ----------		(lb/acre)
Check		2.3 a[y]	6.0 a	511 ab
Orthene 90S	0.5	1.0 b	1.8 a	385 b
Orthene 90S +	0.5 +			
Provado 1.6F	0.0375	1.0 b	2.3 a	517 ab
Bidrin 8EC +	0.25 +			
Provado 1.6F	0.125	0.8 b	2.0 a	494 ab
Provado 1.6F	0.0375	0.5 b	5.0 a	436 ab
Steward 1.25SC	0.09	0.5 b	6.5 a	514 ab
Steward 1.25SC	0.11	0.5 b	6.0 a	503 ab
Strategy .16EC	0.01	0.0 b	6.3 a	558 a

[z] Beat sheet samples were taken on 9 July 1998, three days after a single application.
[y] Means in columns followed by the same letter(s) are not significantly different at ($P < 0.05$).

REDUCING FERTILIZER EXPENSE WITHOUT SACRIFICING YIELD

J. Scott McConnell and William H. Baker[1]

INTRODUCTION

The goal of a good soil fertility program is to supply nutrients to a developing crop, thereby enhancing the probability of economic success. Cotton requires more plant nutrients than most soils provide to achieve maximum economic yields under Mississippi River Delta production conditions. Fertilization of cotton has been extensively studied and is continually being researched to further increase fertilizer use efficiency. As new fertilizer materials and new application technologies become available, and new production systems are introduced, questions regarding cotton fertilization will continue to be important to producers and the environment. Questions all producers need to consider are: Where to fertilize? How much to fertilize? Am I fertilizing for the right production system?

Where to Fertilize?

Fertilizer recommendations are based on soil samples that indicate the properties of the field or portion of the field sampled. There may be several soil types within a single field and these soils may vary considerably in physical and chemical properties. These differences in soil properties may cause fertilizer recommendations to differ substantially among areas within a field. Do not sample across known soil lines when soil sampling. Sampling dissimilar soils and compositing the samples may result in fertilizer recommendations that are not suitable for any soil in the field. Sample a single soil within a field separately from other soils. Look for soil characteristics that indicate soil differences such as color and surface texture. A USDA Soil Survey is an invaluable tool for identifying soils within an area.

When soils do not differ, sometimes areas of higher or lower yield are discernable in a field. This indicates a difference in the production zones with a field. Possible differences within a soil type are drainage, toxic pesticide levels, or differences in nutrient content or pH. Sample different production units separately. When production in a zone within a field is low and the cause is not under fertilization, then the nutrient levels in that zone may be higher than expected. This occurs because fertilizer is not being used in making plant tissue and is not being removed during harvest. Further, this indicates that fertilizer investments in this portion of the field were not increasing yields or profits.

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Geographical Information Systems and Global Positioning Systems (GIS / GPS technology) are being used to more accurately identify production zones and soil differences within a field. Current GIS / GPS methods link a soil sample with the exact position within a field, thereby linking a fertilizer recommendation with each sample. Field-wide trends may then be observed. Currently, three University of Arkansas scientists are conducting field trials with GIS / GPS systems. They are: William H. Baker, Soil Testing Laboratory, Marianna; Mike Daniels, Cooperative Extension Service, Little Rock; and H. Don Scott, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

How Much to Fertilize?

Nitrogen (N) is the most frequently needed and most frequently misapplied nutrient in cotton production. Both under-fertilization and over-fertilization with N may have adverse effects on cotton. Under-fertilization of cotton with N causes stunted plant growth, chlorosis, premature cutout, and yield loss. Yield losses from under-fertilization with N have been shown in many studies. Recent studies indicate that N rates between 90 and 120 lb N/ acre typically maximize yields under intensively managed, irrigated production conditions (McConnell, unpublished data)(Table 1). Yields were maximized under center pivot irrigation and furrow irrigation with 90 lb N/ acre in 1993. Yields were significantly less with lower fertilization rates.

Cotton that receives too much fertilizer N may also undergo yield loss, although this is not common. Under center pivot irrigation, yields were reduced by over-fertilization with N (Table 1). A more typical consequence of over-fertilizing cotton with N is a delay in maturity. Experiments conducted near Rohwer and Manila indicated that optimum yields were obtained with 100 lb N/ acre (McConnell *et al.*, 1995). When N was applied at rates of 150 and 200 lb N/ acre no significant yield increases were observed and maturity was delayed as long as 12 days (Table 2).

Cotton has been targeted as an "environmentally unfriendly" crop due to the potential for stream and groundwater contamination by fertilizer nutrients (Crutchfield *et al.*, 1991). Producers, therefore, need to include environmental considerations in their fertilization practices to prevent further regulation. Deep soil sampling of long-term dryland cotton tests has shown that nitrate-nitrogen may accumulate within certain zones of a soil (McConnell *et al.*, 1996)(Table 3). Accumulations of nitrates were found in plots that had been continuously over-fertilized. No nitrate accumulations were found under irrigated production conditions, regardless of the N application rate.

Fertilizing for the Right Production System?

Dryland cotton tends to be lower yielding than irrigated cotton most years due to the impact of drought stress. Typically, less fertilizer N is needed to achieve maximum yields in dryland culture than in cotton produced with irrigation. Studies conducted at the Southeast Research and Extension Center, Rohwer Division, on the response of dryland cotton to N, indicate the impact of environment on yields (Table 4). No significant yield increase was observed when N rates exceeded 30 lb N/ acre in 1996. Yields of dryland cotton were increased with N rates up to 90 lb N/acre in 1997. Yield responses of irrigated cotton to N may vary, but not as drastically as dryland cotton. Yield potential of irrigated cotton varied substantially between 1993 and 1994, yet both years maximum yield was achieved with 90 to 120 lb N/acre.

Row spacing has been shown to influence the growth patterns of cotton. Studies conducted in Mississippi indicate that cotton grown in 30-in. rows was less prone to yield loss that cotton grown in 40-in. rows (Eblehar *et al.*, 1995). Conclusions from the Mississippi studies indicated that 90 lb N/acre most often resulted in maximum yields.

Cotton plant growth patterns have been shown to change radically in ultra-narrow-row spacing (UNR) culture. Currently, studies are under way at the Southeast Research and Extension Center, Rohwer Division, to examine the optimum N rate for UNR cotton (McConnell, unpublished data)(Table 5). Initial results from these studies indicate that yields were maximized with 50 lb N/acre. Nitrogen fertilizer treatments greater than 50 lb N/acre increased plant height and lateness but did not influence boll load or yield.

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Table 1. Cotton response to six nitrogen (N) fertilization rates under furrow irrigated and moderate frequency center pivot irrigated (MFCP) conditions during 1993 at the Southeast Research and Extension Center, Rohwer Division.

N Rate	MFCP	Furrow
(lb N/acre)	------------- (lb lint/acre)	-------------
150	1262	1334
120	1394	1347
90	1525	1248
60	1346	1198
30	1255	1027
0	1185	784
LSD (0.05)	143	136

Table 2. Cotton response to five nitrogen (N) rates under furrow-irrigated conditions from 1990 to 1991 at the Southeast Research and Extension Center, Rohwer Division. (SEREC) near Rohwer and a producer field near Manila[z].

	SEREC - Rohwer		Manila NAWF=5	
N Rate	Yield	NAWF=5	1990	1991
(lb N/acre)	(lb seedcotton/acre)	------------------- (DAP)		--------------------
200	3364	104	100	89
150	3347	105	102	93
100	3383	93	97	83
50	3141	90	96	74
0	2725	84	96	70
LSD (0.05)	354			

[z] McConnell *et al.* (1995).

Table 3. Residual nitrate-nitrogen (N) in a dryland N-rates test after 12 years of continuous fertilization. Soils were sampled in 1992 at the Southeast Research and Extension Center, Rohwer Division[z].

		N fertilization rate		
Soil depth	Soil horizon	0	60	120
(inches)		---------------- (ppm nitrate nitrogen)		--------------
0-6	Ap	3.2	8.0	8.8
6-12	E	2.2	3.5	41.5
12-18	B1t	2.5	7.5	79.0
18-24	B1t	2.3	17.3	101.2
24-30	B1t	2.3	21.2	86.6
30-36	B1t/B2t	2.0	23.0	68.3
36-42	B2t	1.8	21.2	31.2
42-48	B2t	2.2	12.3	9.2
48-54	B2t	1.7	3.2	3.3
54-60	C	1.8	2.0	1.7

[z] McConnell *et al.* (1995).

Table 4. Cotton lint yield response to nitrogen (N) rates under furrow-irrigation.

	Furrow-Irrigated		Dryland	
N Rate	1993	1994	1996	1997
(lb N/acre)	---------------------------- (lb lint/acre)			---------------------------------
150	1324	1600	1067	1682
120	1347	1602	1035	1629
90	1248	1492	1050	1615
60	1198	1482	1059	1338
30	1027	1215	1048	1067
0	784	873	752	683
LSD (0.05)	136	137	155	217

Table 5. Ultra-narrow-row cotton lint yield response to nitrogen (N) rates in two tests during 1997 and 1998 at the Southeast Research and Extension Center, Rohwer Division.

N Rate	Plant height	Boll load	Seedcotton yield
(lb N/acre)	(inches)	(boll/acre)	(lb/acre)
1997			
100	24.9	393,675	2,938
100	31.3	392,869	3,006
50	29.9	416,263	3,333
0	20.4	242,820	1,529
LSD (0.05)	6.1	119,875	1,099
1998			Lint yield
125	27.5	349,710	1,060
100	30.5	327,928	1,033
75	26.3	341,844	1,034
50	24.4	321,273	899
25	20.4	278,921	745
0	19.9	191,796	468
LSD (0.05)	4.2	48,066	153

LOCATE AND MANAGE YOUR NEMATODES

Terry L. Kirkpatrick[1]

INTRODUCTION

Plant-parasitic nematodes can, and in many cases do, cause considerable economic loss in cotton production in Arkansas. Nematodes are microscopic roundworms that live in the soil and feed on the roots of cotton and other susceptible plant species. In cotton, the damage nematodes cause and the yield reduction that may result from damage ranges from mild (the yield loss may not be enough to justify nematode control) to severe (20-30% yield loss field wide with areas approaching 50% loss). In contrast to insects which may move on their own or be dispersed by wind over a considerable distance, nematodes are much more site specific. On their own, nematodes are capable of moving only a few yards throughout their lifetime, although anything that transports soil from place to place may also move nematodes to new areas. In general, nematode infestations are similar to weed infestations in that certain fields may be heavily infested while nearby fields may not be infested at all. As with weeds, nematodes also have a high reproductive potential and can survive well for relatively long periods of time. Consequently, nematode problems tend to reoccur each year with increasing severity over time.

Fortunately for Arkansas cotton producers, not all nematodes that can regularly be found in association with cotton roots cause economic loss to the crop. There are currently only two types of nematodes that are recognized as important cotton pathogens, the root-knot nematode (*Meloidogyne incognita*) and the reniform nematode (*Rotylenchulus reniformis*). Root-knot nematodes are widely distributed throughout all of our cotton production areas, and may also be a problem in soybean, field corn, and most vegetable and melon crops. The reniform nematode is much less frequently encountered in Arkansas (Table 1), but each year new fields and new areas of the state are found with reniform nematode infestations.

LOCATING NEMATODES

The basis for all nematode management plans is location of the problem and accurate identification of the nematode species involved. Because nematodes are microscopic and symptoms of nematode damage are not always readily visible, detection of a nematode problem requires specialized techniques and a planned approach. Laboratory assay of properly collected soil samples is the most accurate means of locating

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nematode problem fields or areas within fields, and for identification of the species that are present. Detailed guidelines for the proper collection and handling of soil samples for nematode assay are available through all County Extension offices, or they may be obtained through the Arkansas Cooperative Extension Service home page (http:// www.uaex.edu). Once samples have been collected, they can be sent to the Arkansas Nematode Diagnostic Laboratory by any County Extension office. Careful adherence to the sampling and handling guidelines is vital for an accurate nematode assay, and assay results are only as good as the sample that was submitted.

Except for diagnostic samples that may be used to identify the cause of specific symptoms during the growing season, nematode samples are proactive (predictive) in nature, and allow management strategies to be developed for the next crop. In many states, including Arkansas, economic thresholds have been established through research for each economic nematode species on cotton. These thresholds are based on the nematode population density per unit of soil volume for soil samples collected during the late summer or early fall--the period of the year for most crops when nematode population levels have reached their peak. Samples that are collected too early in the crop growing season, or those collected in the winter or early spring, may significantly underestimate the actual population level that is present in a field, and the potential problem that they represent.

Fields, or areas within fields where nematode problems are suspected, should be sampled thoroughly. Although nematodes can be found deep in the soil, during the late summer and early fall the majority of the population will be found most years within 15 to 20 cm (6 to 8 in.) of the surface. Samples should be collected from the root zone rather than from row middles, and an adequate number of individual samples should be collected to accurately represent the area. Individual samples from a given field or area may be combined into one composite sample for assay. Once samples have been collected, the soil should be protected from drying out and from rapid temperature changes. Placing the soil into a plastic bag and then placing the bag into an insulated cooler or ice chest (without ice) is recommended for transporting samples from the field to the office and for short-term storage at room temperature.

NEMATODE CONTROL

There are three options for managing nematode problems in cotton: crop rotation, nematicides, or resistant cultivars. In most cases a combination of these three options may provide the most cost-effective and practical strategy for avoiding economic loss.

Crop Rotation

The right cropping sequence, using resistant or non-host crops in combination with cotton, provides the most sustainable and perhaps the most effective nematode management. Unfortunately, routine crop rotation is the least practical strategy for many producers because of the economic feasibility of crops other than cotton, and in some cases because of land rental or lease agreements. If crop rotation is practiced, it is vital to accurately identify the nematode species present in the field since using the wrong rotational crop may actually increase nematode problems. The frequency of using a rotational crop and the duration (number of years) in the rotational crop are best determined by monitoring nematode populations at the end of each crop. In some cases, a single-year rotation into a nematode resistant crop may lower nematode population density enough to allow cotton production for several seasons before the population again reaches economic levels. In other cases, more than a single-year rotation out of cotton may be necessary to lower nematode populations enough to avoid yield loss in cotton.

Because the root-knot nematode has a broad host range, planning an effective rotation system may be difficult. Field corn, most soybean cultivars, and most vegetables (including watermelon and cantaloupe) are good hosts for root-knot, and their production may increase nematode populations rather than lower them. Grain sorghum appears to be one of the most effective crops for lowering root-knot population levels in rotation with cotton, although continued production of grain sorghum for more than two seasons in a row should be avoided. Some soybean cultivars are resistant to root-knot and provide an economically feasible rotational crop option. In limited areas of the state rotation with peanut, a non-host for the cotton root-knot nematode, can be effective. An economically attractive, but most times impractical, option for root-knot management is rotation of cotton with rice. A single year of rice has been very effective in lowering root-knot populations in fields where flooding of the rice crop is possible.

Where reniform nematodes are a problem, field corn, grain sorghum, and rice are all effective in lowering nematode population levels. In addition, certain soybean cultivars are somewhat resistant to the reniform nematode and may also lower nematode population levels. There are conflicting reports on the ability of peanut to lower reniform nematodes with some showing significant population decreases and others reporting little benefit. No data is available in Arkansas. Many vegetables, including melons, are good hosts for this nematode and should not be grown in rotation with cotton where reniform nematode is present.

Nematicides

For many cotton growers, the application of chemical nematicides is the most attractive option for nematode management. Nematicides are relatively expensive ($25-50 / acre), but may allow economically profitable cotton production in fields where crop rotation is not feasible. The efficacy of any nematicide is influenced by the nematode population level to be managed, the rate of the chemical that is applied, the cotton cultivar that is to be grown, and the weather and other environmental influences that occur following application.

Nematicides fall into two general categories: fumigant nematicides and non-fumigant or granular nematicides. Fumigant nematicides are very effective in controlling nematodes if they are applied properly. They are also the most expensive on a per-acre basis and have the disadvantage of requiring specialized equipment for application. Fumigant nematicides may also be damaging to the crop and must be applied at least a week before the crop is planted. Non-fumigant nematicides may be applied on the day of planting as either an in-furrow or a band-incorporated application. These materials are generally not phytotoxic and may also be applied as a sidedress application post-planting, although data on the effectiveness of this approach is limited in Arkansas. Non-fumigant nematicides are all "contact" poisons and must come in contact with the nematode in the soil in order to be effective. Most non-fumigants are both nematicidal and insecticidal, and their systemic activity against certain insects has led to the misconception that they also control nematodes systemically--which they do not. Nematicide application can result in a significant improvement in cotton yield if applied properly (Table 2), and yield may be improved even where cultivars with moderate levels of genetic resistance are grown (Table 3).

Nematode Resistant Cultivars

The use of nematode resistant cultivars is the most economical approach to nematode management. Unfortunately, cotton cultivars with effective levels of resistance to nematodes are extremely limited. To date no genetic resistance to the reniform nematode has been identified in *Gossypium hirsutum*. A few cultivars have been developed with moderate levels of resistance to the root-knot nematode, and two of these cultivars are adapted to Mid-South growing conditions. The cotton cultivars 'Stoneville LA 887' and 'Paymaster 1560' (but not 'Paymaster 1560BG') have an effective level of root-knot resistance, although neither cultivar is categorized as highly resistant to the nematode. All other cultivars that are currently grown in Arkansas are susceptible to this nematode.

CONCLUSIONS

Nematodes, along with insects, diseases, and weeds, represent a potential threat to profitable cotton production in many parts of Arkansas. Unlike insect pests, nematodes are not capable of moving on their own over much distance, and nematode problems are usually limited to certain fields or even to certain areas within fields. Unfortunately, nematodes are difficult to detect, and positive identification requires soil sampling and laboratory analysis. The basis or any nematode management program is: 1) recognition that a problem exists, 2) location of the specific problem areas or fields, and 3) accurate identification of the nematode species involved. Once the problem has been identified, nematode management strategies using a combination of crop rotation, nematicide application, and resistant cultivars may be developed for sustained control.

ACKNOWLEDGMENTS

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Table 1. Percent of Arkansas nematode samples with root-knot and reniform nematodes, 1996 and 1997.

Year	Percent of samples with: Root-knot	Reniform[z]	Total number of samples
1996	30	6	1,856
1997	25	4	4,467

[z] Counties where the reniform nematode has been found include: Ashley, Chicot, Drew, Jefferson, Lincoln, Lonoke, Mississippi, Monroe, and Poinsett.

Table 2. Cotton yield in a field infested by the reniform nematode (Monroe Co.) and a field infested by the root-knot nematode (Drew Co.) after treatment with nematicides.

Treatment and rate	Cotton lint yield	
	Reniform nematode	Root-knot nematode
	------------- (lb/acre) ------------	
Temik 15G (5 lb/acre in-furrow + 5 lb/acre sidedress)	764 a[z]	1,069 a[z]
Temik 15G (3.5 lb/acre)	648 bc	848 bc
Temik 15G (5 lb/acre)	600 bc	833 bc
Temik 15G (7 lb/acre)	656 bc	845 bc
Untreated Control	581 c	853 bc
Control (Admire 2F @3.2 oz/acre in-furrow)	624 c	747 c

[z] Means within columns followed by the same letter do not differ at $(P < 0.05)$ by Duncan's New Multiple Range Test.

Table 3. Yield of the moderately root-knot resistant cultivar 'Stoneville LA 887' in a *Meloidogyne incognita* infested field after nematicide application.

Treatment	Seedcotton
	(lb/acrecre)
Telone II (4.5 gal/acre) + TSX-DiSyston (5 pt/acre)	2,761 bc[z]
Telone II (4.5 gal/acre) + Temik 15G (3.5 lb/acre)	2,966 a
Telone II (3 gal/acre) + TSX-DiSyston (5 pt/acre)	2,607 cd
Telone II (3 gal/acre) + Temik 15G (3.5 lb/acre)	2,852 ab
Temik 15G (3.5 lb/acre)	2,853 ab
Temik 15G (5 lb/acre)	2,778 b
Temik 15G (7 lb/acre)	2,782 b
Control (TSX-DiSyston @ 5 pt/acre)	2,494 d

[z] Means followed by the same letter do not differ significantly at $(P < 0.05)$ by Duncan's New Multiple Range Test.

PICKING A WINNING COTTON VARIETY

Fred M. Bourland[1]

INTRODUCTION

One of the first decisions made when producing cotton is the choice of which variety to plant. The choice of the right cotton variety can determine the degree of success, or even the difference between success and failure. Therefore, the decision is critical and should use as much information and insight as possible. Choosing the best cotton variety has many similarities to choosing a horse that is likely to win a race. After the race (or season), the winner is usually obvious, but it is then too late to change your choice.

SIMILARITIES BETWEEN COTTON VARIETIES AND RACE HORSES

Cotton varieties are like race horses:

Some are quick out of the gate but poor at the finish line.

Others start slow and finish strong but never quite catch up.

Still others perform great on sunny days but fail dismally when conditions deteriorate.

One might be unduly praised for its good performance but never forgiven when it stumbles.

A few will perform consistently in all situations but seldom finish in first place.

Most will respond to proper management but may balk even with the best treatment.

Many have favorable and profitable features, but a perfect one has never been achieved.

All are bred and groomed with great effort and expense, but few become ranked among the elite.

The best are used as breeding stock, but others only have value in people's memory.

CRITERIA FOR CHOOSING RACE HORSES AND COTTON VARIETIES

Criteria	Race Horse	Cotton Variety
Personal experience	"I know that horse"	Past experience with variety
Relative performance	Racing forms	Variety testing
	Track conditions	Production conditions
Reputation of handling	Stable-Trainer	Company-breeder

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Delivery system	Jockey	Quality control
Genetic background	Pedigree	Pedigree
Appearance	"Horse's mouth"	Fiber quality
	Colors	Morphological traits
	Body conformation	Plant structure
Handicap	Odds	Pest reaction / yield stability
	Extra weight	Technology fee

TIPS FOR CHOOSING COTTON VARIETY

1. There are no sure bets.

Variety by genotype interactions are to be expected. Therefore, one variety is not going to be best for all conditions, and the best variety last year may not be the best this year.

2. Don't bet on long shots.

Long shots at horse races can provide big returns. However, the potential added returns from a long shot cotton variety are not worth the risks of the potential losses. A long shot variety is one that does not have a strong performance history. Usually, there is a reason that a variety does not perform well in variety testing.

3. Be wary of hot tips.

Advertisements provide many hot tips regarding cotton varieties. Data and claims in advertisements should be unbiased. Be sure that these data accurately reflect the relative performance of the variety.

4. Cautiously bet on newcomers.

Don't forsake a favorite race horse or cotton variety too quickly. If a variety has performed consistently well in the past, it will probably perform well in the future. However, producers that are unwilling to try new varieties can miss potential returns. Use caution on new varieties by trying them on a limited basis.

SAFE BETS REGARDING COTTON VARIETIES

A variety becomes more of a safe bet as the amount of information and experience regarding the variety increases. In the past, variety selection was usually based on at least three years of multiple location testing. With this amount of testing, many potential problems and relative performance associated with a variety were usually documented.

The introduction of transgenic cotton varieties has greatly increased the size of variety tests, and has reduced the longevity of new varieties. Consequently, many varieties are being marketed with less than three years in state variety testing programs. Out of the 58 entries in the 1998 Arkansas Cotton Variety Test, two-year means are available for 27 entries and only 11 have three-year means (Bourland *et al.*, 1999). Data for many of the newly marketed varieties are restricted to two-year means. The 13 highest yielding (top half) varieties over six locations of the 1997 and 1998 Arkansas Variety Test are listed in Table 1. Also, a "handicap" (factor that may limit its use) is listed for each variety. Yield, fiber quality, and other data for all entries at each location in 1997 (Bourland *et al.*, 1998) and 1998 (Bourland *et al.*, 1999) are available.

CONCLUSION

The process of picking a winning cotton variety is, in many ways, analogous to picking a winning horse at a race track. Cotton varieties and their relative performance differ greatly. Information regarding their performance can assist producers to make the best choice. State variety testing programs are important sources of unbiased information regarding varieties. In addition, the quality of data from on-farm testing, often conducted by the extension service, has been greatly enhanced by recent improvements in methods of weighing the yields. Data from these large-plot tests should be used in conjunction with data from state variety tests to assist with decisions.

The choice of variety dictates many other decisions throughout the season, and cannot be changed after planting. The choice directly impacts profit because there is relatively little difference is seed costs (excluding technology fees) of a winning and losing cotton variety. Picking a winning cotton variety does not guarantee a profitable season, but is an important, early decision that greatly impacts potential returns.

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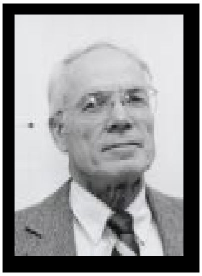
Table 1. Ranking and handicap for the 13 highest-yielding varieties over six locations of the 1997 and 1998 Arkansas Variety Test.

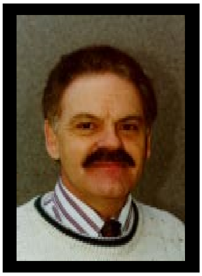
Yield rank	Variety	Handicap
1	Paymaster PM-1560BG	Technology fee, hairy leaf
2	Deltapine DP-5111	Hairy leaf; high micronaire
3	Sure-Grow SG-747	Limited experience
4	Stoneville BXN47	Technology fee; hairy leaf
5	Sure-Grow SG-501	Hairy leaf
6	Stoneville ST-474	Hairy leaf
7	Stoneville ST-373	Bronze wilt
8	Germain's GC-251	Limited experience
9	Paymaster PM-1266	Bronze wilt
10	Deltapine DP-20B	Technology fee, old variety base
11	Sure-Grow SG-125	Recent performance
12	Paymaster PM-1220BG/RR	Technology fee; bronze wilt
13	Paymaster PM-1330BG	Technology fee; hairy leaf



N.P. "Tug" Tugwell

Fred Bourland

Mark Cochran



Derrick Oosterhuis

1999 ARKANSAS COTTON ACHIEVEMENT AWARD

THE COTMAN TEAM

The 1999 Arkansas Cotton Achievement Award was presented to the team of researchers who provided the critical interpretations and intellectual insights that led to the development of the COTMAN cotton crop monitoring system. The team members include Dr. N.P. "Tug" Tugwell (entomologist), Dr. Fred Bourland (cotton breeder), Dr. Mark Cochran (economist), and Dr. Derrick Oosterhuis (crop physiologist), all with the University of Arkansas. Many other researchers in Arkansas and other states provided verification and data during the development of the COTMAN program, but these four were the nucleus without which it would not have been developed. Each team member is an outstanding researcher in his own right, however, the synergism within the team made the whole greater than the sum of the parts. Hence, the achievement award is presented to "the team."

The disciplines represented on the team provided the mix of perspectives that enabled a management program to be developed that focused on the status and performance of the crop in square and fruit production, rather than on individual components in the environment that can reduce these. An idealized crop performance curve was established against which the actual performance of a crop is compared. Monitoring of insect pressure, fertility, water status, etc., continue to be essential, but the COTMAN program allows the producer to determine if and when management inputs are needed and economical based on the performance of the crop. In-season deviation of the crop from the ideal crop development curve indicates that corrective management strategies should be applied. A notable part of the program concerns end-of-season recommendations for termination of management inputs, e.g. insecticides and water. In most cases, COTMAN can significantly reduce the cost of production without reducing yield because the very normal emotional factor of wanting to "protect the last bolls" is removed.

Dissemination of the COTMAN program has received the support of Cotton Incorporated and has been adopted as a crop monitoring tool in a number of states in the Cotton Belt. The Arkansas Cotton Achievement Award recognizes the outstanding work of Drs. Tugwell, Bourland, Cochran, and Oosterhuis as individuals and as members of the team that provided the knowledge and insight that made COTMAN a management tool that helps reduce the cost of cotton production in Arkansas.

Alex Nepomuceno

Award for the
OUTSTANDING GRADUATE STUDENT IN COTTON RESEARCH IN ARKANSAS

Cotton Incorporated
1998

The objective of this award is to recognize outstanding graduate student research in cotton that makes a contribution to the cotton industry in Arkansas. An additional benefit of this procedure will be the compilation of summaries of all graduate research in cotton in progress, which can then be made available to cotton producers and the extension services. A large proportion of the research that is conducted on cotton in Arkansas is done by graduate students. However, this work is often not directly available to other members of the Arkansas cotton fraternity. Furthermore, graduate students represent the future workers and leaders in our cotton industry, therefore, recognition of the work of graduate students by a yearly award is appropriate.

The selection committee consisted of representatives from the Arkansas Cotton State Support Committee, the University of Arkansas Cooperative Extension Service, the USDA (Stoneville, Mississippi), and private industry (Paymaster Cottonseed, Lubbock, Texas). Fourteen graduate research projects were evaluated, each consisting of a two-page summary of the research in progress during 1998. The winner was Alex Nepomuceno who was co-advised by Dr. Derrick Oosterhuis and Dr. Mac Stewart. The title of his research project was "*Physiological and Molecular Characterization of Drought Tolerance in Diverse Cotton Genotypes*." In this research, Alex showed that susceptible and tolerant cotton varieties differed in osmotic adjustment in response to stress, consequently, the tolerant varieties were able to maintain photosynthesis longer. Using a technique called "differential display" of genes expressed, he was able to detect, isolate, and clone gene transcripts that appeared to be uniquely associated with the response of the tolerant varieties to water stress. Alex received $500 plus a certificate in recognition of his research.

1999 SUMMARIES OF COTTON RESEARCH IN PROGRESS

BREEDING AND EVALUATION OF COTTON GENOTYPES

Fred M. Bourland[1]

RESEARCH PROBLEM

Annually, cotton yield losses to diseases, insects, and weed competition are typically estimated to about 10% each. In addition to these losses, about one-third of growers' direct production costs are related to controlling these problems. The effects of these problems could be reduced by improved host plant resistance, and also influenced by development of genotypes that are high yielding, early maturing, and have high fiber quality. The cotton breeding program at the University of Arkansas is designed to provide a continuous supply of such genotypes, which are specifically adapted for cotton production environments encountered in Arkansas. Thus, a strong cotton breeding program helps to sustain the cotton industry in Arkansas. To maintain a strong breeding program, continued research is needed to identify genotypes with favorable genes and incorporate them into adapted lines. Summaries of recent progress in the overall breeding program and in evaluating lines for resistance to *Verticillium dahliae* or it's more common name,Verticillium wilt, are reported here.

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 which are highly adapted to Arkansas environments and possess good host plant resistance traits. Overviews and updates of the current program have been published (Bourland, 1988; 1995a; 1995b; 1996; 1997; 1998).

To supplement selection in the breeding program, work was recently initiated to develop breeding techniques for evaluating resistance to Verticillium wilt in cotton. Resistance and/or tolerance to Verticillium wilt in cotton is typically determined by rating symptoms and/or measuring yield of genotypes grown at a location known to have high incidence of Verticillium wilt. Over the years, genotypes have been evaluated in this way at our Delta Branch Experiment Station at Clarkedale. In strain tests, plants are thinned after final stands are established to encourage incidence of wilt. Results from these evaluations have been inconsistent over years. Heavy symptoms are usually related to low yields in this environment, but often high yielding genotypes also have severe wilt symptoms.

In 1998, work was initiated to adapt a greenhouse method to evaluate seedlings for Verticillium wilt. In addition, cultivars and strains were rated for symptoms and yield

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was evaluated. Verticillium symptoms in 1998 were relatively light, perhaps due to low boll loads. In this report, results from two preliminary greenhouse tests will be reported. The preliminary tests were conducted to establish methods for greenhouse screening of seedlings.

RESEARCH DESCRIPTION

Breeding Program

The selection procedures outlined by Bourland (1998) were used in the University of Arkansas breeding program during 1998. These procedures included screening of breeding lines and evaluation of preliminary and new strains. Evaluation of several advanced strains was impaired by seed delinting problems that ruined seed of several lines. Seed of these lines from a previous year were used to increase seed to enable testing in 1999.

Verticillium Wilt Tests

Two greenhouse tests were conducted in 1998 to help establish techniques for evaluating response of seedlings of cotton genotypes to Verticillium wilt. In the first test, comparisons were made among methods including planting directly into soil with different rates of inoculum mixed or layered into the soil, and dipping seedlings into inoculum then transplanting into soil. A second test was conducted to determine an appropriate inoculum density for evaluating transplanted seedlings response to Verticillium wilt. In each test, a relatively susceptible cultivar ('Sure-Grow 501') was compared to a relatively resistant ('Paymaster HS26') cultivar as determined by field ratings in Tennessee (Chambers, 1998).

RESULTS

Breeding Program

Breeding lines were screened for resistance to seed deterioration, resistance to bacterial blight, morphological traits, yield, and fiber quality. The breeding lines included individual plant selections in the F_2 generation (696 plants from 28 populations) and selections of new progeny (207 of 840 selected) and advanced progeny rows (77 of 340 selected). Of 72 preliminary strains, 24 were selected. Due to seed quality problems, none of new or advanced strains could be eliminated. Registration of two germplasm lines was completed (Bourland *et al.*, 1998).

Verticillium Wilt Tests

The first greenhouse test was initiated in late July and measurements taken through mid-September. Greenhouse sun block and water misters helped to avoid extremely high temperatures, but the reduced light caused plants to become etiolated. No visual symptoms of wilt or height reduction occurred in any of the treatments except the transplant treatments where some inconsistent symptoms occurred. Initially, the soil inoculation with some intact pruning of roots was considered to be an easier method of evaluating seedlings than the transplant method. However, we determined that little or no time was saved with soil inoculation relative to transplanting.

The second Verticillium wilt test was initiated in early November and measurements were taken in mid-December. Leaf symptoms were attained and seedling height was reduced with inoculation. However, plant mortality was very low (only one plant died and that was in the highest inoculum density). Inoculum density significantly affected all measurements except height of soil to cotyledon. Interestingly, Paymaster HS-26 had a higher soil-to-cotyledon height than Sure-Grow 501. Inoculum density by cultivar interaction was significant for the last two height measurements, but was not significant for the leaf symptom rating. As expected, Verticillium wilt affected Sure-Grow 501 more than it did Paymaster HS-26. This significant interaction indicates that this method should effectively separate genotypes for response to Verticillium wilt. Comparing the inoculum rates in this test, either 1×10^6 or 1×10^7 provided ample inoculum and disease response. Since environment will vary over runs, the higher rate might be an appropriate standard.

PRACTICAL APPLICATION

Genotypes with improved host plant resistance (Verticillium wilt as well as other factors) that are adaptable to Arkansas environments and possess good fiber quality are being developed. These genotypes should be valuable as breeding material to commercial breeders or as newly released cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions.

Evaluation of resistance and/or tolerance of genotypes to Verticillium wilt in cotton is often confounded by maturity of the genotypes, interactions with temperature, and variation in inoculum density within a field. By combining greenhouse and field evaluation, we hope to provide additional information on the relative response of different cotton cultivars. This information will assist with cultivar selection in areas where Verticillium wilt is a problem. Similar evaluation of strains will be used to identify lines within the breeding program that possess improved resistance.

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TILLAGE STUDIES ON COTTON

Terry C. Keisling[1]

INTRODUCTION

Deep tillage with implements that have new designs continues to be of interest. This is especially true with the increasing weights of farm machinery and equipment that have sufficient weight to severely compact soil. Soil compaction can limit water infiltration, water storage, and/or root penetration of the soil. Although many deep tillage experiments have been conducted in the past, they were conducted in late winter or early spring when soil was wet and gave no yield increases.

BACKGROUND INFORMATION

Recent work suggested that fall tillage with clays when the soil was dry would give yield responses to soybeans. Experiments were initiated to investigate the influence of the new equipment designs on deep fall tillage when the soil was dry.

MATERIALS AND METHODS

Tillage experiments consisted of 9 treatments arranged in a randomized complete block with 8 replications at two locations, Northeast Research and Extension Center (NEREC) and the Delta Branch Station. The treatments were (1) Check, (2) subsoil in fall with parabolic subsoiler in the seedling row, (3) subsoil in fall with parabolic subsoiler at a 45 degree angle to seedling row, (4) subsoiling shallow in the fall with parabolic subsoiler in the seedling row, (5) Paratill in fall with seedling row, (6) DMI winged tip straight shank run just beneath the plow pan in fall, (7) DMI winged tip straight shank run with tip 12 to 14 inches deep in fall, (8) subsoil in spring with parabolic subsoiler in the seedling row, and (9) subsoiled every other year with a parabolic subsoiler in the seedling row. Experiments were begun at the (NEREC) on a Sharkey silty clay in 1993 and at Delta Branch on Dubbs-Dundee silt loam in 1996.

RESULTS

Results from the deep tillage experiments are shown in Table 1. Note that at NEREC there is a year effect. The year effect was due primarily to treatments giving different yield responses from one year to the next. Other deep tillage treatments were somewhat intermediate between the check and the parabolic subsoiler in the fall. Of particular interest was the lack of response of the implements that did not disturb the soil surface significantly.

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PRACTICAL APPLICATION

Results from two years data at the Delta Branch Station indicated that different implements gave best results. Essentially any implement that was used for deep tillage in the fall gave yield responses except the 45 degree to the seedling row treatment. We will continue the study for one more year to see if further changes occur.

Table 1. Lint yields at the Northeast Research and Extension Center (NEREC) and the Delta Branch Station.

Treatment	NEREC 1995	NEREC 1996	NEREC 1997	Delta 1997 & 98
	---(lb lint/acre)---			
1. Conventional	681 a[z]	555 a	915 a	808 c
2. Parabolic in fall	709 a	589 a	747 a	832 a-c
3. Parabolic in fall 45	—	—	—	806 c
4. Parabolic in spring	733 a	605 a	848 a	807 c
5. Parabolic shallow in fall	—	—	—	822 b-c
6. Para-till in fall	700 a	604 a	816 a	869 a
7. DMI winged tip 12 to 14"	709 a	555 a	749 a	850 a-b
8. DMI winged tip just beneath plow pan in fall	—	—	—	806 c

[z] Yields followed by the same letter within a column are not significantly different at ($P < 0.05$).

AN IMPORTANT NEW PEST INTERACTION ON COTTON, *Meloidogyne incognita* AND *Thielaviopsis basicola*

Nathan R. Walker, Craig S. Rothrock, and Terry L. Kirkpatrick[1]

INTRODUCTION

The root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood, is a serious pathogen of cotton (*Gossypium hirsutum* L.) (Bridge, 1992) throughout the U.S. Cotton Belt. The nematode is present in approximately 30% of cotton fields (Kirkpatrick *et al.*, 1992; Robbins *et al.*, 1989). *Thielaviopsis basicola* (Berk. and Broome) Ferris (*Chalara elegans* Nag Raj & Kendrick), causal agent of black root rot of cotton, is widely distributed in cotton fields throughout Arkansas (Rothrock and Wells, 1992).

Thielaviopsis basicola overwinters as dark, thick-walled chlamydospores that germinate in the presence of the host (Tsao and Bricker, 1966; Candole and Rothrock, 1997). The fungus colonizes the cortical tissues of cotton seedlings and causes a characteristic dark brown to black discoloration of the root and hypocotyl resulting in stunted, less vigorous seedlings (Watkins, 1981). Black root rot is most severe early in the growing season when soil temperature is less than 24°C and soil water content is high (Rothrock, 1992). As soil temperatures increase and the plant develops, the diseased cortical tissue sloughs off and secondary root growth occurs (Mathre *et al.*, 1966; Mauk and Hine, 1988).

Plants affected by *T. basicola* or *M. incognita* are often misdiagnosed as environmental or nutritional problems. However, certain cotton fields in Arkansas have suffered dramatic early-season stand losses and poor growth of surviving plants when both organisms were present. This study was designed to elucidate the effects of the combination of *T. basicola* and *M. incognita* on cotton development.

MATERIALS AND METHODS

Concrete microplots (76 cm-diam x 80 cm), located at the University of Arkansas Southwest Research and Extension Center at Hope, were used in 1994 and 1995 for this study. The microplots, filled with Smithdale fine sandy loam soil (fine loamy siliceous, thermic Typic Paleudult) were fumigated with methyl bromide (100g/m^2) and covered with plastic film for four weeks before use each year. Soil was infested with 20

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spores of *T. basicola* / g soil in 1994, and 20 or 100 spores / g soil in 1995. Soil and tomato root segments containing *M. incognita* were added to microplots to a final density of 10 eggs and juveniles / cm^3 of soil each year. Inoculum of both pathogens was incorporated by mixing thoroughly with a shovel and a rake 10 to 15 cm deep. Treatments consisted of an uninfested control, *M. incognita* alone, *T. basicola* alone, and *M. incognita* and *T. basicola* in combination. Fungicide-treated (metalaxyl [Apron], carboxin [Vitavax], and PCNB; [0.155, 0.788, and 0.788 g ai / kg seed, respectively]) cotton seeds of the root-knot susceptible cultivar 'Suregrow 501' were planted in each plot immediately following infestation. Microplot infestation and planting occurred on 2 May 1994 and 14 April 1995 when the average soil temperature at 10 cm was above 16°C for a 48-hour period. Soil fertility was assayed before planting and microplots were amended with nitrogen (N), phosphorus (P), and potassium (K) according to the Arkansas Cooperative Extension Service guidelines for cotton production (Bonner, 1992). Additional NH_3NO_4 was applied to each plot periodically throughout the growing season to maintain active plant growth. Insect control with esfenvalerate (Asana) and acephate (Orthene) was based on scouting and in accordance with the Arkansas Cooperative Extension Service guidelines for cotton production (Johnson and Jones, 1993).

The number of live plants was determined 28 days after planting (DAP), and plants were thinned to six plants per plot. Plant height-to-node ratio (HNR), measured from the cotyledonary node to the tip of the main-stem terminal, was recorded on all plants 21 DAP. Nematode eggs adhering to root fragments collected during soil processing were extracted. Entire root systems at harvest were evaluated for nematode galling on a scale of 0 to 5 where 0 = no galls per root system, 1 = 1 to 2, 2 = 3 to 10, 3 = 11 to 30, 4 = 31 to 100, and 5 = >100 galls / root system.

In both years the number of days to first cracked boll (DTCB) was monitored for each plot. Seedcotton was harvested by hand from each plot 126 and 136 DAP in 1994, and 109, 116, and 133 DAP in 1995. At harvest, plant heights were measured from the cotyledonary node to the tip of the main-stem terminal. Plants were evaluated according to the COTMAP method (Bourland and Watson, 1990).

Statistical analyses were conducted with SAS (SAS Institute, Cary, North Carolina) to evaluate treatment effects on plant responses and contrasts between treatments. Orthogonal contrasts consisting of *T. basicola* or *M. incognita* alone vs. the control, and *T. basicola* or *M. incognita* alone vs. *M. incognita* + *T. basicola* were conducted for all variables for both years. Treatment means were separated with Fisher's protected LSD at ($P < 0.05$). Due to treatment and environmental differences between 1994 and 1995, data were analyzed by individual years.

RESULTS

1994 test

Plots with *M. incognita* + *T. basicola* had the lowest plant stands among the treatments in 1994 (Table 1). Plots with *M. incognita* alone also had reduced stands when compared to the control plots or those infested with *T. basicola* alone. Plant height-to-node ratios at 21 DAP also were lowest in plots with *M. incognita* + *T. basicola*, with plots infested with *M. incognita* also having reduced ratios compared to the noninfested or *T. basicola* infested plots (Table 1). When orthogonal contrasts were examined *M. incognita* + *T. basicola* reduced height-to-node ratio at 21 days compared to the control or either pathogen alone ($P < 0.01$).

Seedcotton yields for the six plants per microplot were similar among the control, *T. basicola* alone, and *M. incognita* alone treatments, but the *M. incognita* + *T. basicola* treatment resulted in lower total seedcotton weights than all other treatments in 1994 (Table 1). Plant maturity, as determined by the DTCB, was delayed in the *M. incognita* + *T. basicola* treatment. Plant heights and total bolls per plant at harvest in 1994 were reduced in the *M. incognita* and the *M. incognita* + *T. basicola* treatments compared to the control (data not shown). When orthogonal contrasts were examined the combination of the pathogens reduced yield and lengthened DTCB compared to the control or either pathogen alone ($P < 0.05$). The number of eggs recovered at harvest was lower where *M. incognita* + *T. basicola* was applied than in plots infested with the nematode alone. Root galling in *M. incognita*-infested plots was the same with or without *T. basicola* at the end of the season.

1995 test

In 1995, only *M. incognita* + Tb100 lowered plant stand densities when compared to the control (Table 2). The height-to-node ratios at 21 DAP were affected similarly with ratios being significantly less for Tb100 or *M. incognita* than the control and for the combination of Tb100 + *M. incognita* than for either pathogen alone (Table 2). According to orthogonal contrast analysis both pathogens reduced height-to-node ratio compared to the control and *M. incognita* + *T. basicola* was lower than either pathogen alone ($P < 0.05$).

Seedcotton yields for the *T. basicola*-infested plots were not suppressed in 1995 relative to the control, while the treatments *M. incognita* alone, *M. incognita* + Tb20 and *M. incognita* + Tb100 plots were lower than *T. basicola* or control plots (Table 2). Plant maturity (DTCB) was affected by *M. incognita* + *T. basicola* or *M. incognita* alone, with maturity being delayed by 5 to 9 days (Table 2). Plant heights at harvest in 1995 were lowered by the *M. incognita*, *M. incognita* + Tb20, and *M. incognita* + Tb100 treatments compared to *T. basicola* alone at either level and the control (data not shown). As in 1994, the treatments with *M. incognita* and *M. incognita* + *T. basicola* at either level lowered the total number of bolls per plant compared to the control or *T. basicola* alone treatments (data not shown). According to orthogonal contrasts, *M. incognita* + *T. basicola* reduced yield and delayed maturity compared to the control and reduced yield and delayed maturity to a greater degree than either pathogen alone ($P < 0.01$). In addition, orthogonal comparisons indicated that the combination of *M. incognita* + *T. basicola* reduced plant height, and all boll measurements compared to either pathogen alone ($P < 0.05$). The total number of eggs extracted was numerically lowest in the Tb100 treatment. Root galling was not influenced by the presence of *T. basicola*.

DISCUSSION

Neither *T. basicola* nor *M. incognita* is considered to be an acute pathogen of cotton, and seedling or plant mortality in response to infection by either organism is unusual. The infestation levels of both pathogens were typical of populations that have been found in cotton fields within Arkansas. In addition, because *T. basicola* has been observed to be more severe when soil temperatures are cool (Rothrock, 1992), planting dates for the study were determined based on soil temperature in the microplots rather than calendar dates. In both 1994 and 1995, the experiment was planted when minimum daily soil temperatures at 10 cm had remained above 16°C for two consecutive days. However, conditions for the week following planting varied between the two years. In 1994, average soil temperature during the week following planting averaged 16.1°C with cumulative rainfall of 7.9 cm, while in 1995, soil in the microplots was both drier and warmer with an average temperature of 17.8°C and cumulative rainfall of 5.9 cm. These differences may help explain why effects were seen in 1995 with 100 *T. basicola* propagules / g of soil but not with the lower infestation rate.

The effects seen with the combination of *T. basicola* and *M. incognita* were most severe during the early part of the growing season, and these effects were consistent in both years. Increased seedling mortality and suppression of early seedling growth were more severe where both organisms were present than with either pathogen alone. The primary effect of the pathogen combination appeared to be on early seedling survival and development, although the combination of both pathogens also affected certain season-long plant development reducing percentage of bolls in the second fruiting position, DTCB, and yield. *Thielaviopsis basicola* alone did not significantly affect cotton seedling mortality, although the higher level of the pathogen suppressed seedling height-to-node ratio in 1995. Plant growth and development throughout the rest of the season generally was not affected by *T. basicola* in the absence of the nematode. Conversely, infection by *M. incognita* alone resulted in suppression of both growth and development of the plants throughout the season, although effects were not as severe as when both pathogens were present. Nematode infestation slowed early seedling growth and development, delayed fruit maturation, reduced number of bolls, and suppressed yield in 1995.

Early-season effects of concomitant populations of *T. basicola* and *M. incognita* can significantly impact development and yield of cotton. Reduced or erratic plant stands, delayed plant growth, and development are of particular concern with cotton because cotton is a relatively long-season crop and earliness of maturity allows a timely harvest, particularly in the northern portion of the U.S. cotton production region. Unacceptable levels of seedling mortality may require replanting which results in delayed crop development. Of equal concern in most production systems, however, may be impeded early seedling growth and development, resulting in delays in fruiting and crop maturation. It appears from this study that there is a high risk for adverse economic impact due to a combination of *T. basicola* and *M. incognita* in cotton production systems.

ACKNOWLEDGMENT

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Table 1. Cotton emergence and development in microplots infested with *Thielaviopsis basicola* (Tb) and *Meloidogyne incognita* (Mi) in 1994.

Treatment	Stand (%)[z]	Height-to-node ratio[y]	Days to first cracked boll	Yield[x]
Control	75.5	1.47	112	667
TB20	68.9	1.45	112	721
Mi	56.0	1.05	114	649
Mi + Tb20	42.7	0.85	118	513
LSD[w]	9.5	0.10	2	107
Contrast[v]				
Tb+Mi vs. Tb or Mi	NS	**	*	*

[z] Stand counts were made at 28 days after planting.
[y] Height to node ratio = plant height per number of nodes at 21 days after planting.
[x] Seed cotton yield in grams per microplot harvested by hand two times.
[w] Data are the means of 10 replications. Means within a column are not significantly different if the magnitude of the difference is not greater than the LSD value according to Fisher's protected LSD at ($P < 0.05$).
[v] Orthogonal contrasts between the Tb+Mi treatment and treatments containing either pathogen alone were significant at ($P < 0.01$) (**), ($P < 0.05$) (*), or nonsignificant at ($P < 0.05$) (NS).

Table 2. Cotton emergence and development in microplots infested with *Thielaviopsis basicola* (Tb) and *Meloidogyne incognita* (Mi) in 1995.

Treatment	Stand (%)[z]	Height-to-node ratio[y]	Days to First cracked boll	Yield[x]
Control	75.9	1.62	123	387
TB20	75.0	1.70	123	387
Tb100	66.9	0.64	124	375
Mi	68.6	1.07	130	252
Mi + Tb20	66.6	1.02	132	193
Mi+Tb100	57.5	0.43	129	238
LSD[w]	12.4	0.13	2.4	60
Contrast[v]				
Tb+Mi vs. Tb or Mi	NS	*	**	**

[z] Stand counts were made at 28 days after planting.
[y] Height to node ratio = plant height per number of nodes at 21 days after planting.
[x] Seed cotton yield in grams per microplot harvested by hand two times.
[w] Data are the means of 10 replications. Means within a column are not significantly different if the magnitude of the difference is not greater than the LSD value according to Fisher's protected LSD at ($P < 0.05$).
[v] Orthogonal contrasts between the Tb+Mi treatment and treatments containing either pathogen alone were significant at ($P < 0.01$) (**), ($P < 0.05$) (*), or nonsignificant at ($P < 0.05$) (NS).

WATER DEFICIT AND POTASSIUM PARTITIONING IN COTTON

Dennis L. Coker and Derrick M. Oosterhuis[1]

RESEARCH PROBLEM

Little information is available regarding the impact of water deficit on potassium (K) deficiency and partitioning throughout the cotton plant, particularly during the flowering and boll development stages when K needs are greatest. We hypothesize that the water status of the plant directly affects K partitioning or distribution from plant roots and/or leaves. Therefore, the objective of this study was to evaluate the effect of water deficit stress and K deficiency on K partitioning into plant organs and on the dry matter yield of greenhouse and field-grown cotton.

BACKGROUND INFORMATION

Adequate K is crucial for cotton fiber development and quality (Cassman *et al*., 1990). Numerous investigations of the K requirement for modern cotton production have implicated it's importance in metabolic and photosynthetic processes by maintaining adequate water relations (Kerby and Adams, 1985). Cotton is more sensitive to low soil K than most other major row crops and shows K deficiency symptoms on soils not considered low in K (Cassman *et al*., 1989). Potassium is the most abundant cation (80% of total) in cotton phloem sap, cell cytoplasm, and cotton fiber. In addition, K may be taken into the cotton plant in large amounts prior to peak demand since K deficiencies occur late in the growing season when the developing boll load becomes the dominant sink for available K (Oosterhuis, 1995). These K deficiencies have been widespread across the U.S. Cotton Belt in recent years and have been related to modern cultivars with higher yields and smaller fruiting windows as well as to soil fixation, inadequate root growth, and Verticillium wilt. Potassium partitioning in the cotton plant becomes more important as the growing season progresses because K absorption prior to flowering is slow (Halevy, 1976).

RESEARCH DESCRIPTION

Cotton growth and K partitioning under limited soil solution K and water were studied in greenhouse and field environments. Treatments consisted of (1) high soil K (HK) well watered (WW), (2) HK water deficit (WD), (3) low soil K (LK) WW, and

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(4) LK WD. A randomized block design was used with five replications in the greenhouse and four replications in the field. Cultivar 'DPL 20' (early maturing) was planted into Sunshine growing medium in 2-L pots in the greenhouse. Cultivar 'SG 125' was planted into a Captina silt loam at the Arkansas Agricultural Experiment and Research Station, Fayetteville, on 15 May 1998. Stomatal resistance and plant available water were monitored upon initiation of each of two water deficit stress cycles in the greenhouse. Plants were harvested for growth analysis, dry matter, and nutrient determination of various organs at the end of each stress cycle. In the field, leaf water potential was monitored throughout the season using a portable Scholander pressure chamber to determine irrigation timing in the field. Beginning at the pinhead square stage (PS), a water deficit stress was imposed in the WD plots by withholding irrigation until the leaf water potential reached –20 bars (a moderate stress). Plant samples were collected from the field at PS, first flower (FF), and at peak flower, i.e., first flower + 5 weeks (FF+5) for the same measurements collected in the greenhouse study. Final yield of lint and seedcotton was determined by hand picking cotton from a 2 m length of row and counting the number of bolls.

RESULTS AND DISCUSSION

Greenhouse Dry Matter and K

A greater reduction in dry matter and plant tissue K occurred at low soil K levels with increasing stress cycles or plant age compared to high soil K (data not shown). At 43 days after planting (DAP), leaf, petiole, and total dry weights were reduced by a significantly greater margin from HK to LK under WW compared to WD conditions (Table 1). We know this from the KxW interactions at the 0.1 and 0.08 levels, respectively. Also, component dry weights were usually reduced by a significant amount (P<0.05) under the WD condition for either level of K but most consistently for high K. This relationship seems to indicate that additional biomass was accumulated in response to greater K availability under the WW condition. Potassium concentration in all organs decreased significantly (P<0.05) from high to low soil K supply for either level of water (Table 2). Potassium concentration in each organ also decreased by a bigger margin from high to low K under the WW condition, particularly in roots where the KxW interaction was significant at the 0.07 level. We concluded from these observations that K uptake by roots was greater under the WW conditions.

Field Dry Matter and K

Beginning at the FF stage, the dry matter of all plant organs decreased slightly from high to low soil K under WD conditions only (Table 3). Leaf, petiole, stem, and fruit K concentration decreased significantly (P<0.05) from high to low soil K under either level of water but by a greater margin for the WD condition (Table 4). In fact, K concentration in the leaves and petioles decreased by a significantly greater margin (P<0.07 and 0.05, respectively) from HK to LK under WD conditions than the WW conditions. For K use efficiency (KUE) or total plant K/ total plant biomass, the pattern of change was similar to the greenhouse (data not shown) in that significant decreases were observed from HK to LK within either level of water (Fig. 1). However, the margin of decrease was significantly greater (P<0.06) from HK to LK for the WD vs. the WW condition. At FF+5 weeks, dry weight components decreased numerically from HK to LK under the WW conditions only. Changes in K concentration at FF+5 weeks were similar to changes at FF and under the WD condition leaf, stem, and carpel wall K decreased by a greater margin compared to the WW treatment.

Field Final Harvest Components

Lint yields decreased by a 6% greater margin from high to low soil K under WD vs. WW conditions (Fig. 2). The number of open bolls decreased significantly (P<0.05) with respect to lower K under either level of water (data not shown).

PRACTICAL APPLICATION

This research will improve our understanding of cotton K requirement as affected by water-deficit stress, and thereby allow farmers to manage K inputs and realize greater profits through higher yields and fiber quality from cotton grown under limited water. Overall, our greenhouse results indicate that K concentration and dry matter in cotton at the PS stage was more affected by a second water deficit stress event. Root K concentration compared to K in other organs was especially sensitive to LK under WW conditions. Our field results indicate that the level of K fertility is especially important for maximum lint yield when cotton is grown under increasingly limited water inputs such as in a dryland setting.

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Table 1. Dry weights of plant components for cultivar 'DPL 20' under well watered (WW) or water deficient (WD) and high potassium (HK) or low potassium (LK) conditions until 43 days after planting (DAP) (end of second stress).

	Dry weight					
Treatment	Leaf	Petiole	Stem	Squares	Root	Total
	($g\ plant^{-1}$)					
HK WW	13.99 a[z]	2.47 a	8.07 a	0.53 ab	3.97 a	29.03 a
HK WD	9.87 b	1.74 b	5.73 b	0.52 ab	3.10 a	20.96 b
LK WW	12.45 a	2.09 b	7.53 a	0.68 a	4.12 a	24.18 b
LK WD	10.41 b	1.78 b	5.63 b	0.44 b	3.81 a	22.08 b

[z] Numbers followed by the same letter within a column are not significantly different ($P < 0.05$).

Table 2. Potassium content of plant components for cultivar 'DPL 90' under well watered (WW) or water deficient (WD) and high potassium (HK) of low potassium (LK) conditions until 43days after planting (DAP) (end of second stress).

	Potassium concentration			
Treatment	Leaf	Petiole	Stem	Root
	K ($g\ kg^{-1}$)			
HK WW	25.5 b[z]	67.6 a	35.0 ab	33.8 a
HK WD	28.3 a	69.1 a	38.1 a	24.7 b
LK WW	20.1 d	50.0 b	26.2 c	19.7 c
LK WD	22.9 c	56.6 b	31.7 b	16.2 c

[z] Numbers followed by the same letter within a column are not significantly different ($P < 0.05$).

Table 3. Dry weights of plant components for field-grown cultivar 'SG-125' under well watered (WW) or water deficient (WD) and high potassium (HK) or low potassium (LK) conditions at the first flower (FF) stage.

Treatment	Dry weight				
	Leaf	Petiole	Stem	Fruit	Total
	($g\ m^{-2}$)				
HK WW	205.4 ab[z]	51.2 a	233.7 ab	16.6 ab	541.1 ab
HK WD	164.7 b	37.1 b	183.0 b	20.8 ab	429.1 b
LK WW	241.6 a	56.6 a	273.4 a	21.5 a	653.1 a
LK WD	162.0 b	35.1 b	169.8 b	16.3 b	426.4 b

[z] Numbers followed by the same letter within a column are not significantly different ($P < 0.05$).

Table 4. Potassium concentration of plant components for field-grown cultivar 'SG-125' under well watered (WW) or water deficient (WD) and high potassium (HK) of low potassium (LK) conditions at the first flower (FF) stage.

Treatment	Potassium concentration			
	Leaf	Petiole	Stem	Fruit
	K ($g\ kg^{-1}$)			
HK WW	13.98 ab[z]	25.58 a	13.53 a	21.90 a
HK WD	16.43 a	29.73 a	13.45 a	21.13 a
LK WW	11.18 bc	17.88 b	10.18 b	20.75 a
LK WD	9.08 c	13.28 b	7.65 b	19.43 b

[z] Numbers followed by the same letter within a column are not significantly different ($P < 0.05$).

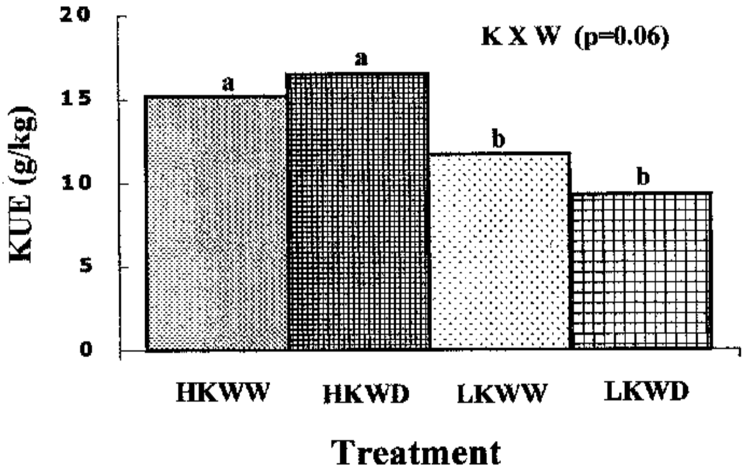

Fig. 1. Effect of soil K level and water availability on KUE (total plant K / total plant dry matter) of field-grown cotton in 1998.

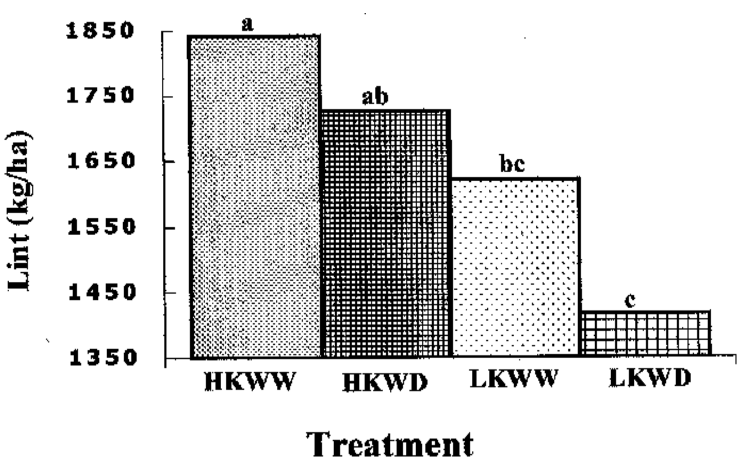

Fig. 2. Effect of soil K level and water availability on lint yield of field-grown cotton in 1998.

EFFECTS OF FOLIAR APPLICATION OF GLYCINE BETAINE ON FIELD-GROWN COTTON

Cassandra R. Meek and Derrick M. Oosterhuis[1]

RESEARCH PROBLEM

Plants attempt to tolerate or resist stresses due to decreased water availability by making osmotic adjustments to cells through increases in inorganic ions or organic solutes (Hendrix and Pierce, 1983). Glycine betaine is a natural constituent of cells that enables plants to decrease their osmotic potential for increased drought tolerance. More research needs to be conducted to determine if exogenous application of glycine betaine can affect drought tolerance and yield of cotton plants.

BACKGROUND INFORMATION

Glycine betaine has been exogenously applied to various crops in an effort to improve water deficit and heat stress tolerance as well as yield. Recently, the quaternary ammonium compound, glycine betaine, has received attention as a nontoxic solute used in osmotic adjustment (Agboma *et al.*, 1997a,b; Makela *et al.*, 1997, 1999). Previous studies have addressed effects of glycine betaine on plants such as maize and sorghum (Agboma *et al.*, 1997a), tobacco (Agboma *et al.*, 1997b), pea and turnip (Makela, 1997), tomato (Makela *et al.*, 1999), and cotton (Gorham and Jokinen, *In press*). Results have been variable and appear to depend on numerous factors such as type of crop, timing and rate of application, and environmental conditions.

RESEARCH DESCRIPTION

The field study was conducted at the Arkansas Agricultural Research and Extension Center in Fayetteville. The cotton (*Gossypium hirsutum* L.) cultivar 'Sure-Grow 125' was planted into a Captina silt loam soil on 15 May 1998. Irrigation was applied equally to all treatments when needed according to Arkansas Cooperative Extension recommendation. A watering was withheld two weeks after first-flower (FF) in an effort to impose mild water-deficit stress. The experiment consisted of 8 treatments (Table 1) in a randomized complete block design with four replications. Glycine betaine was supplied in the form of the commercial product GREENSTIM® (Finnsugar Bioproducts, Helsinki, Finland). The adjuvants used were non-ionic in composition. Foliar applications were made in the early morning using a CO_2 backpack sprayer calibrated to de-

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liver a volume of 200 L/ha (20 gal/acre) with a three-nozzle assembly directed at the terminal and into the middle of the canopy.

Photosynthetic rates and stomatal resistances were measured within two hours of solar noon at four, five, and six weeks after FF in Treatments 1, 2, 6, and 8 using a LICOR-6200 portable photosynthesis system. Midseason boll numbers were recorded for all treatments four weeks after FF. Final plant maps were established according to the COTton MAPping (COTMAP) program to determine specific growth differences between treatments. Yield determination was accomplished by hand harvesting two 1-m rows from each plot.

RESULTS

Yield Components

Midseason boll number (Table 2) was significantly higher in Treatment 3 (two applications of GREENSTIM at 6 kg/ha with no adjuvant) compared to untreated plants. No significant differences ($P < 0.05$) were observed in yield, although numerically, the control plants had the lowest seed cotton yields. Treatment 8 (four applications of GREENSTIM at 3 kg/ha of MONSOON) had the lowest number of final bolls, yet highest boll weights.

Photosynthetic Parameters

No significant differences in photosynthetic rate (Table 3) were detected between treatments. Stomatal resistance was significantly higher at four weeks after first flower in Treatment 8 (four applications of GREENSTIM at 3 kg/ha with MONSOON) when compared to control plants.

Plant Mapping

Significant differences were observed in number of effective sympodia and boll retention in the second fruiting position (Table 4). In both of these measurements, Treatment 8 (four applications of GREENSTIM at 3 kg/ha with MONSOON) was significantly higher than control plants. Although not significant, control plants had a higher percentage of total bolls on monopodial branches.

PRACTICAL APPLICATION

Although few significant differences were observed between treated and untreated plants, trends suggest foliar application of GREENSTIM could possibly increase yields of cotton. Further research will be conducted to evaluate the rate and timing of GREENSTIM application, and the responses to foliar application of GREENSTIM in cotton under well-watered conditions and more intense water-deficit stress.

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Table 1. Treatment used in field study

Treatment	Description
1	Control - sprayed with water only[z]
2	GREENSTIM applied at 3 kg/ha[z]
3	GREENSTIM applied at 6 kg/ha[z]
4	GREENSTIM applied at 3 kg/ha - 0.2% v/v DYNE-AMIC[z]
5	GREENSTIM applied at 6 kg/ha - 0.2% v/v DYNE-AMIC[z]
6	GREENSTIM applied at 3 kg/ha - 0.5% v/v MONSOON[z]
7	GREENSTIM applied at 6 kg/ha - 0.5% v/v MONSOON[z]
8	GREENSTIM applied at 3 kg/ha - 0.5% v/v MONSOON[y]

[z] Foliar applications made at one and two weeks after first flower.
[y] Foliar applications made at one, two, three, and four weeks after first flower.

Table 2. Effects of foliar application of glycine betaine on yield and yield components of field-grown cotton in 1998 at Fayetteville. Midseason boll number was measured four days after the third foliar application. Seed cotton yield, final boll number, and boll weights were measured at harvest.

Treatment	Midseason boll number	Final boll number	Boll weight	Seed cotton yield
	no./m^2	no./m^2	g/boll	g/m^2
Control[z] water only	40.0	34.5	4.99	400.3
GREENSTIM[z] 3 kg/ha				
no adjuvant	53.8	35.0	4.99	430.3
GREENSTIM[z] 6 kg/ha				
no adjuvant	57.8	37.1	4.99	457.3
GREENSTIM[z] 3 kg/ha				
DYNE-AMIC	49.3	38.0	4.70	441.8
GREENSTIM[z] 6 kg/ha				
DYNE-AMIC	51.3	35.4	4.97	433.7
GREENSTIM[z] 3 kg/ha				
MONSOON	44.5	38.0	4.86	456.0
GREENSTIM[z] 6 kg/ha				
MONSOON	53.0	35.1	4.90	423.2
GREENSTIM[y] 3 kg/ha				
MONSOON	55.3	33.0	5.33	437.4
LSD (0.05)	NS	NS	0.34	NS

[z] Foliar applications made at one and two weeks after first flower.
[y] Foliar applications made at one, two, three, and four weeks after first flower.

Table 3. Photosynthesis and stomatal resistance rates of field-grown cotton receiving foliar applications of glycine betaine in 1998 at Fayetteville. Measurements were taken with Licor 6200 at four, five, and six weeks after first flower (FF+4, FF+5, and FF+6, respectively).

	Photosynthesis			Stomatal resistance		
Treatment	FF+4	FF+5	FF+6	FF+4	FF+5	FF+6
	--------- (µmol $CO_2/m^2/s$) ------			---------- ($mol/m^2/s$) ----------		
Control[z] water only	33.4	36.3	22.6	0.132	0.120	0.801
GREENSTIM[z] 3 kg/ha						
no adjuvant	33.0	25.8	20.6	0.190	0.217	0.677
GREENSTIM[z] 3 kg/ha						
MONSOON	33.6	26.0	17.9	0.162	0.147	0.804
GREENSTIM[y] 3 kg/ha						
MONSOON	30.8	33.3	19.4	0.249	0.194	1.002
LSD (0.05)	NS	NS	NS	0.102	0.007	NS

[z] Foliar applications made at one and two weeks after first flower.
[y] Foliar applications made at one, two, three, and four weeks after first flower.

Table 4. Select plant mapping (COTMAP) data obtained at harvest.

Treatment	Mean no. effective fruiting branches	Mean boll retention 2nd position	Total bolls on monopodia
	-------------- (no./plant)	------------	(%)
Control[z] water only	6.53	14.25	31.88
GREENSTIM[z] 6 kg/ha			
no adjuvant	7.58	18.00	32.28
GREENSTIM[z] 6 kg/ha			
MONSOON	8.35	18.38	25.28
GREENSTIM[y] 3 kg/ha			
MONSOON	9.25	18.78	27.18
LSD (0.05)	1.97	3.65	0.55

[z] Foliar applications made at one and two weeks after first flower.
[y] Foliar applications made at one, two, three, and four weeks after first flower.

EVALUATION OF MEISTER PROGRAMMED NITROGEN FERTILIZER ON CONVENTIONAL COTTON WITH EMPHASIS ON PLACEMENT METHODS AND YIELD

Derrick M. Oosterhuis and Adele Steger[1]

RESEARCH PROBLEM

Current fertilization practices involve preplant or sidedress soil applications either prior to planting or early in the growing season. A programmed release fertilizer potentially increases efficiency by releasing nutrients during the season according to crop requirements, and it reduces traffic across the field. The objective of this study was to provide a field evaluation of the polyolefin-coated, Meister programmed release nitrogen (MPRN) fertilizer with regard to placement of fertilizer in the planted row and timing of application. In addition, the study provides a continued field evaluation of MPRN soil-applied fertilizer used in combination with Asset RTU™ for their effects on lint yield in cotton production.

BACKGROUND INFORMATION

Previous studies from 1996 and 1997 showed a trend towards numerically higher (4%) lint yields in both years in the treatment receiving 80% MPRN when compared with the 100% nitrogen (N) control treatment (Steger and Oosterhuis, 1998). In 1997, lint yield was significantly higher ($P<0.05$) in the 80% MPRN treatment compared with the 100% conventional N treatment (Oosterhuis and Steger, 1998). Asset RTU, a root stimulant reported to be effective in increasing early season root growth in cotton, was added to this study to evaluate combinations with slow release fertilizer.

MATERIALS AND METHODS

In 1998, the study was conducted at the Delta Branch Station in Clarkedale. The cotton cultivar, 'Suregrow 125' was planted into a moderately well-drained Dundee silt loam soil on 6 May 1998. Plots consisted of 4 rows spaced 38 in. apart and 50 ft in length with seven replications. Insect and weed control were according to standard cotton recommendations. The trial was furrow irrigated as needed. Petioles from the uppermost fully-expanded leaves were sampled at pinhead square, first flower, and three weeks after first flower, and analyzed for nitrogen. Soil samples at the 0 to 6 in. and 6 to 12 in. depth were taken at 28 days after planting, two weeks after pinhead square, and two weeks after first flower in the control treatment (100 lb NH_4NO_3-N/acre), the treatment receiving 80 lb MPRN/acre in 2x2 application, and the control

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treatment where no additional N was applied. Plant height and number of main-stem nodes were measured at approximately 50% open flower and again following defoliation at the end of the growing season. A random, 50-boll sample was handpicked from each plot to determine boll weight and gin turnout. Subsamples of these samples were sent to Louisiana State University for lint quality testing (HVI). The center two rows of each plot were machine harvested at approximately 60% open boll to determine final yield. Fertilizer treatments are listed in Table 1. Asset RTU was applied post-emergence over-the-top to two of the treatments (2x2 and 2x12) to evaluate its effect in combination with MPRN. In addition, the potential leaching of nitrates below the root zone was examined by analyzing soil samples taken during the growing season.

RESULTS AND DISCUSSION

Petiole Nitrogen Concentration

At pinhead square, petiole nitrogen concentration was highest in the treatment receiving MPRN (80 lb N/acre) with 2x2 placement (2 in. deep and 2 in. to the side of the planted row) (data not shown). At three weeks after first flower, all treatments had a relatively low petiole nitrate concentration except the treatment receiving a banded application of MPRN (80 lb N/acre) at pinhead square.

Plant Height and First Fruiting Branch

At 50% open flower, the two MPRN treatments (2x2 and 2x12 placement) were numerically the tallest although there were only slight differences among treatments in main-stem node number (data not shown). The conventional nitrogen treatment (NH_4NO_3) and the MPRN (2x2) with ASSET RTU were the tallest and had the greatest number of main-stem nodes at harvest compared with all other treatments.

Lint Yield and Yield Components

Lint yield, boll weight, and percent gin turnout are shown in Table 2. The highest yields were obtained from the treatments receiving MPRN at pinhead square, MPRN in a 2x2 placement, and MPRN on 1 April (five weeks prior to planting). All MPRN treatments had a higher numerical yield than the control although only the early applied MPRN and the pinhead square MPRN application were significant. When MPRN was applied in a 2x2 placement with the addition of Asset RTU, there was a 9% increase in yield when compared with the same application without Asset RTU.

Lint Quality (HVI)

Differences for lint quality among treatments are shown in Table 3. Significant differences between the control and the MPRN treatments were exhibited for micronaire and uniformity index.

Soil Nitrate Concentration

Soil nitrate concentrations at three sample dates are shown in Fig. 1. Nitrate levels at both the 0 to 6 in. and the 6 to 12 in. depth were higher in the conventional plots (NH_4NO_3) at all three sample dates except for 28 days after planting when nitrates were higher at 0 to 6 in. in the MPRN plots. This implied slower release of nitrogen from the soil in the MPRN treatments and an increased availability of nitrogen for the plant's use later in the growing season.

PRACTICAL APPLICATION

MPRN is a potential alternative N source in field cotton production. The results from 1998 were variable, although MPRN still performed favorably compared to the conventional N treatment. In 1997, there was evidence that by N fertilizer inputs could be reduced by as much as 40% with MPRN without resulting in a lint yield decrease below that of the conventionally-applied fertilizer. Other potential advantages included the potential to decrease groundwater contamination and increase nutrient uptake efficiency, and the reduction of field traffic with only a single fertilizer application.

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Table 1. Treatments in continued evaluation of Meister programmed release nitrogen (MPRN). Clarkedale, 1998.

Treatment	Rate	Placement
Control	no N applied	-----
Conventional	100 lb N/acre NH_4NO_3	50 lb N at planting and 50 lb N at pinhead square
MPRN	80 lb N/acre MPRN	incorporated into row on 1 April
MPRN	80 lb N/acre MPRN	2 in. deep and 2 in. to the side at planting (2x2)
MPRN	80 lb N/acre MPRN	2 in. deep and 12 in. to the side at planting (2x12)
MPRN	80 lb N/acre MPRN	4 in. band over planted row at pinhead square
MPRN	80 lb N/acre MPRN	2x2 at planting plus ASSET RTU™[z] post-emergence
MPRN	80 lb N/acre MPRN	2x12 at planting plus ASSET RTU post-emergence

[z]ASSET RTU™ was applied at a rate of 2 pt/acre.

Table 2. Lint yield and yield components. Clarkedale, 1998.

Treatment	Lint yield	Boll weight	Gin turnout
	(lb/acre)	(g/boll)	(%)
Control	762	4.67	38.9*
Conventional	725	5.16	36.4
MPRN - 1 April	829*	4.70	39.3*
MPRN - 2x2	776	4.92	37.9*
MPRN - 2x12	789	4.95	37.4*
MPRN - pinhead square	867*	4.78	38.4*
MPRN - 2x2 + RTU	846*	5.13	37.9*
MPRN - 2x12 + RTU	788	4.98	37.6*
LSD (0.05)	92.1	0.42	0.01

* Significantly different ($P < 0.05$) from the conventional N treatment.

Table 3. Lint quality (HVI). Clarkedale, 1998.

Treatment	Length	Micronaire index	Strength	Elongation	Uniformity index
	(in.)		(g/tex)	(%)	
Control	1.14	4.57	25.37	8.03	83.7
Conventional	1.16	4.27	27.23	8.03	83.3
MPRN - 1 April	1.17	4.53*	26.47	8.03	83.8
MPRN - 2x2	1.14	4.43	24.87	8.17	84.5
MPRN - 2x12	1.16	4.23	25.40	8.00	83.0
MPRN - pinhead square	1.16	4.63*	25.53	8.13	84.0
MPRN - 2x2 + RTU	1.15	4.33	24.50	8.53	85.3*
MPRN - 2x12 + RTU	1.16	4.43	25.97	8.30	84.2
LSD (0.05)	NS	0.251	NS	NS	1.95

*Significantly different ($P < 0.05$) from the conventional N treatment.

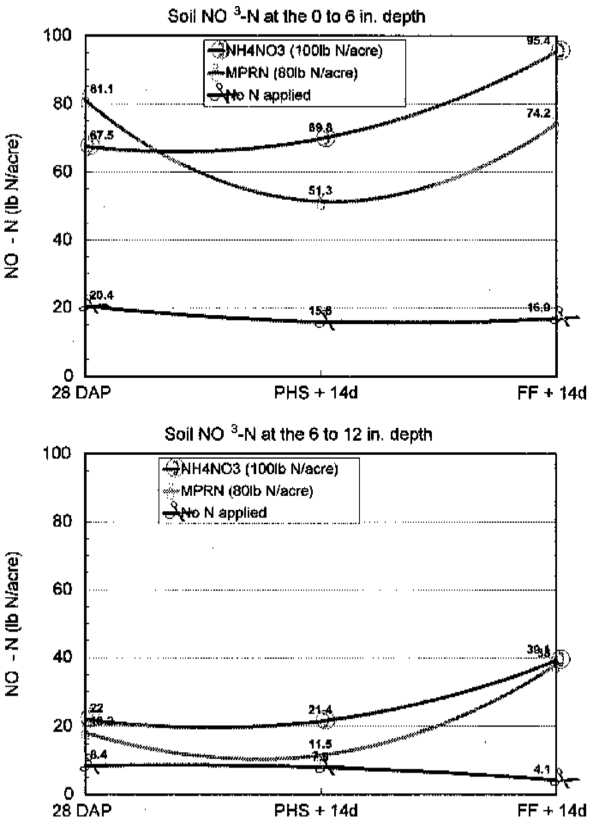

Fig. 1. Soil nitrate (N) at the 0 to 6 in. depth and the 6 to 12 in. depth at various sampling times during the growing season.

CHARACTERIZATION OF BORON USE AND DISTRIBUTION IN THE COTTON PLANT AND EVALUATION OF THE EFFECTIVENESS OF FOLIAR FEEDING WITH BORON

Derrick M. Oosterhuis and Adele Steger[1]

RESEARCH PROBLEM

Boron (B) is an essential element required by cotton (*Gossypium hirsutum* L.) for optimal growth and development, particularly in the role of carbohydrate translocation. A deficiency in B may cause a decrease in the fruiting index (boll dry weight / stem) of cotton due to its direct role in flowering and fruiting (Joham, 1986). The objective of the 1998 study was to characterize the uptake and partitioning of B, and to compare a soil application at planting with foliar applications during flowering. We also looked for nitrogen (N) and boron interactions under conditions of high and low soil N.

BACKGROUND INFORMATION

Anderson and Boswell (1968) applied B to field-grown cotton at rates of 0, 0.4, and 0.8 lb B / acre. Over a three-year period, the 0.4 lb / acre rate caused a 7.3% increase in seedcotton yield at first pick supporting a relationship between B and crop earliness. Our study was initiated in 1995 and became a part of the present regional study in 1996. Results from 1997 indicated that total B concentration in the plant peaked at first flower with the majority of the total B accumulating in the leaf tissue. A higher concentration of B occurred in the low N plots when compared with the high N plots.

MATERIALS AND METHODS

The study was conducted at the Arkansas Agricultural Experiment Station in Fayetteville. The cotton cultivar 'Suregrow 125' was planted on 15 May into a Captina silt loam soil. Treatments were split for N (main plot) and B (subplot) with five replications. Nitrogen was applied at the two true-leaf stage and at pinhead square for a total of 100 lb N / acre (high nitrogen plots) and 50 lb N / acre (low nitrogen plots). Boron treatments were as follows: (1) an untreated control with no additional B applied; (2) soil-applied SOLUBOR at 2.0 lb B / acre applied with nitrogen fertilizer at the two true-leaf stage; (3) soil-applied SOLUBOR at 1.0 lb B / acre applied with nitrogen fertilizer at the two true-leaf stage followed by three foliar applications of SOLUBOR at 0.4 lb B / acre at one, two, and four weeks after first flower; and (4) foliar-applied SOLUBOR

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at 0.6 lb B / acre at one, two, and four weeks after first flower. Plots consisted of four rows, 20 ft in length, spaced 38 in. apart. Nutrient analysis from soil samples taken at the 0 to 6 in. depth prior to planting gave the following results: pH, 5.9; EC, 62 μmhos / cm; phosphorus (P), 145 lb / acre; potassium (K), 192 lb / acre; calcium (Ca), 1224 lb / acre; magnesium (Mg), 73 lb / acre; sodium (Na), 5 lb / acre; sulfur (S), 23 lb / acre; iron (Fe), 186 lb / acre; manganese (Mn), 198 lb / acre; zinc (Zn), 12 lb / acre; copper (Cu), 1.9 lb / acre; B, 0.04 lb / acre; and NO_3-N, 9 lb / acre. Growth and nutrient analyses were conducted at pinhead square (41 days after planting [DAP]), first flower (62 DAP), and three weeks after first flower (83 DAP) on leaves, petioles, stems, and fruit harvested from one meter of row in each plot. Lint yield and boll weight were determined by hand harvesting a 2-m row length of seedcotton from each plot.

RESULTS AND DISCUSSION

Total B in the plant during season is shown in Fig. 1. At pinhead square and first flower, there were no real differences among treatments although soil-applied B was slightly greater than other treatments and slightly higher in the low N plots compared with high N plots. At three weeks after first flower, soil- + foliar-applied B was greater compared with other B treatments and total B was higher in high N plots compared with low N plots.

Distribution of B in the plant during season is shown in Fig. 2. Petiole and stem B did not change much between sampling dates, although B concentration in the stem decreased more in high N plots than low N plots. Leaf B was lower in the control treatment at all sampling dates compared with soil-applied and soil- + foliar-applied B. Leaf B was greater in the low N plots in soil + foliar B treatment, but B concentration was lower in the fruit (squares and bolls) in the low N plots compared with high N plots at three weeks after first flower. There were greater differences in fruit B in high N plots at first flower and three weeks after first flower when compared with low N plots.

Lint yield and boll weight are given in Fig. 3. Yields were greater in the control treatment in the high N plots when compared with all other treatments. In low N plots, yields were greatest in the foliar-applied and soil- + foliar-applied B treatments.

PRACTICAL APPLICATION

The effect of soil- or foliar-applied B on plant growth and yield was not clearly evident, possibly due to the extremely stressful growing season in 1998. The highest B concentration occurred in the soil + foliar B treatment. Leaves had the highest B followed by the bolls. Boll B concentration was increased by B application, especially by the soil + foliar application and was reflected in increased boll weight and yield in the low N regime. Lint yield was highest in the two foliar B treatments and lowest in the soil-applied treatments in the low N regime. However, the reverse occurred in the high N regime. This research will be repeated in 1999 at additional locations.

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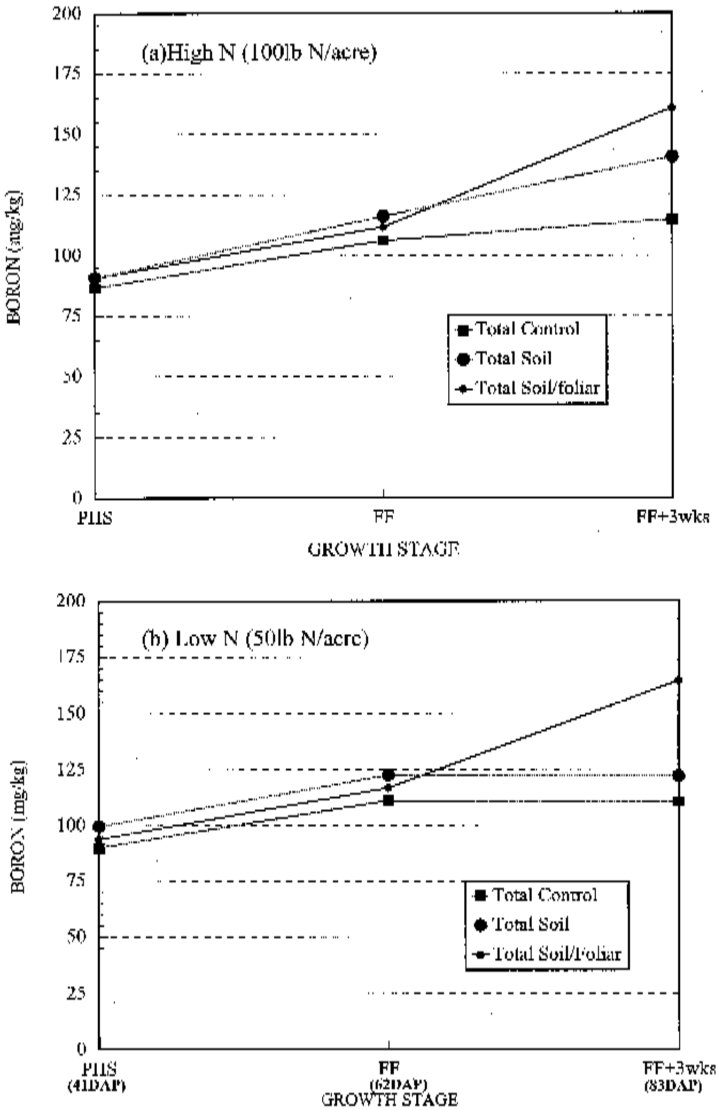

Fig. 1. Total boron in plant during the growing season in the untreated control, soil-applied, and soil - + foliar-applied boron treatments, (a) high nitrogen (N) plots (100 lb N/acre) and (b) low nitrogen plots (50 lb N/acre).

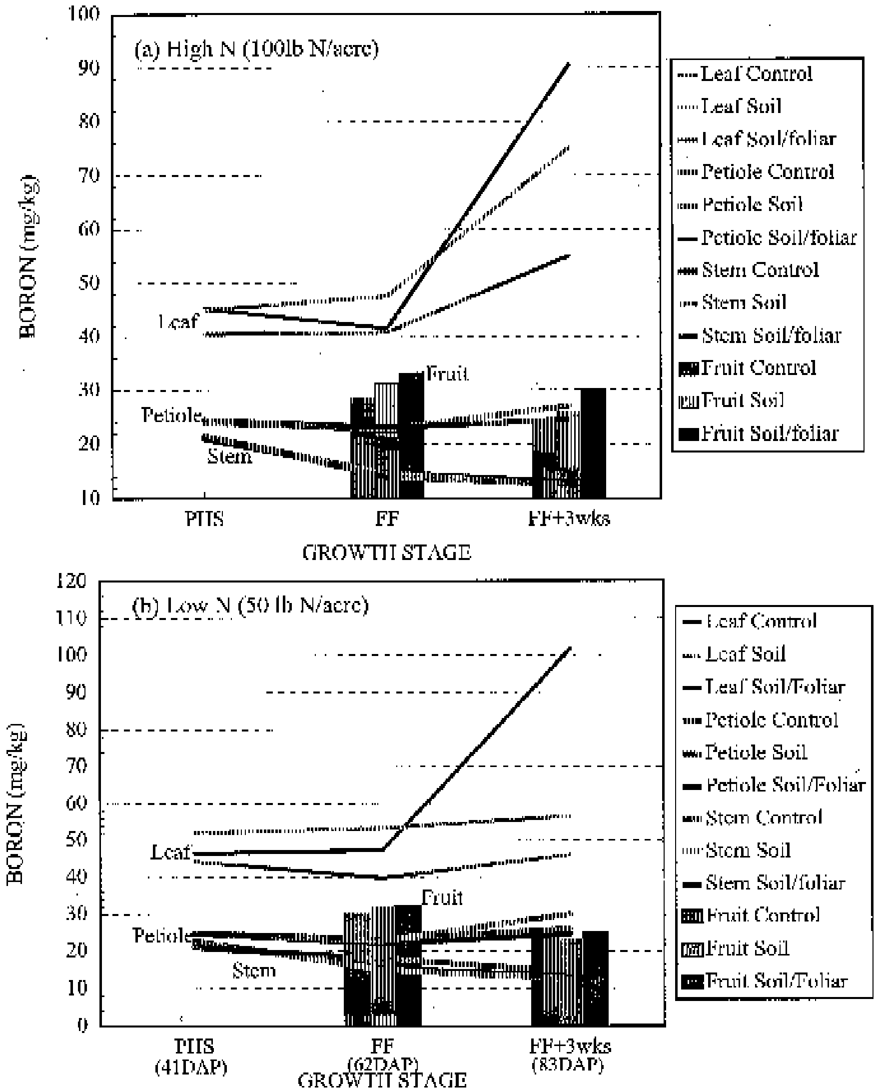

Fig. 2. Distribution of boron in cotton plant during the growing season in the untreated control, soil-applied and soil- + foliar-applied boron treatments, (a) high nitrogen plots (N) (100 lb N/acre) and (b) low nitrogen plots (50 lb. N/acre).

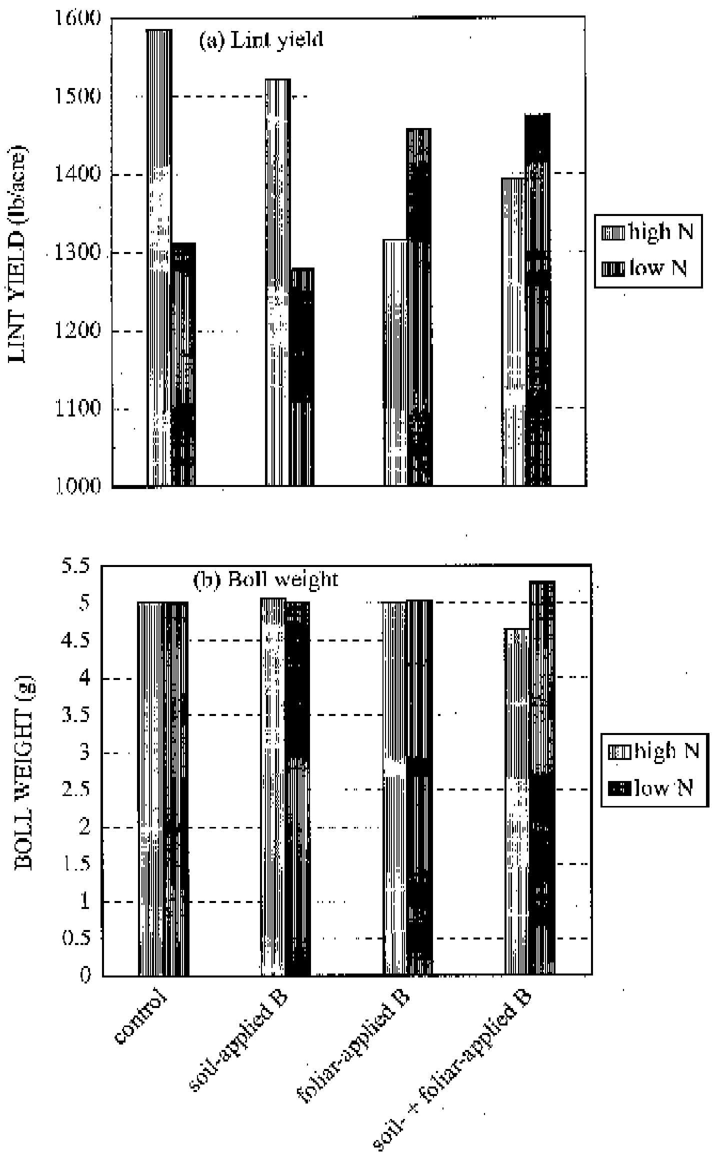

Fig. 3. Lint yield (a) and boll weight (b) as affected by high (100 lb N/acre) and low nitrogen (N) (50 lb N/acre) status and boron treatments.

CHEMICAL AND PHYSICAL REMOVAL OF LATE-SEASON COTTON FRUIT TO IMPROVE YIELDS AND CONTROL BOLL WEEVILS

Robert S. Brown, Derrick M. Oosterhuis, and Fred M. Bourland[1]

RESEARCH PROBLEM

Increasing yields in cotton (*Gossypium hirsutum* L.) and better management of late-season insects are two on-going concerns for many researchers and producers in Arkansas. Preliminary studies have shown that removal of squares at five nodes above the uppermost white flower (NAWF=5) +350 heat units may actually divert carbohydrates to developing upper-canopy bolls with a resultant yield advantage (Kim and Oosterhuis, 1998). Furthermore, research and field observations have indicated that terminating insecticides at 350 heat units after physiological cutout (NAWF=5) results in higher yields than when terminating at either 250 or 450 heat units (Oosterhuis *et al.*, 1999). The objective of this study was to evaluate the efficiency of various chemicals in removing fruit above NAWF=5. If this research is successful we hypothesize that producers can enjoy the benefits of higher yields and better management of weevil populations.

BACKGROUND INFORMATION

COTMAN, a successful management program for cotton, provides the basis for measuring the efficiency of management strategies that promote earliness in the cotton crop. NAWF is an integral concept used in COTMAN for basing end-of-season decisions. It has been reported that bollworm (*Helicoverpa zea)* and boll weevil (*Anthonomus grandis)* damage to cotton bolls decreases dramatically at about 350 heat units after NAWF=5 (Bagwell, 1995). This fact is used in the COTMAN cotton monitoring program for timing the termination of insecticide applications at 350 heat units after the last effective flowering population at NAWF=5 (Cochran *et al.,* 1995). This timely but early termination of insecticide application could save growers a significant amount of money, especially in the southern part of Arkansas (Cochran *et al.*, 1994). However, if termination occurs too early yields could be significantly reduced.

RESEARCH DESCRIPTION

A field experiment was planted into a moderately well-drained Hebert silt loam at the Southeast Research and Extension Center, Rohwer Division, and a moderately well-

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drained Dundee silt loam at the Delta Branch Station at Clarkedale. Two Deltapine cultivars were used, an early maturing 'DP20B' cultivar and a late-season 'NuCotn33B' cultivar. To provide two growth patterns, we included two planting dates (early and mid-May). Treatments included a hand square removal, mechanical topping (physical removal of fruit), cyclanilide (Finish®) at 0.1 lb / acre, ethephon at 0.2 lb / acre, chlormequat (CCC) at 8 oz / acre, and maleic hydrazide (used in tobacco) at 2 lb / acre (chemical removal). A randomized complete block design with four replications was used. At the NAWF=5 stage, 20 to 30 first position white flowers at NAWF=5 were tagged in the center two rows of each 4-row plot. Daily heat units after NAWF=5 were accumulated until 350 heat units were reached and the seven treatments were then applied using a CO_2 backpack sprayer calibrated to deliver 10 gallons of solution / acre. Two weeks after applying treatments, first position square shed was determined for the 5 nodes above, and 5 nodes below the tagged node at NAWF=5, as well as at the tagged NAWF=5 position. Total seedcotton yield, boll weight at NAWF=5, and HVI (fiber quality) were determined for the various treatments at final harvest.

RESULTS

Efficiency of Square Removal

At Rohwer (southeast Arkansas), cyclanilide and ethephon were the most effective chemicals removing a significantly higher percentage (P<0.05) of upper-canopy fruit than the control, for the DP20B cultivar (Table 1). For the NuCotn33B cultivar, ethephon gave the highest upper-canopy fruit shed of 73%, which was significantly higher than the 67% by the control. At Clarkedale (northeastern Arkansas) there was no significant difference (P<0.05) among treatments for square shed for the DP20B cultivar. However, chlormequat outperformed the other treatments by shedding 89% of the squares above NAWF=5, which was significantly higher than the other treatments for the NuCotn33B cultivar (Table 2). Overall, there was no treatment effect on square shed below the tagged NAWF=5, and only the maleic hydrazide treatment showed significant shedding of fruit at the NAWF=5 position when compared to the control treatment.

Seedcotton Yields

There were no significant differences between treatments at Clarkedale with respect to seedcotton yield (Table 3). At Rohwer, there were no significant differences in treatment effects on yield for the DP20B cultivar. The differences seen for the NuCotn 33B cultivar were significant with the control giving the highest yields and the mechanical topping treatment giving the lowest yields (Table 4).

First Position Boll Weights at NAWF=5

For the boll weight at NAWF=5 there were no significant differences between treatments at Clarkedale (Table 3). At Rohwer, the hand square removal treatment gave the highest boll weight at NAWF=5 for the DP20B cultivar, and the control and mechanical topping treatments gave the lowest boll weights. For the NuCotn 33B cultivar, ethephon and cyclanilide gave significantly higher boll weights than the control, which was the lowest (Table 4).

PRACTICAL APPLICATION

The primary objective of this study was to evaluate various chemicals to determine which chemicals were the most effective at removing unwanted upper-canopy fruit late in the growing season. Secondly, we wanted to determine if this removal of fruit effected subsequent seedcotton yields. There was evidence that some chemicals could be helpful in achieving this goal but more research needs to be performed. This research could give growers better yields and control of late-season insects.

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Table 1. First position fruit shed percentages at tagged NAWF=5, as well as above and below the tag two weeks after application of treatments, Rohwer. (Planting date 6 May 1998.)

	Deltapine 20B			NuCotn 33B		
Treatment	NAWF=5	Above	Below	NAWF=5	Above	Below
	(shed %)					
Control	28.2 a[z]	51.1 b	41.3 a	13.8 c	67.1 ab	48.6 a
Chlormequat	21.2 a	63.2 ab	48.2 a	20.4 bc	68.6 ab	48.3 a
Maleic Hydrazide	26.9 a	63.2 ab	37.9 a	41.4 a	59.8 b	52.2 a
Ethephon	30.4 a	67.1 a	40.7 a	22.6 bc	73.1 a	47.1 a
Cyclanilide	24.4 a	67.0 a	44.0 a	28.5 abc	63.1 ab	52.1 a
Mech. Topping	35.8 a	-----[y]	-----[x]	33.0 ab	-----[y]	-----[x]
Hand sq. removal	13.3 a	-----[y]	-----[x]	28.3 abc	-----[y]	-----[x]

[z]Treatment means within a column followed by the same letter are not significantly different at ($P<0.05$).
[y]All squares removed by treatment.
[x]Fruit shed not recorded.

Table 2. First position fruit shed percentages at tagged NAWF=5, as well as above and below the tag two weeks after application of treatments, Clarkedale. (Planting date 6 May 1998.)

	Deltapine 20B			NuCotn 33B		
Treatment	NAWF=5	Above	Below	NAWF=5	Above	Below
	(shed %)					
Control	16.8 a[z]	85.0 a	55.6 a	55.7 a	86.3 ab	55.6 a
Chlormequat	14.0 a	84.4 a	50.6 a	28.0 b	88.8 a	57.5 a
Maleic Hydrazide	24.9 a	87.5 a	47.5 a	38.3 ab	86.3 ab	58.8 a
Ethephon	23.1 a	85.6 a	49.4 a	35.2 ab	79.4 b	55.0 a
Cyclanilide	9.2 a	85.6 a	56.9 a	19.2 b	83.8 ab	52.5 a
Mech. Topping	19.5 a	-----[y]	-----[x]	26.8 b	-----[y]	-----[x]
Hand sq. removal	17.2 a	-----[y]	-----[x]	23.8 b	-----[y]	-----[x]

[z]Treatment means within a column followed by the same letter are not significantly different at (P<0.05).
[y]All squares removed by treatment.
[x]Fruit shed not recorded.

Table 3. Effect of chemical and physical fruit removal on seedcotton yield and average boll weight at NAWF=5, Clarkedale. (Planting date 6 May 1998.)

	Deltapine 20B		NuCotn 33B	
Treatment	Seedcotton yield	Average boll weight	Seedcotton yield	Average boll weight
	(kg/ha)	(g)	(kg/ha)	(g)
Control	2383 a[z]	4.39 a	1919 a	4.06 a
Chlormequat	2151 a	4.51 a	1540 a	4.44 a
Maleic Hydrazide	2313 a	4.21 a	1714 a	3.90 a
Ethephon	2407 a	4.49 a	1863 a	3.86 a
Cyclanilide	2336 a	4.67 a	1918 a	4.13 a
Mech. Topping	2372 a	4.14 a	1722 a	3.85 a
Hand sq. removal	2406 a	4.37 a	1936 a	4.31 a

[z] Treatment means within a column followed by the same letter are not significantly different at ($P < 0.05$).

Table 4. Effect of chemical and physical fruit removal on seedcotton yield and average boll weight at NAWF=5, Rohwer. (Planting date 6 May 1998.)

	Deltapine 20B		NuCotn 33B	
Treatment	Seedcotton yield	Average boll weight	Seedcotton yield	Average boll weight
	(kg/ha)	(g)	(kg/ha)	(g)
Control	3101 a[z]	3.60 b	3390 a	3.55 b
Chlormequat	3068 a	3.93 ab	2918 bc	3.66 ab
Maleic Hydrazide	3032 a	4.15 ab	3188 ab	3.65 ab
Ethephon	3047 a	4.00 ab	3025 bc	4.23 a
Cyclanilide	3136 a	4.20 ab	2965 bc	4.19 a
Mech. Topping	3073 a	3.60 b	2875 c	3.94 ab
Hand sq. removal	2998 a	4.46 a	3089 abc	3.86 ab

[z] Treatment means within a column followed by the same letter are not significantly different at ($P < 0.05$).

CHARACTERIZATION OF THE FRUITING GROWTH CURVE USED IN CROP MONITORING

Derrick M. Oosterhuis, Fred M. Bourland, and Adele Steger[1]

RESEARCH PROBLEM

The COTMAN crop monitoring program follows the progress of squares and flowers in relation to main-stem nodal development to assist with end-of-season management decisions (Bourland *et al.*, 1992). Comparing actual recorded fruiting data with a standard 'target' fruiting growth curve is one facet of these crop monitoring procedures and serves as a basis for management decisions. More field data is necessary in order to understand the effect of major production inputs, such as mepiquat chloride (Oosterhuis *et al.*, 1991) and nitrogen (N) (Maples *et al.*, 1990), and how these may influence the fruiting growth curve.

BACKGROUND INFORMATION

The currently used standard fruiting growth curve in COTMAN is based upon number of calendar days from planting. However, there is sufficient evidence in the physiological literature to indicate that heat unit accumulation may be more accurate and indicative of prevailing growing conditions (Brown, 1989; Burke *et al.*, 1988; Reddy *et al.*, 1991). Information is needed about the relationship between the fruiting growth curve and heat unit accumulation. The objectives of this study were (1) to characterize the standard fruiting growth curve in cotton with regard to days after planting and heat unit accumulation, for several geographical locations, between major phenological stages (pinhead square, first flower, and physiological cutout [NAWF=5]), and (2) to determine the effect of production management inputs, mepiquat chloride, and soil nitrogen status, on the fruiting growth curve. This is the second year of this study which is also repeated in Louisiana, Georgia, and Virginia.

RESEARCH DESCRIPTION

The cotton cultivar 'Suregrow 125' was planted on 15 May 1998 into a Captina silt loam soil. Treatments were an untreated control; two foliar applications of PIX™ at pinhead square and first flower (4 oz / acre and 12 oz / acre, respectively); and low nitrogen. A preplant and pinhead square application of nitrogen fertilizer (NH_4NO_3) was applied to the control and Pix™ plots (total 100 lb N / acre) and the low nitrogen plots

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(total 50 lb N/acre). The experimental design was a randomized complete block with three replications. Measurements included COTMAN crop monitoring records, and number of days and heat units from planting until pinhead square, first flower, and NAWF=5. First position white flowers were tagged at NAWF=7, 6, 5, and 4 beginning at NAWF=7. These tagged flowers were harvested as open bolls at the end of the growing season. Fruit retention and boll weight (number of bolls required for 1 lb of seedcotton) were calculated at each tagged main-stem nodal position. Insect control and irrigation were applied as needed throughout the growing season according to standard cotton recommendations.

RESULTS

Figure 1 shows the three treatment curves plotted against the standard target fruiting growth curve. The control treatment best tracked the standard growth curve, although the PIX treatment reached physiological cutout (NAWF=5) one day earlier, 75 days after planting, compared with the control, and five days earlier compared with the low nitrogen treatment. Physiological cutout occurred at 80 days after planting in the target growth curve. At first flower (60 days after planting in the target curve), the apogee in the control was just above NAWF=8 and approximately NAWF=7.7 in the PIX treatment and close to NAWF=7 in the low nitrogen treatment. This indicates an early-season stress in these treatments as the nodes above white flower count at first flower should be closer to 9.25. Heat unit accumulation after planting and days after planting until pinhead square, first flower and NAWF=5 for all treatments is shown in Table 1.

Figure 2 shows the effect of the treatments on the number of bolls required to produce 1 lb of seedcotton as boll position progressed towards the terminal (i.e., NAWF=7, 6, 5, and 4). In the control treatment, there was an increase in the boll number required to produce 1 lb of seedcotton as the position progressed towards the terminal, except at NAWF=6, where there was a decrease to approximately 82 bolls/lb seedcotton. The PIX treatment required consistently fewer bolls to produce 1 lb of seedcotton when compared with both other treatments after NAWF=6.

Fruit retention as the crop progressed towards physiological cutout (NAWF=5) is shown in Fig. 3. Fruit retention appeared to drop constantly between NAWF=7 and NAWF=4, except in the PIX treatment were retention remained close to 50% at all nodes.

PRACTICAL APPLICATION

The fruiting development curve for all treatments was delayed compared to the standard *target development curve*. The number of fruiting nodes at first flower was decreased by both mepiquat chloride and low nitrogen. The mepiquat chloride treatment reached physiological maturity (NAWF=5) earlier than the control, whereas nitrogen stress delayed maturity. The comparison of heat units vs. calender days for comparing fruiting development curves to interpret growth problems was not clear. This study will be repeated at four geographical locations in 1999, and the data for three years (1997 to 1999) will be compiled to determine the reliability of the current target development curve and characterize the effect of production inputs on the development of the fruiting curve.

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Table 1. Heat unit accumulation after planting and days after planting until pinhead square, first flower, and NAWF-5 for all treatments, Fayetteville, 1998.

	Days after planting			Heat units after planting		
Treatment	PHS[z]	FF[y]	NAWF=5[x]	PHS[z]	FF[y]	NAWF=5[x]
Untreated control	41	70	76	658	1111	1463
PIX™	41	70	75	658	1111	1433
Low nitrogen	41	70	80	658	1111	1560

[z]Pinhead square.
[y]First flower.
[x]Nodes above white flower = 5.

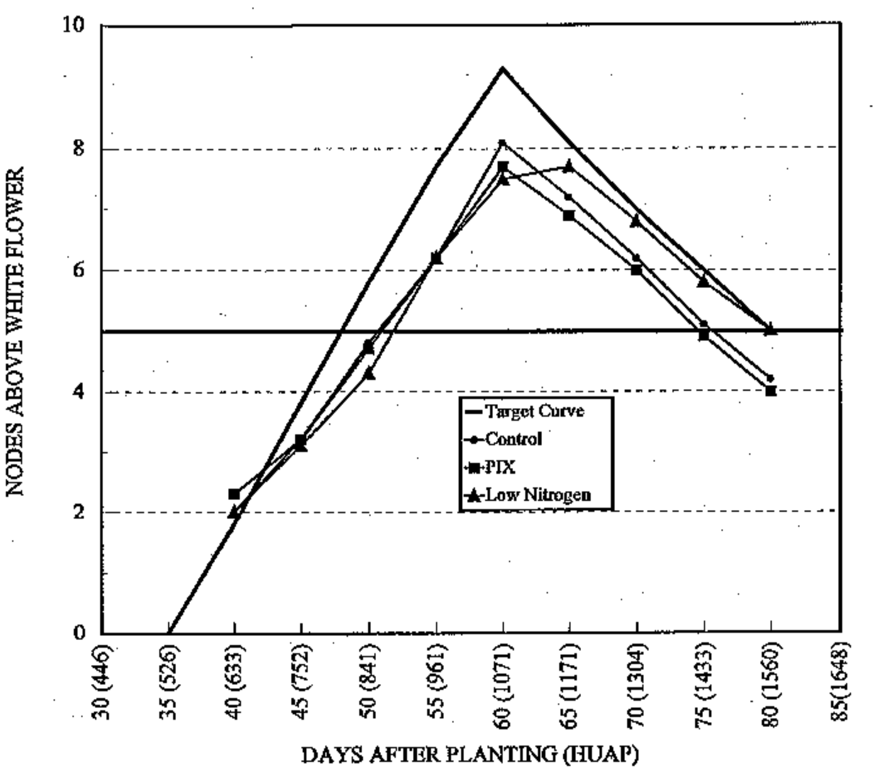

Fig. 1. Effect of PIX™ and low nitrogen treatments on the target development curve, Fayetteville 1998.

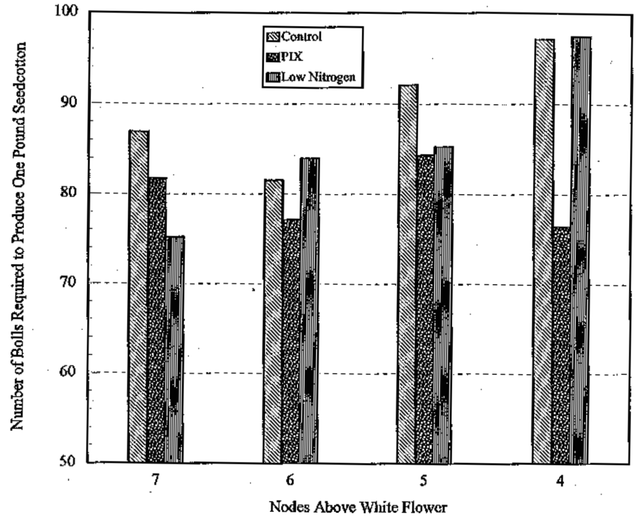

Fig. 2. The number of bolls required to produce 1 lb of seedcotton at nodes above white flower = 7, 6, 5, and 4. Fayetteville, 1998.

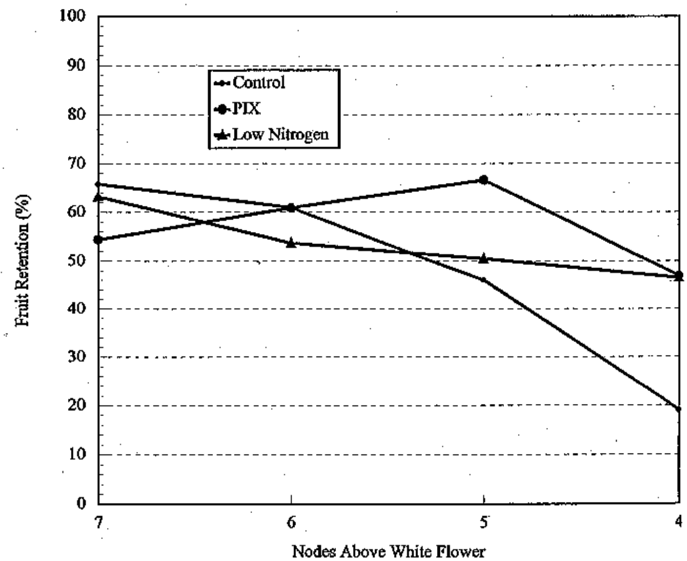

Fig. 3. Fruit retention at nodes above white flower = 7, 6, 5, and 4. Fayetteville, 1998.

EFFECT OF LATE-SEASON FRUIT REMOVAL AT NAWF=5 PLUS 350 HEAT UNITS ON COTTON YIELD AND QUALITY

Derrick M. Oosterhuis, Charles T. Allen, Fred M. Bourland, Robert S. Brown, and Michelle J. Kim[1]

RESEARCH PROBLEM

The crop monitoring program COTMAN uses the concept of 350 heat units after anthesis of the last effective flower population at NAWF=5 for termination of insecticide applications. It has been reported that terminating insecticides at 350 heat units after physiological cutout (five nodes above the upper most white fower [NAWF=5]) results in a higher yield than when terminating earlier or later than 350 heat units, although the evidence for this is lacking. It is hypothesized that insect damage to upper canopy (above NAWF=5) squares results in improved partitioning of carbon to lower developing bolls (Kim and Oosterhuis, 1998). The objective of this study was to investigate the effect of different times of upper canopy square removal after physiological cutout (NAWF=5) on subsequent boll weights at or below NAWF=5. The movement of carbohydrates from upper canopy leaves with squares removed to developing bolls lower in the plant was followed using a ^{14}carbon (^{14}C) labeling technique.

BACKGROUND INFORMATION

Cotton (Gossypium hirsutum L.) is a perennial with an indeterminate growth habit and will continue to produce fruit as long as the season persists. However, these late-formed bolls are often small in size, lower in fiber quality, costly to protect, and provide a food source for insects. In most crop monitoring programs, such as COTMAN (Danforth and O'Leary, 1998) a major aim is to identify the last effective boll population and project a date for insecticide termination (Oosterhuis *et al.*,1996). It has been shown that bollworm and boll weevil damage to cotton bolls decreases dramatically at about 350 heat unit accumulation after anthesis (Bagwell, 1995). This finding was supported by Kim (1998) who showed increased resistance of the boll wall to penetration at NAWF=5 plus 350 heat units associated with increased lignification and tannin concentration of the boll wall endocarp. This phenomenon is made use of in COTMAN for decisions about late-season termination of insecticide applications at 350 heat units after NAWF=5.

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RESEARCH DESCRIPTION

Three field studies and a ^{14}C labeling study were conducted to evaluate this hypothesis. Field experiments were conducted in Fayetteville, in 1996, and at Rohwer in southeastern Arkansas, and Clarkedale in northeastern Arkansas in 1998. Cotton cultivar 'Deltapine 20' was hand planted in early May each year. Rows were spaced 0.9 m apart in a north-south direction and plots were 4 rows wide and 5 m long with 10 plants per meter. All plots received fertilizer and pesticide applications following cotton production recommendations for Arkansas. The field studies were furrow irrigated as needed. The experiments were arranged in a randomized block design with four treatments and three replications. Treatments consisted of a control with no fruit removal, and a simulated upper canopy fruit damage (hand removal) of all upper canopy squares at approximately 250, 350, and 450 heat units after NAWF=5. Taggings of 50 white flowers per plot were made at the first fruiting position of the main-stem node at NAWF=5. At final harvest, the tagged bolls were harvested as well as the boll immediately below NAWF=5. Regrowth was also recorded.

In 1998, a growth chamber experiment was conducted in Fayetteville to study the effect of square removal on ^{14}C movement from upper canopy leaves with squares removed to developing bolls lower in the plant. The ^{14}C technique involved enclosing the selected upper canopy main-stem leaf in a plastic bag containing a septum and small vial of lactic acid. The source of ^{14}C ($NaH^{14}CO_3$) was injected into the lactic acid via the septum in the plastic bag and the resulting $^{14}CO_2$ fixed by the leaf. After 15 minutes, the leaf and bolls were removed, dried, combusted, and the ^{14}C fixation determined in a liquid scintillation counter.

RESULTS AND DISCUSSION

The Field Studies

In Fayetteville in 1996, square removal significantly increased the lint weight of the boll at NAWF=5, but not the total boll weight (Fig. 1). In 1998 at Rohwer, boll weight in the NAWF=5 plus 350 heat units square removal treatment was significantly ($P<0.05$) higher than the control. Furthermore, there was a trend for the 350 heat units treatment to have higher yields than the 250 or 450 heat units treatment, both of which were higher than the control (Fig. 2a). The pattern for boll weight for Clarkedale in 1998 was similar with the NAWF=5 plus 350 heat units treatment having the highest yields, although the other trends were not clear (Fig. 2b). In 1996 in Fayetteville, the weight of the boll immediately below the tagged node at NAWF=5 also showed a trend for a weight increase associated with upper canopy square removal, particularly at NAWF=5 plus 350 heat units (Kim, 1998). However, the pattern between treatments at the immediate node below NAWF=5 was unclear. The possible explanation is that when squares were removed, the immediate sink was removed. Therefore, the available carbohydrates from the upper canopy source leaves were translocated to alternative sinks such as the boll developing below the area of square removal. This was confirmed in the ^{14}C labeling study.

^{14}C Study

At 351 heat units after NAWF=5 there was a greater amount of ^{14}C translocated to the upper developing boll from the ^{14}C-labeled main-stem leaf than in the 240 or 467 heat unit treatments (Table 1). These results support those of the field study and our hypothesis that available carbohydrates from the upper canopy source leaves were translocated to alternative sinks such as bolls developing below the area of square removal. Boll weight at the node at NAWF=5 was again highest in the 310 heat unit treatment (Table 1).

PRACTICAL INFORMATION

Results indicate possible yield benefits of square removal (by insects) at about 350 heat units after physiological cutout (NAWF=5). This was related to the translocation of carbohydrates from upper canopy leaves with squares removed to alternative sinks such as the boll developing below the area of square removal. The data supports the COTMAN concept of insecticide termination at 350 heat units after NAWF=5.

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Table 1. Effect of upper canopy square removal on boll weight and translocation of ^{14}C from the labeled upper canopy main-stem leaf to the boll at the first fruiting position at NAWF=5. Growth chamber, 1998.

Treatment	Boll dry weight	^{14}C Translocated[z]
	(g)	(%)
240 Heat units[y]	3.3	1.8
351 Heat units	3.8	75.4
467 Heat units	2.8	44.4
$LSD_{(0.05)}$	0.91	63.2

[z] Calculated from leaf percent of leaf ^{14}C that moved to the boll.
[y] Squares removed by hand at 247 heat units at NAWF=5.

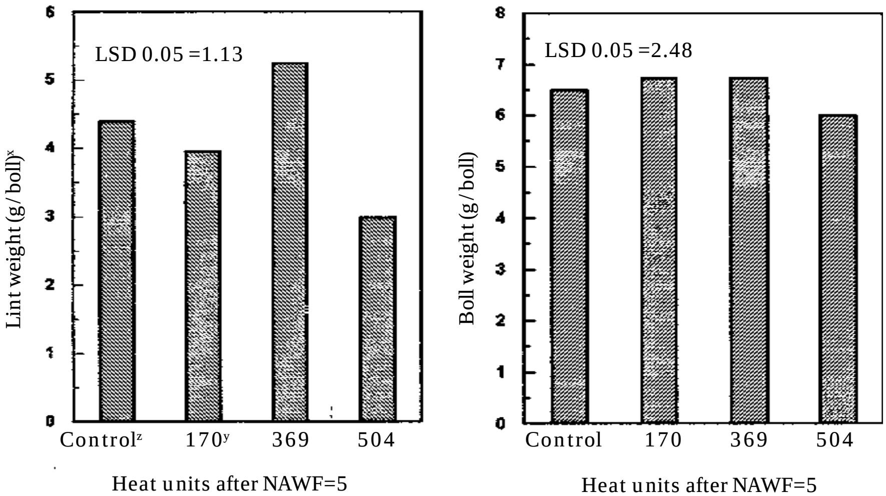
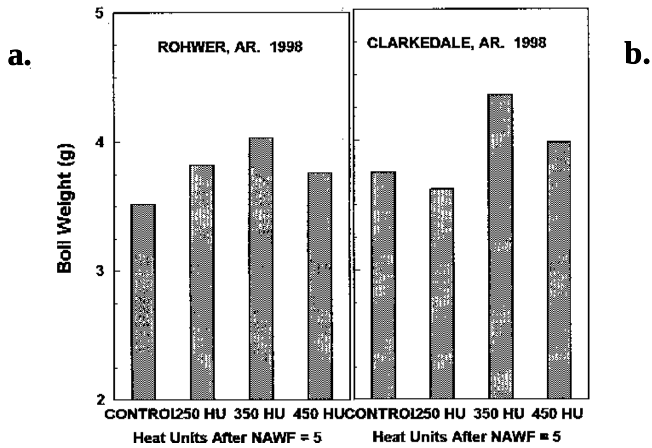


Fig. 1. Means of boll dry matter (upper canopy at NAWF=5, and immediately below NAWF=5) of regrowth after square removal above NAWF=5 at 170 heat units, 39 heat units, and 504 heat units post anthesis. Fayetteville, 1996.

[z] No square removal.
[y] Square removal on 23 August 1996 at 170 heat unit accumulation.
[x] Lint and boll weight were measured from samples from the first sympodial fruit position at the NAWF=5 main-stem node and at the node immediately below.



Figs. 2 a, b. Means of boll dry matter (upper canopy at NASW=5, and immediately below NAWF=5) of regrowth after square removal above NAWF-5 at 250, 350, and 450 heat units after NAWF=5. Rohwer and Clarkedale, 1998.

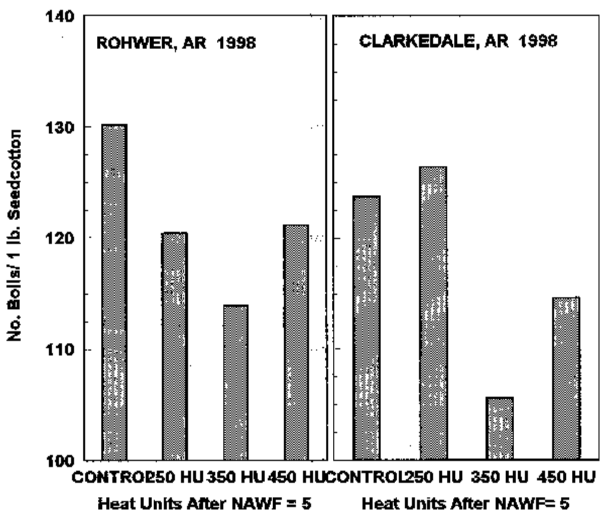


Fig. 3. The number of bolls required to make a pond of seed cotton when squares were removed at 250, 350, and 450 heat units after NAWF=5. Rohwer and Clarkedale, 1998.

A NEW METHOD OF ASSESSING PLANT STRESS USING THE RATIO OF THE CHANGE IN SQUARE SHEDDING TO NUMBER OF MAIN-STEM NODES

Derrick M. Oosterhuis, N. Philip Tugwell, Tina G. Teague, and Diana M. Danforth[1]

RESEARCH PROBLEM

Cotton (Gossypium hirsutum L.) is reputed to have the most complex growth habit of all major row crops. Furthermore, the plant has a very dynamic response to management and environmental stress. It is imperative to balance insect control and plant growth early in the season. Unfortunately, monitoring systems usually record one or the other, i.e., insect scouting or plant growth. It is obvious that these two are intimately related and should be monitored and evaluated together, especially in early season (prior to first flowers) when preconditions are set that can dictate plant response for the remainder of the growing season. A way of doing this is to follow the change in shedding (from insects mainly, if the crop is irrigated and well fertilized) in relation to changes in plant growth. We propose a unique method of assessing these variables using the change in the ratio of square shedding to increased number of main-stem nodes with sympodia between the last two sample dates. This research reports on a method of detecting stress early in order to allow timely management inputs.

BACKGROUND INFORMATION

COTMAN is a cotton crop information system that records changes in the fruiting dynamics of the cotton plant as well as plant growth parameters that are useful as a prompter of timely management decisions. The proposed new method of assessing stress uses the change in the ratio of square shedding to increased number of main-stem nodes (with sympodia) between the last two sample dates. This information is routinely recorded in the COTMAN where main-stem nodes with sympodia are referred to simply as squaring nodes and first position square shed rates are expressed rather than retention (Danforth and O'Leary, 1998).

RESEARCH DESCRIPTION

The cultivar 'SureGrow 125' was planted 11 May 1998 in a randomized split-split plot experiment with four replications at the University of Arkansas Cotton Branch

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Experiment Station in Marianna. Sub-sub plots were 4 rows wide and 33 ft long, bordered by two fallow rows. Cotton was grown according to extension recommendations. All plots were furrow-flood irrigated using alternate rows eight times at 45, 52, 59, 73, 80, 87, 93, and 106 days after planting.

Treatments consisted of simulated insect damage, three plant densities, and two plant growth regulators (PGRs). Plant monitoring information about plant growth patterns was collected from three plant stand densities, with and without first position square removal, and plant growth regulators (PIX or PGR-IV) under different levels of the *aggregate change in the Retention / Growth Balance (ARGB). RGB* is calculated using sampling data already taken in COTMAN.

The "aggregate Change in the Retention / Growth Balance (RGB)" is calculated as ARGB = (X2*Y2 - X1*Y1) / (X2-X1), where X1 and X2 are the number of squaring nodes at two consecutive sampling dates, and Y1 and Y2 are the square shed rate at two consecutive sampling dates.

The split-split plot experiment was designed to provide varying levels and types of plant stress. The main plot treatments consisted of first position square removal vs. no removal. One square per plant was hand removed 38 and 48 days after planting (DAP). The sub-plot treatments consisted of three levels of plant growth regulators; none, PGR-IV at 4 oz / acre, or Mepiquat Chloride (MC) at 7.6 oz / acre applied 43 and 53 DAP. Three plant population densities consisted of 10,778; 31,014; and 80,194 plants / acre hand thinned 18 days after planting. The plant growth regulators were applied in 10 gallons of water with a modified CO_2 backpack sprayer. COTMAN data collection on 40 plants per treatment began 15 June, 35 days after planting and continued through 86 days after planting. COTMAP data were collected just after defoliation. Final boll numbers and yield were recorded.

RESULTS AND DISCUSSION

Three types of COTMAN data with possible application in early-season decision-making were investigated: (1) plant growth curves, (2) physiological maturity (NAWF=5), and (3) the aggregate changes in the Retention Growth Balance (ARGB). The utility of each was evaluated as a decision aid.

Plant Growth Patterns and Maturity

The pattern of plant growth as measured by the number of squaring nodes for the three plant densities and compared to the *target development curve* are presented in Fig. 1. The patterns show clear evidence of stress due to plant density. By the second sampling date, it was obvious that the three plant types were developing more rapidly than the target curve. By the third sampling date, the growth pattern in the high stand density was beginning to slow down below target rates. An important note is that by detecting stress early we can exploit it with timely management decisions. The curves also clearly show that the higher stand densities matured a little quicker than the target curve. Maturity was affected as indicated by a shorter interval of time to NAWF=5 in the higher density treatments, i.e., 63, 73, and 81 days from planting to NAWF=5 or physiological cutout (for definition, see Oosterhuis *et al.*, 1996) for high, medium, and low stand densities, respectively (Fig. 1). Similarly as expected, MC treated plants matured earlier than the PGR-IV or untreated control (data not shown). Stand density and plant growth regulators significantly affected lint yields (Table 1). Yields were increased with increasing stand density. Mepiquat Chloride also significantly increased yields.

Square Shed

Fruit shed increased with increasing plant density and decreased slightly with plant growth regulators (data not shown) and this was reflected in final mean boll numbers per plant (Table 2). However, square removal had no effect on final boll numbers per plant due to compensation. There was a significant three-way interaction in relation to early fruiting (stand density, “insect damage,” and plant growth regulators).

Retention Growth Balance

The aggregate change in the *Retention Growth Balance*, calculated each time COTMAN data was collected, was sufficiently sensitive to show the square removal treatment. For example on 22 June the ARGB was 0.066 for no square removal (a single square per plant hand removed 38 and 48 DAP) and 0.375 for square removal, and on 1 July the difference was even larger, i.e., 0.028 and 0.429 for the control and square removal treatments, respectively (Table 3). This indicated that as squares were lost, stress was reduced, and plants grew larger vegetatively before more squares were set slowing growth. Plant growth regulator treatments were applied above and below an arbitrary RGB of 0.35 chosen based on previous experience. Mepiquat Chloride and PGR-IV were applied to determine the range of plant responses under defined conditions. This approach appeared to work well. Both height control (data not shown) and yield (Table 1) responses were apparent. The aggregate change in retention and growth was easily detected. Further research will be required to define the proper balance in retention and growth for different plant activities.

PRACTICAL INFORMATION

This research confirms the dynamic nature of cotton growth and response to management and environment. COTMAN fruiting curves compared to the *target development curve* show clear evidence of stress due to plant population density. It was also obvious that the cotton crop can tolerate a high rate of square shed (30% first positions in this case) without undue yield loss. The study also clearly demonstrated that the aggregate change in the Retention Growth Balance is a very sensitive indicator of change in plant stress and can be exploited in timely management decisions. A related report in this publication uses the same retention / growth balance relationship for early detection of stress for triggering irrigation (Teague *et al.*, 1999).

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Table 1. Effects of plant growth regulators and stand density on yield.

Treatment	Lint yield
	(lb/acre)
Stand density:	
low	856 b [z]
medium	1066 a
high	1107 a
Plant growth regulator:	
untreated	990 b
PGR-IV	996 ab
Mepiquat Chloride	1043 a

[z] Numbers followed by the same letter are not significantly different (*P* < 0.05).

Table 2. Effects of plant growth regulators, insect damage, and stand density on boll number per plant.

Treatment	Insect damage[z]	Plant population density: Low	Medium	High
		---------------- (bolls/plant)		--------------
Untreated	none	36	15	10
"	damaged	29	15	8
PGR-IV	none	38	15	7
"	damaged	40	15	9
Mepiquat Chloride	none	41	18	8
" "	damaged	38	17	9

[z] Insect damage was simulated by hand removal of squares.

Table 3. Measurement of loss of a single square per plant with the Retention Growth Balance (RGB).

Treatment	RGB values: 22 June	1 July
No square removal	0.066	0.028
Square removal[z]	0.375	0.429
LSD (0.05)	0.031	0.089

[z] Hand removal of one square per plant.

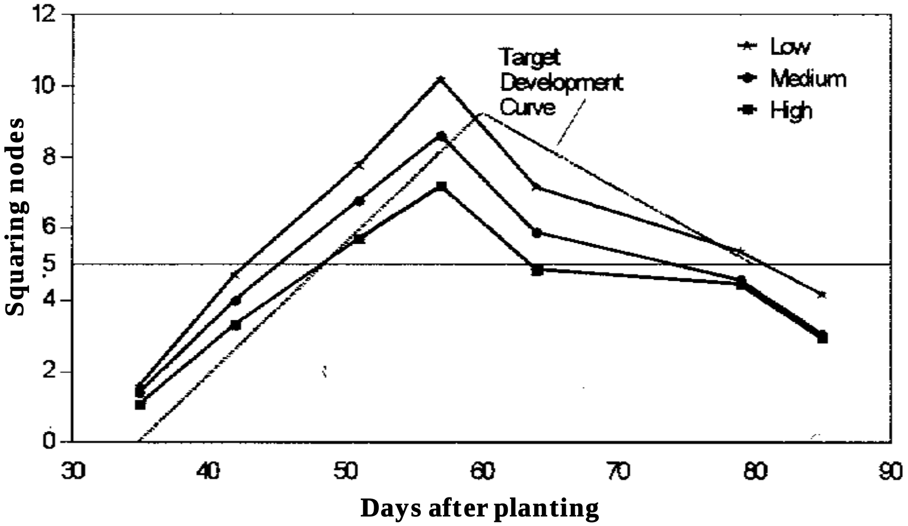

Fig. 1. Plant stress associated with low, medium, and high stand densities.

FIELD EVALUATION OF PLANT GROWTH REGULATORS

Derrick M. Oosterhuis and Duli Zhao[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) is perennial with an indeterminate growth habit that is very responsive to changes in the environment. The desire to manipulate plant growth, while maximizing yield, has led to interest in plant growth regulators (PGRs). In the past two decades, many new plant growth regulator (PGR) compounds have been developed and tested on field-grown crops. The objective of this study was to evaluate promising new and existing commercially available PGRs for effect on plant growth, maturity, and yield of field-grown cotton in Arkansas.

BACKGROUND INFORMATION

Field evaluation of available PGRs has been routinely conducted at the University of Arkansas for the past 15 years (e.g., Urwiler *et al.*, 1988; Oosterhuis and Janes, 1994; Oosterhuis *et al.*, 1996). Research has been directed towards (a) determining the effect of PGRs on growth and yield (Oosterhuis and Zhao, 1998), (b) investigating the physiological effects and underlying mechanisms of PGRs (Guo *et al.*, 1994), and (c) studying the effects of PGRs under stress conditions, i.e. drought, flooding or shade (Zhao and Oosterhuis, 1997; 1998). These studies promote our understanding of how individual PGRs work and assist with recommendations regarding the use of PGRs in current cotton production systems in Arkansas.

RESEARCH DESCRIPTION

A field experiment was planted into a Calloway silt loam soil at the Delta Branch Station in Clarkedale, on 6 May using the cotton cultivar 'Suregrow 125'. Treatments consisted of an untreated control, Early Harvest, PGR-IV, Mepiquat Chloride and MepPlus (renamed PIX Plus in 1995). Table 1 shows rates and timing of each treatment. Foliar spray applications were made with a CO_2 backpack sprayer calibrated to deliver 10 gallons solution / acre. The experimental design was a randomized complete block with six replications. Fertilizer, weed, and insect control measures were according to Cooperative Extension Service recommendations. Plots were furrow irrigated as needed throughout the growing season. Measurements were also made to understand the mode of action of these PGRs but the results are not reported here.

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RESULTS

Lint Yield

There was no significant increase in yield from any of the PGRs tested in 1997 and 1998 (Table 2). In 1997, Mepiquat Chloride significantly decreased yield. The effect of PGRs on lint yield from 1992 until 1997 was presented by Oosterhuis and Zhao (1998). Over the past seven years, these studies have shown a large year-to-year variability in growth and yield response with most PGRs performing inconsistently and showing little or, in the past two years, no significant increase in yield. Only PGR-IV and Mepiquat Chloride have shown reasonably consistent results. Over the past three years the PGRs tested have shown an effect on yield ranging from -1.2% to +1.5%. This is insignificant (i.e., a +1.5% increase on a two bale crop would only be about 14 lb lint/acre) and would not warrant the use of the PGRs tested for yield enhancement.

In-furrow Applications of PGRs at Planting

Generally, the use of PGRs such as Early Harvest and PGR-IV, as an in-furrow application at planting have not produced a yield increase at harvest. Earlier studies in the growthroom showed a positive enhancement of root growth and seedling development for PGR-IV either as a seed treatment or an in-furrow application. Results to date indicate that in-furrow applications of PGRs can enhance early seedling growth, but usually with no yield advantage at harvest.

Plant Height

Only the two growth retardants, Mepiquat Chloride and PIX Plus, consistently and significantly influenced (reduced) plant height (data not shown).

Maturity

Nodes above white flower measurements (NAWF) as an indication of physiological maturity showed that only the Mepiquat Chloride and PIX Plus treatments were significantly lower ($P<0.05$) than all other treatments at each sampling date. Plants in the Mepiquat Chloride and PIX Plus treatments reached physiological cutout (NAWF = 5) approximately a week earlier than the untreated control. However, there was not a clear trend towards early cutout or earlier maturity (open boll counts taken at the end of the growing season) between any other PGR and the control.

Mode of Action

Physiological measurements have also been made of the effects of PGRs on growth, dry matter production, and partitioning on photosynthesis, respiration, electrolyte leakage, carbohydrate status, and ^{14}Carbon (^{14}C) translocation from the leaf to the boll. The results of these studies help to understand the mode of action of the PGRs concerned but are not reported here.

PRACTICAL APPLICATION

The primary objective of this study was to evaluate and compare PGRs under field conditions for their effect on growth and yield. In 1997 and 1998, the PGRs tested did not increase yield. In 1997, Mepiquat Chloride significantly decreased yield. Generally, over the past seven years, our studies have shown a large year-to-year variability in growth and yield response with most PGRs performing inconsistently and showing little or no significant increase in yield. Over the past three years, the PGRs tested have only shown an effect on yield ranging from -1.2% to +1.5% which would not warrant the use of the PGRs tested for yield enhancement.

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Table 1. Treatments, rates, and timing of PGR applications in 1997 and 1998.

Treatment	Timing	Rate 1997	Rate 1998
Control	No PGRs added	----	----
Early Harvest	IF[z]	2 oz/acre	2 oz/acre
Early Harvest	PHS[y], FF[x]	4 oz/acre, 4 oz/acre	4 oz/acre, 4 oz/acre
PGR-IV	PHS, FF	4 oz/acre, 4 oz/acre	4 oz/acre, 4 oz/acre
Mepiquat Chloride	PHS, FF	8 oz/acre, 8 oz/acre	3 oz/acre, 6 oz/acre
PIX Plus[w]	PHS, FF	8 oz/acre, 8 oz/acre	3 oz/acre, 6 oz/acre

[z] IF = in-furrow at planting.
[y] PHS = pinhead square.
[x] FF = first flower.
[w] Formerly MepPlus

Table 2. Effects of PGR application on yield and yield components of cotton at Clarkedale from 1997 to 1998.

Treatment	Boll size 1997	Boll size 1998	Lint fraction 1997	Lint fraction 1998	Lint yield 1997	Lint yield 1998
	----- (g boll^{-1}) -----		------- (%) -------		---- (lb acre^{-1}) ----	
Control	4.7	4.2	38.3	37.5	1083	896
Mepiquat Chloride	5.1	4.1	36.9	37.9	981	907
PIX Plus[z]	5.3	4.1	37.0	37.6	1012	922
PGR-IV	4.6	4.1	38.5	37.5	1104	860
EH (In-furrow)	4.8	4.0	39.2	37.9	1077	905
EH (Foliar)	4.7	4.3	39.2	37.5	1116	901
$LSD_{(0.05)}$	0.3	NS[y]	0.8	NS	84	NS

[z] Formerly MepPlus.
[y] NS = not significant ($P < 0.05$).

EVALUATION OF PLANT GROWTH REGULATORS AS IN-FURROW APPLICATIONS TO ENHANCE COTTON GROWTH AND YIELD

Derrick M.Oosterhuis and Adele Steger[1]

RESEARCH PROBLEM

In the Mid-South, U.S. cotton (*Gossypium hirsutum* L.) is often planted into cool, wet soils that create unfavorable conditions for stand establishment and early-season growth. Various plant growth regulators (PGRs) have been proposed as suitable for enhancing emergence, seedling growth, and yield of cotton. However, in most cases the evidence for this is lacking.

BACKGROUND INFORMATION

The plant growth regulator PGR-IV (Microflo) has been shown to enhance root growth and seedling development in cotton in growth chamber environments (Oosterhuis and Zhao, 1994), but the evidence for any benefit in the field is lacking. With the PGR *Early Harvest* (Griffin Corporation), there is no clear evidence to substantiate claims of increased root growth and seedling development. Asset™ and Asset RTU™ (Helena Chemical Co.) are fertilizer additives with growth promoting capabilities. In growthroom studies Asset increased seedling emergence, number of lateral roots, plant height, and total leaf area. Field studies have been less conclusive and more variable with no yield advantages from Asset (Steger and Oosterhuis, 1997). The objective of this field study was to compare PGR-IV, Early Harvest, Asset, and Asset RTU for their effect on early seedling development and yield in cotton.

RESEARCH DESCRIPTION

In 1998, a field study was conducted at the Southeast Research and Extension Center, Rohwer Division, on a moderately well-drained Hebert silt loam. The cultivar 'Suregrow 125' was planted on 6 May in plots consisting of 4 rows spaced 38 in. apart and 30 ft in length. The trial was furrow irrigated as needed. The statistical design was a randomized complete block with six replications. Treatments were as follows: a control with no added plant growth regulator; Asset applied at 6 oz/acre; Asset RTU applied at 1 pt/acre; Early Harvest applied at 2 oz/acre; and PGR-IV applied at 2 oz/acre. All applications were applied in-furrow at planting with the spray equipment calibrated to deliver 5 gallons solution/acre. Stand counts were taken at 7, 9, and 12 days after

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planting to determine emergence rates among the treatments. Plant height and first fruiting branch were determined at pinhead square, and petioles from the uppermost fully-expanded leaves were sampled at pinhead square and first flower to determine nutrient concentrations. Final lint yield was determined by mechanically harvesting the center two rows of each plot at the end of the growing season.

RESULTS

Seedling Emergence

Seedling emergence was similar in all treatments at 7, 9, and 12 days after planting (Table 1) indicating that Asset, Early Harvest, and PGR-IV had no advantageous effect on emergence.

Plant Height and First Fruiting Branch

There were no significant differences in plant height and the main-stem node of the first fruiting branch among treatments at pinhead square (Table 2) indicating that the chemical treatments had no advantageous effect on shoot growth.

Petiole Nutrient Concentration

Petiole nutrient concentrations for nitrogen (N), phosphorus (P), and potassium (K) at both pinhead square and first flower are shown in Table 3. Nitrogen was significantly higher ($P<0.05$) in the Asset RTU treatment when compared with the Asset and the control treatment at pinhead square. The pattern was not clear at first flower although PGR-IV lowered the N concentration.

Lint Yield

Significant lint yield differences did not occur among the treatments (Table 4). This was possibly associated with severe mid-to late-season weather conditions in 1998.

PRACTICAL APPLICATION

The primary objective of this study was to provide field data evaluating the effect of applying PGRs (PGR-IV and Early Harvest), Asset or Asset RTU at planting on the early growth and yield of field-grown cotton. In 1998, there were no positive effects on emergence, seedling development, or yield from any of the chemicals applied.

LITERATURE CITED

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Table 1. Seedling emergence at 7, 9, and 12 days after planting (DAP), 1998.

Treatments	7 DAP	9 DAP	12 DAP
	(number of plants/30 row ft)		
Control	13	14	13
Asset	13	14	13
Asset RTU	12	13	13
Early Harvest	11	14	14
PGR-IV	12	13	13
LSD (0.05)	NS[z]	NS	NS

[z] NS = not significant ($P < 0.05$).

Table 2. Plant height and first fruiting branch at pinhead square, 1998.

Treatments	Plant height	First fruiting branch
	(cm)	(main-stem node #)
Control	9.7	5.4
Asset	9.9	5.4
Asset RTU	9.4	5.4
Early Harvest	9.5	5.3
PGR-IV	9.4	5.3
LSD (0.05)	NS[z]	NS

[z] NS = not significant ($P < 0.05$).

Table 3. Petiole nutrient concentrations at pinhead square and first flower, 1998.

Treatments	Pinhead square			First flower		
	N	P	K	N	P	K
	---------- (ppm) ----------		(%)	-------- (ppm) --------		(%)
Control	15101 b[z]	2656	6.4	5869 a	2872	5.5
Asset	15199 b	2737	6.3	3633 ab	2945	5.7
Asset RTU	19616 a	2659	6.5	4973 ab	2873	6.0
Early Harvest	15574 ab	2644	6.6	3672 ab	2831	5.6
PGR-IV	15473 ab	2571	6.7	3387 b	2977	5.7
LSD (0.05)	4168	NS	NS	2284	NS	NS

[z] Numbers followed by the same letter within a column are not significantly different ($P < 0.05$) from the control.

Table 4. Effect of chemical treatments at planting on lint yield, Rohwer, 1998.

Treatment	Lint yield
	(lb lint/acre)
Control	1211
Asset	1117
Asset RTU	1092
Early Harvest	1172
PGR-IV	1162
LSD (0.05)	148 (NS)[z]

[z] NS = not signficant ($P < 0.05$).

COMPARISON OF COTTON YIELD RESPONSES TO MEPPLUS AND PIX™

Duli Zhao and Derrick M.Oosterhuis[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) is a perennial crop with an indeterminate growth habit and is very responsive to environmental changes and management. Consequently, producers and researchers have long been interested in the use of plant growth regulators (PGRs) for adjusting plant vegetative and reproductive growth and improving cotton yield. Mepiquat Chloride (PIX™) has been the most widely used PGR in U.S. cotton production to control plant size. The yield benefit from PIX varied with years and locations.

BACKGROUND INFORMATION

MepPlus is a new PGR from Micro Flo Company (Lakeland, Florida). It consists of Mepiquat Chloride (MC) and the bacteria *Bacillus cereus*. In 1999, MepPlus was renamed PIX Plus and marketed by the BASF Corporation. Recent studies have indicated that applying MepPlus had a similar effect on plant height control as applying PIX. Additionally, MepPlus has been reported to improve leaf photosynthesis (Wells, 1997), dry matter partitioning (Oosterhuis *et al*., 1998), and lint yield (Parvin and Atkins, 1997; Wells, 1997) of field-grown cotton compared with both untreated control and PIX-treated plants. Field studies were conducted at the two locations in Arkansas in 1997 and 1998 in order to compare MepPlus with PIX for effects on and lint yield and yield components of field-grown cotton.

RESEARCH DESCRIPTION

Field trials were conducted at the two locations: Clarkedale and Fayetteville, in 1997 and 1998. At Clarkedale, the cotton cultivar 'Suregrow 125' was seeded on 7 May 1997 and 1998 at the Delta Branch Experiment Station. Rows were spaced 38 in. apart and oriented in a north to south direction. Each plot consisted of 4 rows, 50 ft in length.

At Fayetteville, cotton cultivars 'DPL 20' (1997) or Suregrow 125 (1998) were planted on 19 May 1997 and 15 May 1998, respectively, at the Arkansas Agricultural Experiment Station. Plots consisted of 4 rows, 16.5 ft in length, spaced 39 in. apart with 3 plants ft^{-1} row. Weeds and insect control, fertilizer management, and furrow irrigation were applied as needed according to Arkansas cotton production recommen-

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dations.

At both locations three treatments were used consisting of (1) an untreated control, (2) MepPlus, and (3) PIX. The timing and rate of applying PGRs at the two locations in 1997 and 1998 are given in Table 1. The PGRs were applied in 10 gallons of water acre^{-1} using a CO_2-pressurized backpack sprayer. Experiments were arranged in a randomized complete block design with six replications.

Plant height, the number of main-stem nodes, and the nodes above white flower (NAWF) of different treatments were recorded during the growing season. Before harvesting, distributions of bolls in the plant canopy were investigated using a plant mapping computer program. All bolls in 1 m of the middle row of each plot were harvested by hand, weighed, and ginned to determine seedcotton weight per boll (boll weight) and lint percentage. A mechanical picker was used to harvest the middle two rows of each plot at Clarkedale. All bolls from 2 m of the center rows in each plot were collected by hand in Fayetteville for seedcotton estimations. Lint yield was calculated according to seedcotton weight and lint percentage. The fiber quality (HVI) was also determined.

RESULTS

Plant Growth

Plants receiving MepPlus and PIX were significantly shorter than untreated control plants three (1997) or six weeks (1998) after the PGRs were first applied. However, there were no significant differences between MepPlus and PIX. The number of main-stem nodes did not differ among treatments including MepPlus and MC (data not shown). Therefore, the height / node ratios were similar for both PGR treated plants and much smaller than the control. Decreased plant height was mainly due to the shorter internode length rather than the decreased number of main-stem nodes.

Accumulation and Partitioning of Dry Matter

Plant growth analysis at 90 DAP indicated that there were no significant differences in the number of bolls and leaf area index among treatments, although MepPlus and PIX treatments had a numerically lower leaf area index than the control (data not shown). Among the three treatments, no significant differences were observed in total dry weight and fruit dry weight, although the dry weights of stems and leaves for both PGR-treated plants were lower than the control. The fraction of fruit dry weight in total dry matter of the MepPlus treatment (41%) was significantly higher than that of both the control (33%) and the PIX treatment (34%) (Oosterhuis *et al.*, 1998). This indicated that applying MepPlus improved partitioning of dry matter in plants compared to PIX and the untreated control, and more assimilate was translocated into the fruits (squares and bolls) of MepPlus-treated plants.

Yield and Yield Components

In 1997 at Clarkedale, lint yield of the PIX treatment was significantly decreased compared to the control, and the MepPlus treatment was numerically but not significantly lower than the untreated control (Table 2). In 1998, lint yields of MepPlus and PIX treatments were increased by 49 and 11 lb / acre, respectively, than the untreated control although the differences were not statistically significant.

At Fayetteville, MepPlus treatment showed the highest, and PIX the lowest lint yield among the three treatments in 1997 (Table 3). In 1998, the MepPlus treatment had a significantly higher lint yield (18%) than the control. MepPlus treatments yielded 35 to 55 (in 1997) or 38 to 112 (in 1998) lb lint / acre more than PIX treatments in the two locations.

Of the three yield components, MepPlus and PIX applications increased the average boll weight, decreased lint percentage, and did not affect the number of bolls in 1997 (Table 2). In 1998, the yield components did not differ among treatments.

Fiber Quality

Both PGRs did not affect fiber quality parameters measured except for fiber length (Table 3). Application of MepPlus and MC increased fiber length, especially the 2.5% span length.

PRACTICAL APPLICATION

Similar to PIX, application of MepPlus can significantly control plant height, but had no effect on the number of main-stem nodes. MepPlus more efficiently improved assimilate partitioning between vegetative and reproductive organs, and resulted in significantly more dry matter being partitioned into fruits compared to both the untreated control and PIX (Oosterhuis *et al.*, 1998). In 1997, lint yield was not significantly different between the two PGR treatments. MepPlus treatments yielded a 60 lb / acre higher lint yield than PIX treatments and a 40 lb / acre higher yield than the untreated control averaged over both locations for two years although some increases in yields were not statistically significant ($P < 0.05$). Therefore, MepPlus may have the potential to replace PIX in U.S. cotton production.

LITERATURE CITED

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Table 1. The timing and rate of MepPlus and PIX treatments at two locations, Clarkedale and Fayetteville, in 1997 and 1998.

Treatment	1997	1998
Clarkedale		
Control	—[z]	---
MepPlus	4 oz./A at ES[y], ES+9 d, FF, and FF+9 d	3 oz./A at ES & 6 oz./A at FF
PIX	4 oz./A at ES, ES+9 d, FF, and FF+9 d	3 oz./A at ES & 6 oz./A at FF
Fayetteville		
Control	---	---
MepPlus	8 oz./A at ES and FF	4 oz./A at ES & 8 oz./A at FF
PIX	8 oz./A at ES and FF	4 oz./A at ES & 8 oz./A at FF

[z] Without MepPlus and MC.
[y] ES = early square stage; FF = first flower stage. In this study, the ES and FF stages are defined as 50% of plants in the field having a square and a white flower, respectively.

Table 2. Effect of MepPlus and PIX application on lint yield and yield components of field-grown cotton at Clarkedale.

Treatment	Boll wt.	Boll no.	Ginning turnout	Lint yield
	($g/boll^{-1}$)	($no./m^{-2}$)	(%)	($lb/acre^{-1}$)
1997				
Control	5.1 b[z]	78 a	39.8 a	1242 a
MepPlus	5.8 a	73 a	38.4 b	1160 ab
PIX	5.6 a	74 a	38.3 b	1125 b
1998				
Control	4.2 a	76 a	37.5 a	896 a
MepPlus	4.3 a	79 a	38.2 a	945 a
PIX	4.1 a	77 a	37.9 a	907 a

[z] Means with the same letter within a column and within a year are not significant ($P < 0.05$).

Table 3. Effect of MepPlus and PIX application on lint yield and yield components of field-grown cotton at Fayetteville.

Treatment	Boll wt.	Boll no.	Ginning turnout	Lint yield
	(g/boll^{-1})	(no./m^{-2})	(%)	(lb/acre^{-1})
1997				
Control	4.2 b[z]	77 a	39.0 a	1110 a
MepPlus	4.4 a	77 a	38.9 a	1133 a
PIX	4.1 b	79 a	37.3 b	1078 a
1998				
Control	4.3 b	83 a	37.0 a	1012 b
MepPlus	4.8 a	82 a	38.9 a	1181 a
PIX	4.6 a	80 a	38.0 a	1069 ab

[z] Means with the same letter within a column and within a year are not significant ($P < 0.05$).

Table 4. Effect of MepPlus and PIX application on fiber quality: micronaire (MIC), length (UHM), uniformity index (UI), strength (ST), and elongation (EL) at Clarkedale.

Treatment	MIC	UHM	UI	ST	EL
		(in.)	(%)	(g tax^{-1})	(%)
1997					
Control	4.48 a[z]	1.18 b	83.7 a	29.7 a	6.78 a
MepPlus	4.55 a	1.21 a	84.3 a	29.7 a	6.63 a
PIX	4.51 a	1.22 a	83.9 a	30.0 a	6.65 a
1998					
Control	4.25 a	1.12 b	83.3 a	26.9 a	7.98 a
MepPlus	4.18 a	1.18 a	84.1 a	26.0 a	7.83 a
PIX	4.37 a	1.17 ab	83.7 a	26.4 a	7.93 a

[z] Means with the same letter within a column are not significant ($P < 0.05$).

COTTON RESPONSE TO IN-FURROW APPLICATION OF AMISORB, ASSET, AND PGR-IV

William C. Robertson, Andy Vangilder, Blair Griffin, and Steve Rodery[1]

RESEARCH PROBLEM

Starter fertilizers are commonly used in many crops. Products such as AmiSorb, a nutrient absorption enhancer (AmiLar Int.); Asset™, a fertilizer additive (Helena); and PGR-IV a plant growth regulator (MicroFlo), when added to starter fertilizers, have the potential to increase lint yield by improving early-season plant growth. The objective of this study was to evaluate the yield response of cotton to in-furrow starter fertilizer (11-37-0) containing AmiSorb, Asset, or PGR-IV.

BACKGROUND INFORMATION

Demand for data by producers concerning AmiSorb and Asset is great. However, field testing of AmiSorb and Asset is limited. Field research conducted in Arkansas indicated that emergence at 6 and 11 days after planting (DAP) was not enhanced by AmiSorb, Asset, or PGR-IV when compared to other PGRs (Steger and Oosterhuis, 1997). These authors reported no significant differences among treatments for plant height or number of main-stem nodes 28 DAP. However, starter fertilizers were not used in their study. Additional field information regarding the use of these products with a starter fertilizer (11-37-0) is needed.

RESEARCH DESCRIPTION

A study consisting of five treatments in 1997 and six treatments in 1998 was conducted to evaluate AmiSorb, Asset, and PGR-IV (Table 1). These studies were conducted at three locations in eastern Arkansas in producer fields (Table 2). Producers managed all other inputs according to their established production strategies. A once-over harvest using the producer's picker was used. The entire length of the plot was picked and weighed in boll buggies equipped with load cells. Lint fraction was determined by ginning grab-samples on a laboratory gin.

RESULTS

Emergence differed in Desha County in 1997 and 1998 (Tables 3 and 4). In 1997, emergence in the untreated control (UTC) exceeded all other treatments with the ex-

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[1] Extension Agronomist - Cotton; Clay County Extension Agent; Desha County Extension Agent; and Crittenden County Extension Agent.

ception of 11-37-0 + Asset. No other treatments differed statistically ($P < 0.05$). In 1998, emergence of 11-37-0 + Asset was exceeded by all other treatments including the UTC. Lint yield was not influenced by in-furrow treatments (Tables 3 and 4).

PRACTICAL APPLICATION

In-furrow treatments used alone or in combination with a starter fertilizer (11-37-0) did not enhance emergence or lint yield compared to that of the UTC in these studies. Other sources or methods of applying starter fertilizers should be evaluated. More field testing is needed to better evaluate how Asset and AmiSorb may best be used.

LITERATURE CITED

Steger, A. and D.M. Oosterhuis. 1997. Seed treatment with plant growth regulators to enhance emergence and seedling growth. p. 1396. *In*: National Cotton Council, Memphis, Tennessee.

Table 1. Field location, producer, and variety tested in 1997 and 1998 demonstrations.

Demo	County	Producer	Year	Variety
1	Clay	Mike Morgan	1997	ST 474
2	Clay	Mike Morgan	1998	DP 5111
3	Crittenden	John Morrison	1997	SG 125
4	Crittenden	Mack Ray	1998	ST BXN47
5	Desha	Steve Stevens	1997	SG 501
6	Desha	Steve Stevens	1998	DP 32B

Table 2. Treatment combinations and rates of in-furrow products used in 1997 and 1998 demonstrations.

Treatment	Rates[z]	1997	1998
	(product/acre)		
UTC	–	x	x
11-37-0	1.5 gal	x	x
11-37-0 + Asset	1.5 gal + 5.3 oz	x	x
11-37-0 + AmiSorb	1.5 gal + 2.0 qt	x	–[y]
AmiSorb	2.0 qt	-–	x
11-37-0 + PGR-IV	1.5 gal + 2.0 oz	x	x
PGR-IV	2.0 oz	-–	x

[z] Applied in a volume of 3 gal/acre.
[y] Treatment not included.

Table 3. LSD 0.05 values for emergence and lint yield in 1997 and 1998 demonstrations.

	Clay		Crittenden		Desha		Mean	
Parameter	97	98	97	98	97	98	97	98
Emergence	NS[z]	NS	NS	NS	17.4	4.7	NS	NS
Lint yield	NS	NS	NS	NS	NS	NS	NS	NS

[z] NS = non significant ($P < 0.05$).

Table 4. Emergence and lint yields in 1997 and 1998 demonstrations.

	Emergence		Lint yield	
Treatment	1997	1998	1997	1998
	(# of plants/14 row ft)		------ (lb/acre) ------	
UTC	72	47	1277	814
11-37-0	58	46	1235	830
11-37-0 + Asset	61	41	1224	805
11-37-0 + AmiSorb	58	–[z]	1238	–
AmiSorb	–	45	–	795
11-37-0 + PGR-IV	67	44	1237	787
PGR-IV	–	47	–	818

[z] Treatment not included.

COTTON YIELD RESPONSE TO MEPPLUS AND MEPIQUAT CHLORIDE

William C. Robertson, April Fisher, Keith Martin, Margy Cannon, and Jeff Jones[1]

RESEARCH PROBLEM

Plant growth regulator (PGR) use of compounds containing Mepiquat Chloride (MC) such as PIX (BASF), Mepichlor (MicroFlo), and Mepex (Griffin) to control plant height is widespread. A new product, MepPlus, which contains MC and *Bacillus cereus* became commercially available in 1998. Comparisons between MepPlus and MC outside of small plot research is limited in Arkansas (Oosterhuis *et al.*, 1998; Robertson, 1998). The objective of this study was to compare MepPlus and MC in actual production situations.

BACKGROUND INFORMATION

MepPlus is promoted as an improved formulation of MC (Parvin and Atkins, 1997). Small plot studies in 1996 and 1997 in central Arkansas revealed trends for improvements in lint yields ranging from 5 to 9% with MepPlus compared to MC (Oosterhuis *et al.*, 1998; Robertson, 1998). Preliminary research suggest MepPlus possesses the following advantages over MC: 1) similar height control, 2) less impact on node development, 3) blockier plant structure, and 4) higher yields.

RESEARCH DESCRIPTION

MepPlus and MC were evaluated in production fields using producer established rates and timings at various locations in eastern Arkansas (Table 1). The experimental design was a randomized complete block design with plots running the entire length of the field. Producers managed all other inputs according to their established production strategies. A once-over harvest using the producer's picker was used. The entire length of the plot was harvested and weighed in a boll buggy equipped with load cells. Lint fraction was determined from ginning grab-samples on a laboratory gin.

RESULTS

Height control was very similar for MepPlus and MC (data not shown). Appearance late season varied from a distinct blockier appearance for MepPlus at some locations to no visual differences between treatments at others. No visual differences be-

[1] Extension Agronomist - Cotton; Jefferson County Extension Agent - Agriculture; Mississippi County Extension Agent - Staff Chairman; St. Francis County Extension Agent - Staff Chairman; and Seasonal Agricultural Technician, Cooperative Extension Service.

tween treatments were observed at harvest. Visual observations regarding maturity or ease of defoliation did not reveal difference between the two treatments. Significant yield differences were not observed ($P < 0.05$). However, MC-treated plots numerically out-yielded MepPlus treatments at four of the five locations for an average of 42 lb lint / acre (Table 2). Lint fraction differences were not observed.

PRACTICAL APPLICATION

The benefits of height control, earliness, or other responses often observed with the use of MC or MepPlus compared to an untreated control were not addressed in this study. However, no differences in maturity, defoliation, or lint fraction were observed between MepPlus and MC. Despite trends of increased lint yield for MepPlus compared to MC in small plots, demonstrations in 1998 using producers' set rates and timings reveal little benefit of MepPlus to that of MC.

LITERATURE CITED

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Table 1. Field location, producer, variety, and plant growth regulator usage in 1998 demonstrations.

Demo	County	Producer	Variety	# of Applications	Total rate (oz/acre)
1	Desha	Steve Stevens	SG 501	3	37
2	Jefferson	Mike Bryant	DP 50B	4	33
3	Jefferson	Mike Bryant	ST 373	3	28
4	Mississippi	Lowry Robinson	ST BXN47	3	26
5	St. Francis	Joe Whittenton	ST 474	3	36

Table 2. Lint yield from treatments in 1998 demonstrations.

	Demonstration					
Treatment	1[z]	2	3	4	5	Mean
MepPlus	987	989	996	825	1125	985
MC	1062	1092	1005	812	1139	1027
LSD 0.05	NS	NS	NS	NS	NS	NS

[z] For details see Table 1.

COTTON YIELD RESPONSE TO MIDBLOOM APPLICATIONS OF PGR-IV

William C. Robertson, Gus Lorenz, Kenneth R. Williams, Steve Rodery, April Fisher, and Blair Griffin[1]

RESEARCH PROBLEM

Plant growth regulators (PGRs) are widely used in cotton to control growth and enhance yield. Research indicates that mid- to late-flowering applications of PGR-IV have the potential to enhance maturity and yield (Oosterhuis *et al.*, 1997). The objective of this replicated field study was to evaluate the yield response of cotton treated with PGR-IV during the third or fourth week of flowering.

BACKGROUND INFORMATION

Field observations in a production field in southeast Arkansas in 1994 with late applications of 4 oz/acre of PGR-IV applied four weeks after flowering have shown enhanced boll opening and increased yield. Subsequent field plot research in Arkansas has indicated the potential of using PGR-IV during late-flowering to enhance yield. In five field studies conducted from 1994 to 1996, yield response ranged from an increase of 107 lb lint/acre to decrease of 11 lb lint/acre at 3 to 4 weeks after first flower (Oosterhuis *et al.*, 1997). Although yield responses were positive in four of five studies, yields did not differ statistically ($P < 0.05$) from that of the control.

RESEARCH DESCRIPTION

A PGR-IV application made during the third to fourth week of flowering was evaluated at various locations in eastern Arkansas in 1997 and 1998 (Table 1). The experimental design was a randomized complete block with plots running the entire length of the field. PGR-IV was applied at 6.0 oz product/acre during the third to fourth week of flowering in fields that received no other PGR-IV applications. Producers managed all other inputs according to their established production strategies. A once-over harvest using the producer's picker was used. The entire length of the plot was picked and weighed in a boll buggy equipped with load cells. Lint fraction was determined from ginning grab-samples on a laboratory gin.

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[1] Extension Agronomist - Cotton; Extension IPM Coordinator; Ashley County Extension Agent - Staff Chairman; Crittenden County Extension Agent; Jefferson County Extension Agent; and Desha County Extension Agent.

RESULTS

Lint yields were not improved statistically with mid- to late-bloom applications of PGR-IV (Table 2). A numerical yield increase was observed in one location of three in each year of the study. However, a statistical yield decrease was only observed in Jefferson County in 1997.

PRACTICAL APPLICATION

Although results varied, research in Arkansas and results from these demonstrations failed to produce significant positive yield responses compared to untreated plots. As a result of inconsistent responses, further studies are needed before PGR-IV use at the third to fourth week of flowering can be recommended by the Cooperative Extension Service.

LITERATURE CITED

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Table 1. Field location, producer, and variety tested in 1997 and 1998 demonstrations.

Demo	County	Producer	Year	Variety
1	Ashley	James Crossley	1998	ST 373
2	Crittenden	John Morrison	1997	SG 125
3	Crittenden	Mack Ray	1998	ST BXN47
4	Desha	Steve Stevens	1997	SG 501
5	Jefferson	Mike Bryant	1997	SG 125
6	Jefferson	Mike Bryant	1998	DP 50B

Table 2. Lint yield from 1997 and 1998 PGR-IV (6.0 oz/acre 3-4 wk of flower) midbloom demonstrations.

	1997				1998				Overall
	2[z]	4	5	Mean	1	3	6	Mean	mean
	(lb/acre)								
UTC	1169	1376	1292	1310	1095	770	840	913	1112
PGR-IV	1270	1362	1249	1301	1066	764	865	911	1106
LSD 0.05	NS[y]	NS	21	NS	NS	NS	NS	NS	NS

[z] For details see Table 1.
[y] NS = non significant ($P < 0.05$).

COTTON HARVEST AID TRIALS IN ARKANSAS

William C. Robertson, Jeff Jones, and Paul S. Ballantyne[1]

RESEARCH PROBLEM

New harvest aid products have been developed and marketed in Arkansas in recent years. It is common practice to tank-mix harvest aid products, particularly defoliants and boll openers. The objective of this study was to evaluate new and old harvest aid compounds containing defoliants and boll openers under irrigated field conditions.

BACKGROUND INFORMATION

As new harvest aid products are developed, information about how they perform alone and in tank-mix combinations with other products is needed. Many of the new products have defoliation and boll opening properties. In order to compare products and combinations on a more equal basis, all treatments contained a boll opening component.

RESEARCH DESCRIPTION

A uniform study containing 12 treatments was conducted at three locations in eastern Arkansas (Table 1). Harvest aids were applied with a self-propelled high clearance sprayer calibrated to deliver 13 gal/acre. The three sites were similar and averaged 4.0 nodes above cracked boll, 45% open, and 30% defoliated at initial treatment. Visual ratings for defoliation, desiccation, open bolls, and overall performance were recorded.

RESULTS

The farmer standard Def+Dropp+Prep resulted in the greatest defoliation (Table 2). CottonQuik+Dropp performed similarly to Def+Dropp+Prep (90% defoliation). However, CottonQuik+Def did not produce satisfactory results with such a low rate of Def in the tank-mix (77% defoliation). Dropp Ultra when substituted for Dropp in Def+Dropp+Prep gave slightly better regrowth inhibition but slightly less defoliation (95 % vs. 90% regrowth inhibition and 88% vs. 92% defoliation, respectively). The Ginstar tank-mix was slightly behind the Dropp Ultra tank-mix (86% vs. 88% defoliation). Finish with Def performed well; however, the addition of Roundup Ultra to this combination appeared to reduce defoliation activity (88% vs. 86% defolition). Harvade performance (Harvade+Dropp+Prep) was adequate, but was not as effective as the

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Def+Dropp+Prep tank-mix (87% vs. 92% defoliation). The old standby, Def+Prep (83% defoliation) was not as efficacious as other mixtures.

PRACTICAL APPLICATION

Many of the newer products, such as Finish, CottonQuik, and Ginstar, appear to fit into many of our existing harvest aid programs. Environmental conditions and the status of the crop can have a significant impact on the efficacy of some products. Defoliation is sometimes described as more art than science; however, these ratings may offer insight into the efficacy of new products compared to industry standards.

Table 1. Harvest aid compounds and rates evaluated in 1998.

Abbreviation	Product and rate
	(product/acre)
CQDf	CottonQuick 1.75 qt + Def 5.0 oz
CQDp	CottonQuick 1.75 qt + Dropp 0.06 lb
DfPr	Def 1.0 pt + Prep 1.33 pt
DfPrRU	Def 1.0 pt + Prep 1.33 t + Roundup Ultra 1.5 pt
DfDpPr	Def 0.75 pt + Dropp 0.1 lb + Prep 1.33 qt
DfDUPr	Def 0.75 pt + Droop Ultra 0.1 lb + Prep 1.33 pt
DfGSPr	Def 0.75 pt + Ginstar 4.0 oz + Prep 1.33 pt
GSPr	Ginstar 8.0 oz + Prep 1.33 pt
FiDf	Finish 1.0 qt + Def 6.0 oz
FiDfRU	Finish 1.0 qt + Def 6.0 oz + Roundup Ultra 1.5 pt
HaDpPr	Harvade 8.0 oz + Drop 0.1 lb + Prep 1.33 pt + COC 1.0 pt
HaGSPr	Harvade 8.0 oz + Ginstar 4.0 oz + Prep 1.33 + COC 1.0 pt

Table 2. Performance of harvest aid treatments in 1998 (mean of three locations).

Treatment	Defoliation (14 DAT)	Performance rating (14 DAT)	Terminal regrowth (21 DAT)
		(%)	(%)
DfDpPr	92	90	10
CQDp	90	88	22
DfDUPr	88	87	5
FiDf	88	74	68
DfGSPr	87	84	20
HaGSPr	87	91	23
HaDpPr	87	89	22
FiDfRU	86	83	45
GSPr	86	84	27
DfPrRu	84	76	48
DfPr	83	70	72
CQDf	77	69	92

FINISH PERFORMANCE IN NORTHEAST ARKANSAS

Earl D. Vories and Robert E. Glover[1]

RESEARCH PROBLEM

Most years the cotton (*Gossypium hirsutum* L.) crop in northeast Arkansas will need both defoliation and boll opening in preparation for harvest. The objective of this study was to observe the effectiveness of the Rhone Poulenc product Finish (cyclanilide + ethephon).

RESEARCH DESCRIPTION

The cultivar 'Suregrow 125' was planted 19 May on Sharkey silty clay. University of Arkansas Cooperative Extension Service recommendations were followed for fertility, weed, and insect control. The crop was irrigated once in late June. Plots were four 38-in. rows wide by 50 ft long. Observations were made from the two center rows. Treatments were applied with a backpack sprayer. The total spray volume was 19 gpa, with two nozzles per row at 40 psi. Table 1 shows the treatments employed. The study was designed as randomized complete blocks with four replications.

The test was initiated 14 September when boll counts indicated approximately 30% open bolls and 6 nodes above cracked boll. Subjective observations of the percentages of leaves removed from the plant and bolls sufficiently open for mechanical harvest were made for each plot. Ratings were made the day before treatment and three times after the initial treatment. In addition to the Fisher's least significant difference (LSD), linear contrasts were used to compare "Groups," representing the three Finish combinations (i.e., Finish alone, Finish followed by [fb] Folex and Finish + Folex) averaged over the three rates (Table 1).

RESULTS

No significant treatment effect was observed for percent defoliation (average of 33%) or for percent open bolls (average of 32%) before treatment, indicating no bias. No significant treatment effect was observed for percent open bolls (average of 41%) on the first observation after treatment (3 days after initial treatment - DAIT). Significant differences in percent defoliation were observed, with all treated plots significantly more defoliated than the untreated check. Defoliation among the treated plots ranged from 62% to 72% with no obvious trend to the data. Although there was a

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significant Groups effect, there was not a clear differentiation among the groups (Fig. 1). Significant differences in percent defoliation and percent open bolls were observed at 8 DAIT. For defoliation, all treated plots were significantly more defoliated than the untreated check. Although the ratings suggest that the checks were more defoliated at 3 DAIT (38%) than 8 DAIT (33%), the likely explanation is that rain slowed the natural defoliation and washed away some of the fallen leaves that were used as a reference.

There was a significant Groups effect, with: Finish fb Folex the most defoliated; Finish + Folex less defoliated; and Finish alone least defoliated (Fig. 1). All treated plots were significantly more open than the untreated check. Values among the treated plots ranged from 64 to 80%. The Groups effect was significant, with Finish + Folex significantly less open than the other two groups (Fig. 2). Significant differences in both percent defoliation and percent open bolls were observed at 13 DAIT. All treated plots were significantly more defoliated than the untreated check. All of the treated plots were essentially unchanged from 8 DAIT. The untreated check was significantly less open than all treated plots. Values among the treated plots ranged from 80 to 85%. The Groups effect was significant, with Finish fb Folex significantly more open than the other groups (Fig. 2).

Although temperatures were favorable for boll opening (highs 84 to 97°F; only one night <60°F), the crop appeared to have more unopened bolls than normal for ethephon application at 30% open bolls. Even the 2.0 lb ethephon / acre rate in the standard (Treatment 11) only reached 83% open bolls by 13 DAIT (data not included).

PRACTICAL APPLICATION

Most years the cotton crop in northern Arkansas will need both defoliation and boll opening in preparation for harvest. In this study, Finish followed three days later by 0.5 pt Folex / acre was the most effective treatment at defoliation and boll opening. A tank-mix of these products did not appear as effective. Even with warm temperatures, the crop contained several bolls that did not open during the study period for any of the treatments.

ACKNOWLEDGMENT

The authors acknowledge the financial support of Rhone Poulenc Ag Company.

Table 1. Treatments employed in the 1998 Rhone Poulenc cotton defoliation study at Northeast Research and Extension Center, Keiser.

#	Treatment
1	Untreated check
2	Finish at 1.0 lb ethephon/acre
3	Finish at 1.33 lb ethephon/acre
4	Finish at 1.5 lb ethephon/acre
5	Finish at 1.0 lb ethephon/acre fb 0.5 pt Folex/acre at 3 days
6	Finish at 1.0 lb ethtphon/acre + 0.5 pt Folex/acre
7	Finish at 1.33 lb ethephon/acre fb 0.5 pt Folex/acre at 3 days
8	Finish at 1.33 lb ethephon/acre + 0.5 pt Folex/acre
9	Finish at 1.5 lb ethephon/acre fb 0.5 pt Folex/acre at 3 days
10	Finish at 1.5 lb ethephon/acre + 0.5 Folex/acre
11	Standard: PREP at 2.0 lb ethephon/acre + 0.5 pt Folex/acre
Groups:	
	Finish alone (average of 2, 3, 4)
	Finish fb Folex (average of 5, 7, 9)
	Finish + Folex (average of 6, 8, 10)

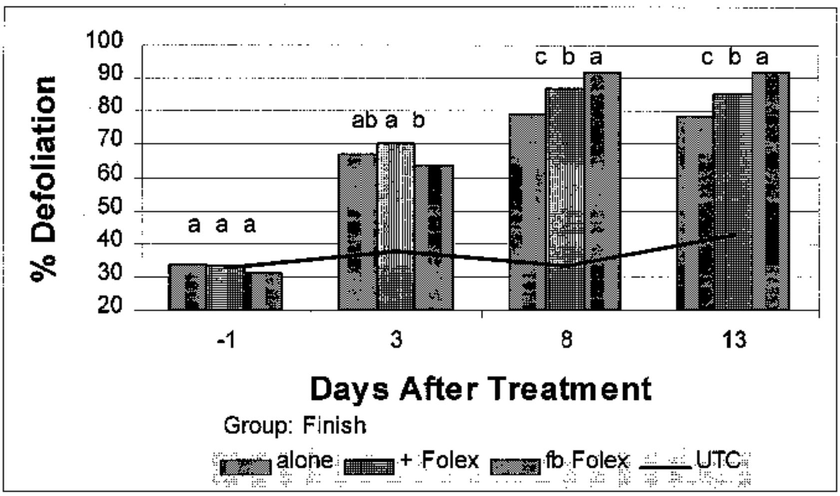

Fig. 1. Defoliation response for Finish "Groups" in 1998 Rhone Poulenc cotton defoliation study at Northeast Research and Extension Center, Keiser. Treatments with the same letter were not significantly different at the α = 5% level (Untreated control [UTC] not included in comparisons).

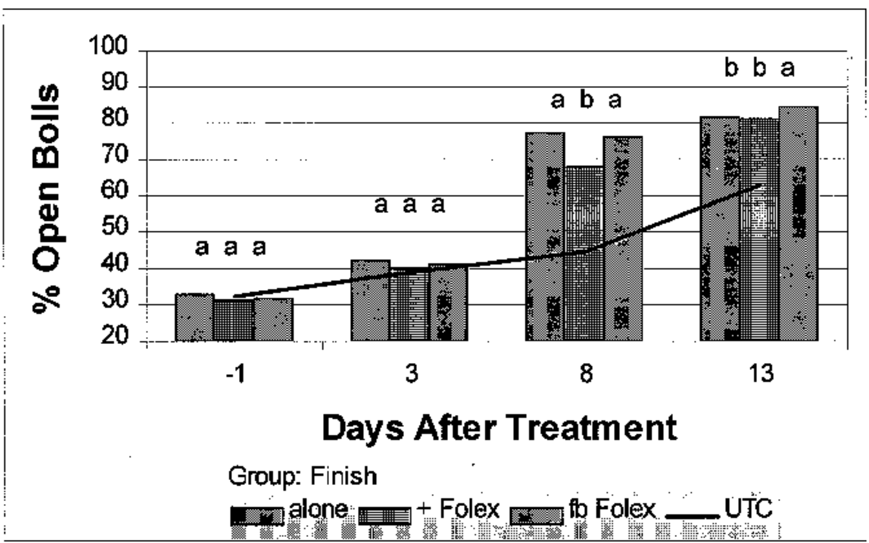

Fig. 2. Boll opening response for Finish "Groups" in 1998 Rhone Poulenc cotton defoliation study at Northeast Research and Extension Center, Keiser. Treatments with the same letter were not significantly different at the α = 5% level (Untreated control [UTC] not included in comparisons).

FOLIAR NITROGEN FERTILIZATION OF COTTON IN SOUTHEAST ARKANSAS[1]

J. Scott McConnell, William H. Baker, B. Steve Frizzell, and Cliff S. Snyder[2]

RESEARCH PROBLEM

Early-season, soil-applied nitrogen (N) fertilizer may not meet the full season N needs of a developing cotton (*Gossypium hirsutum* L.) crop. Early work indicated that supplemental N, either soil- or foliar-applied, may help meet crop N needs and increase yields (Maples and Baker, 1993). The objective of these studies was to determine when an increase in cotton yield may be realized from foliar N applications.

BACKGROUND INFORMATION

Foliar fertilization of cotton with 23% N (urea) solutions with the Cotton Nutrient Monitoring Program (CNMP) is an accepted practice among Arkansas producers to meet late-season N requirements (Snyder, 1991). Recent research indicates that the response of cotton to foliar N may not be as dramatic as observed in earlier work (Parker *et al.*, 1993).

RESEARCH DESCRIPTION

A long-term study of soil-applied N fertilization and irrigation of cotton is being used to determine the impact of foliar N fertilization. Soil-applied N rates range from 0 to 150 lb N/acre in 30-lb N/acre increments. Three foliar N treatments (23% N [urea] solution) were applied at rates of 10 lb N/acre/treatment in 10 gal water/acre. First applications of the foliar treatments were made when the cotton reached first flower. Second and third applications were made two and four weeks after the initial application, respectively.

RESULTS

Irrigated cotton responded to foliar fertilization treatments with increased yield when soil N was restricted to preplant and first square application totaling 120 lb N/acre or less in 1993 (Table 1). Although the foliar N x soil N interaction was not significant for yield in 1994, 1995, or 1996, the foliar N treatments significantly increased

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yields (Tables 2, 3, and 4). Trends in the 1994 through 1996 results were similar to those observed in 1993. The 1997 irrigated crop was delayed in maturity due to early season flooding. Interactions between soil-applied and foliar-applied N treatments did not significantly affect lint yield, although both main effects did significantly influence yield (Table 5). Trends in lint yield response were similar to the first four years of study.

Dryland cotton responded to foliar fertilization treatments with increased yield when soil N rates were low (0 and 30 lb N/acre) in 1993 and 1995 (Tables 1, 3, and 4). Soil-applied N rates of 90, 120, and 150 lb N/acre did not significantly increase cotton yields compared to 60 lb N/acre. Dryland cotton did not significantly respond to either foliar N treatments or the foliar N x soil N interaction in 1994 (Table 2). In 1997, the dryland crop was very high-yielding. Interactions between soil-applied and foliar-applied N treatments did not significantly affect lint yield, although both main effects did significantly influence yield (Table 5). Trends in lint yield response were similar to the first four years of study.

Primary differences in petiole NO_3^--N concentrations were due to the soil-applied N fertilizer (Table 6). Foliar treatments tended to have little effect on petiole NO_3^--N levels in cotton fertilized with any rate of soil applied N.

PRACTICAL APPLICATIONS

Results indicate that foliar N applications may increase cotton lint yield when soil-applied N is low. Yield trends indicate that foliar fertilization of cotton receiving the optimum rate or more of soil-applied N was found to have little affect on lint yield. Petiole NO_3^--N concentrations were primarily dependant on soil-applied N fertilizer. Foliar N treatments were not found to have significant, consistent effects on petiole NO_3^--N concentration.

ACKNOWLEDGMENTS

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Table 1. Lint yield response of cotton grown with soil-applied nitrogen (N) fertilization rates under two irrigation methods with foliar 30 lb N/acre (Fol) and 0 lb N/acre (Untrt) in 1993.

Soil N rate			Irrigated			Dryland		
PP[z]	FS	FF	Fol	Untrt	Mean	Fol	Untrt	Mean
------- lb N/acre ------			------------------------------ lb lint/acre ------------------------------					
75	75	0	1321	1326	1324	1006	1095	1051
50	50	50	1249	1345	1292	1032	1143	1088
30	60	60	1316	1391	1358	1066	1191	1122
60	60	0	1419	1347	1383	957	1073	1022
40	40	40	1324	1339	1331	1088	1271	1179
45	45	0	1410	1247	1320	990	1138	1065
30	30	30	1379	1377	1378	1012	1104	1058
30	30	0	1335	1198	1267	930	1032	987
15	15	0	1117	1027	1067	1007	949	978
0	0	0	912	784	855	835	693	764
LSD(0.05)[y]				216			204	
LSD(0.05)[x]				351			334	

[z] Preplant (PP), First Square (FS) and First Flower (FF).
[y] LSD(0.05) for comparing two soil applied fertilization means within the same foliar fertilization (either Foliar or Untreated) in the same irrigation.
[x] LSD(0.05) for comparing two soil applied fertilization means in different foliar fertilization in the same irrigation.

Table 2. Lint yield response of cotton grown with 10 soil-applied nitrogen (N) fertilization rates and splits under two irrigation methods with foliar 30 lb N/acre (Fol) and 0 lb N/acre (Untrt) in 1994.

Soil N rate			Irrigated			Dryland		
PP[z]	FS	FF	Fol[y]	Untrt	Mean	Fol	Untrt	Mean
------- lb N/acre ------			------------------------------ lb lint/acre ------------------------------					
75	75	0	1765	1643	1704	1423	1513	1468
50	50	50	1598	1632	1616	1640	1501	1481
30	60	60	1684	1698	1691	1519	1559	1539
60	60	0	1666	1549	1608	1424	1381	1403
40	40	40	1633	1618	1626	1417	1328	1372
45	45	0	1630	1602	1616	1310	1330	1320
30	30	30	1618	1492	1555	1349	1359	1354
30	30	0	1575	1482	1529	1344	1226	1275
15	15	0	1413	1215	1314	1219	1085	1152
0	0	0	1085	873	979	908	833	870
LSD(0.05)					95			128
Mean			1567	1481		1337	1312	
LSD(0.05)[x]				351			NS	

[z] Preplant (PP), First Square (FS) and First Flower (FF).
[y] No significant soil N x foliar N interactions were observed.
[x] LSD(0.05) for comparing foliar applied fertilization treatment means.

Table 3. Lint yield response of cotton grown with 10 soil-applied nitrogen (N) fertilization rates and splits under two irrigation methods with foliar 30 lb N/acre (Fol) and 0 lb N/acre (Untrt) in 1995.

Soil N rate			Irrigated			Dryland		
PP[z]	FS	FF	Fol[y]	Untrt	Mean	Fol	Untrt	Mean
------- lb N/acre ------			------- lb lint/acre -------					
75	75	0	1425	1393	1409	862	954	908
50	50	50	1322	1373	1348	918	1039	979
30	60	60	1434	1368	1401	859	971	915
60	60	0	1420	1376	1398	835	879	857
40	40	40	1425	1360	1393	889	1032	969
45	45	0	1230	1236	1233	895	945	920
30	30	30	1329	1280	1305	890	947	919
30	30	0	1208	1097	1153	887	852	870
15	15	0	1114	980	1047	823	781	802
0	0	0	852	704	778	695	523	609
LSD(0.05)[x]					127			
LSD(0.05)[w]						240		
LSD(0.05)[v]						193		
Mean			1276	1217		856	892	
LSD(0.05)[u]			28					

[z] Preplant (PP), First Square (FS) and First Flower (FF).
[y] No significant soil N x foliar N interactions were observed.
[x] LSD for comparing soil N treatment means in the irrigated test.
[w] LSD for comparing foliar N means in the same soil N treatment in the dryland test.
[v] LSD for comparing foliar N means in different soil N treatments in the dryland test.
[u] LSD for comparing foliar fertilization means in the irrigated test.

Table 4. Lint yield response of cotton grown with 10 soil-applied nitrogen (N) fertilization rates and splits under two irrigation methods with foliar 30 lb N/acre (Fol) and 0 lb N/acre (Untrt) in 1996.

Soil N rate			Irrigated			Dryland		
PP[z]	FS	FF	Fol[y]	Untrt	Mean	Fol	Untrt	Mean
------ lb N/acre ------			------ lb lint/acre ------					
75	75	0	1604	1630	1617	1043	1067	1055
50	50	50	1517	1543	1530	939	1116	1027
30	60	60	1660	1578	1619	1013	1078	1045
60	60	0	1671	1522	1597	1010	1035	1021
40	40	40	1675	1589	1627	1090	1164	1127
45	45	0	1610	1495	1552	1105	1050	1078
30	30	30	1615	1527	1571	1047	1126	1086
30	30	0	1575	1652	1613	1103	1059	1081
15	15	0	1416	1167	1291	1107	1048	1074
0	0	0	1102	868	998	843	752	802
LSD (0.05)[x]					164			
LSD (0.05)[w]						214		
LSD (0.05)[v]						447		
Mean			1542	1469		1028	1056	
LSD (0.05)[u]			55					

[z] Preplant (PP), First Square (FS) and First Flower (FF).
[y] No significant soil N x foliar N interactions were observed.
[x] LSD for comparing soil N treatment means in the irrigated test.
[w] LSD for comparing foliar N means in the same soil N treatment in the dryland test.
[v] LSD for comparing foliar N means in different soil N treatments in the dryland test.
[u] LSD for comparing foliar fertilization means in the irrigated test.

Table 5. Lint yield response of cotton grown with 10 soil-applied nitrogen (N) fertilization rates and splits under two irrigation methods with foliar 30 lb N/acre (Fol) and 0 lb N/acre (Untrt) in 1997.

Soil N rate			Irrigated			Dryland		
PP[z]	FS	FF	Fol[y]	Untrt	Mean	Fol	Untrt	Mean
------- lb N/acre ------			-------------------------------- lb lint/acre --------------------------------					
75	75	0	1752	1739	1746	1730	1681	1706
50	50	50	1591	1679	1636	1793	1777	1785
30	60	60	1801	1576	1689	1811	1867	1839
60	60	0	1757	1553	1655	1705	1629	1667
40	40	40	1714	1751	1733	1797	1799	1798
45	45	0	1629	1590	1609	1726	1614	1670
30	30	30	1529	1368	1480	1807	1754	1781
30	30	0	1538	1457	1498	1587	1338	1462
15	15	0	1324	1102	1213	1215	1067	1141
0	0	0	933	764	849	851	683	767
LSD (0.05)[x]					187			173
Mean			1276	1217		856	892	
LSD(0.05)[w]			28			47		

[z] Preplant (PP), First Square (FS) and First Flower (FF).
[y] No significant soil N x foliar N interactions were observed.
[x] LSD for comparing soil N treatment means.
[w] LSD for comparing foliar fertilization means in the irrigated test.

Table 6. Selected petiole NO_3^--N responses of irrigated cotton grown with three soil-applied nitrogen (N) fertilization rates with an additional foliar 30 lb N/acre (Fol N) from 1993 to 1997.

Soil N rate				Sample period						
PP[z]	FS	FF	Fol N	1	2	3	4	5	6	7
------ lb N/acre -----				ppm NO_3^--N						
1993										
50	50	50	Yes	18765	6771	10100	7074	12242	6771	949
50	50	50	No	19339	5898	10378	4175	10663	5898	1039
45	45	0	Yes	14652	5281	6789	3009	2211	5281	581
45	45	0	No	11747	5480	7210	1190	516	5480	578
0	0	0	Yes	3440	968	1440	410	348	968	287
0	0	0	No	8491	2014	1546	2055	4455	2014	287
1994										
50	50	50	Yes	10166	10715	11072	13901	8104	2912	393
50	50	50	No	7378	8231	7978	13201	8116	3201	300
45	45	0	Yes	4639	6193	3643	1460	227	101	268
45	45	0	No	3768	5266	2564	478	63	106	204
0	0	0	Yes	148	50	236	108	58	123	249
0	0	0	No	335	59	285	154	58	106	291
1995										
50	50	50	Yes	11190	13720	7453	11374	4338	2399	674
50	50	50	No	1,071	13024	5657	7639	4220	552	161
45	45	0	Yes	11201	7848	1380	522	321	122	66
45	45	0	No	----	8109	810	500	565	16	20
0	0	0	Yes	1321	1159	447	20	591	64	20
0	0	0	No	879	3364	14	20	96	9	14
1996										
50	50	50	Yes	10744	11443	8631	8421	7816	4425	1913
50	50	50	No	10341	9631	4727	6546	4544	2268	459
45	45	0	Yes	9816	9639	4062	1243	671	314	66
45	45	0	No	9090	7506	1821	878	571	68	155
0	0	0	Yes	207	258	371	359	168	21	66
0	0	0	No	975	256	268	304	168	21	13
1997										
50	50	50	Yes	7798	10290	3769	3229	1834	541	51
50	50	50	No	6191	6393	3430	1042	756	201	83
45	45	0	Yes	4886	1012	465	360	150	201	6
45	45	0	No	6684	1283	401	197	150	16	17
0	0	0	Yes	329	1	61	352	150	197	61
0	0	0	No	560	1	61	105	197	61	108

[z] Preplant (PP), First Square (FS) and First Flower (FF).

NITROGEN FERTILIZATION OF ULTRA-NARROW-ROW COTTON[1]

J. Scott McConnell and Robert C. Kirst, Jr.[2]

RESEARCH PROBLEM

Ultra-narrow-row (UNR) cotton (*Gossypium hirsutum* L.) represents a unique development in cotton production for Arkansas. Ultra-narrow-row cotton is a drill-planted, stripper-harvested, non-irrigated, low-input production system designed to maximize economic returns. Research that provides information on UNR production parameters is scant. Optimum nitrogen (N) fertilization rates and how UNR cotton uses N are unknown. The objective of this pilot study was to gain experience with UNR cotton production and determine how UNR cotton would respond to N fertilization.

BACKGROUND INFORMATION

Recently, interest in UNR cotton production has increased. It has long been known that plants grown in very narrow rows intercept and use sunlight more efficiently. Potential benefits of UNR cotton production include reduced production costs (irrigation, insecticide application, and harvest equipment); use of poorer soils; decreased soil erosion; and use of the same equipment for cotton, soybeans, and cereal crops. Potential drawbacks of UNR cotton include increased weed pressure in low stand areas, the need for of different equipment (e.g. precision drill planter, finger stripper harvester), and the possibility that lint quality may decline. Cultivar differences, fertility requirements, effect of planting date, and many other production parameters for optimum growth and yield of UNR cotton grown in Arkansas are unknown.

RESEARCH DESCRIPTION

A block of UNR cotton was drill-planted (John Deere 750 drill) on 19 May 1997 at the Southeast Research and Extension Center, Rohwer Division, for a pilot study of UNR cotton response to N fertilization. Fertilizer treatments of 100 lb urea-N/acre, 100 lb Meister-N/acre, 50 lb urea-N/acre, and 0 lb N/acre were strip-applied with a fertilizer buggy just prior to squaring.

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The test was expanded in 1998 to include N rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre. The test design was a randomized complete block. Nitrogen treatments were applied as the crop reached the two true-leaf stage.

The measurements taken on the UNR cotton included seedcotton yield, plant height, plant population, boll load, and boll weight. All data were analyzed using the Statistical Analysis System (SAS). F-tests and least significant differences (LSD) were calculated at the ($P < 0.05$) level of probability.

RESULTS

Pilot Study - 1997

Ultra-narrow-row cotton fertilized with either 50 or 100 lb N/acre, regardless of N source, did not differ in yield (Table 1). Cotton receiving no N fertilizer was significantly lower yielding than cotton that received N fertilizer. The tallest plants were found in plots receiving 100 and 50 lb N/acre; the unfertilized cotton was shortest. The 100 lb Meister-N/acre was intermediate in height. Although plant populations were found to differ by as much as 32,000 plants/acre, no significant differences were found as a function of N treatment. Boll load and boll weight were both greatest and not significantly different for the fertilized UNR cotton and lowest for the untreated cotton.

N-Rates Study

The results of the first year of the study correlate with the results of the pilot study. The N fertilization rate necessary to produce maximum yield was 50 lb N/acre (Table 2). Although a trend of higher yield was observed with greater N rates, the differences were not significantly different from the 50 lb N/acre treatment. Plant height increased with increasing N fertilization up to 100 lb N/acre. No significant differences in plant population were found as a function of N treatment. Boll load and boll weight were found to follow similar trends in response to N fertilization as lint yield. The 50 lb N/acre treatment maximized boll load and boll weight. Additional N did not significantly increase either boll load or boll weight.

PRACTICAL APPLICATION

The results from this test are preliminary and final conclusions should not be drawn from these data. The response of UNR cotton to N fertilization treatments indicate that the N required for maximum yield will be less than for cotton grown in conventionally-spaced rows. Yields were not found to increase with N rates above 50 lb N/acre in two different tests. Additionally, the 50 lb N/acre treatment was found to maximize both the boll load and boll weight. The parameters measured in this study indicate that the growth and management of UNR cotton may be substantially different from conventionally grown cotton.

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Table 1. Seedcotton yield, plant height, plant population, boll load and boll weight of cotton growth in ultra-narrow-rows with 0, 50, and 100 lb N/acre and with 100 lb N/acre at the Southeast Research and Extension Center, Rohwer Division, in 1997.

Seedcotton N rate[z]	Plant yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(in.)	(plants/acre)	(boll/acre)	(g/boll)
100 (M)	2938	24.9	115360	393675	3.36
100	3008	31.3	140368	392869	3.44
50	3333	29.9	108099	416263	3.58
0	1529	20.4	118587	242820	2.87
LSD(0.05)	1099	6.1	NS[y]	119875	0.38

[z] Urea as source except for Meister (M) nitrogen.
[y] Not significant.

Table 2. Lint yield, plant height, plant population, boll load, and boll weight of cotton growth in ultra-narrow-rows with 0, 25, 50, 75, 100, and 125 lb N/acre at the Southeast Research and Extension Center, Rohwer Division, in 1998.

N rate[z] (urea)	Lint yield	Plant height	Plant population	Boll load	Boll weight
(lb N/acre)	(lb/acre)	(in.)	(plants/acre)	(boll/acre)	(g/boll)
125	1060	27.5	153074	349710	3.31
100	1033	30.5	168199	327928	3.39
75	1034	26.3	160334	341844	3.30
50	899	24.4	175460	321273	3.12
25	745	20.4	177275	278921	2.93
0	468	19.9	171225	191769	2.84
LSD(0.05)	153	4.2	NS[y]	48,066	0.28

[z] Urea as source except for Meister (M) nitrogen.
[y] Not significant.

LONG-TERM IRRIGATION METHODS AND NITROGEN FERTILIZATION RATES IN COTTON PRODUCTION: THE LAST FIVE YEARS[1]

J. Scott McConnell, William H. Baker, and Robert C. Kirst, Jr.[2]

RESEARCH PROBLEM

Management of nitrogen (N) and irrigation are two very important aspects of cotton (*Gossypium hirsutum* L.) production. The interactions of N fertilizer and irrigation are not well documented under the humid production conditions of southeast Arkansas (McConnell *et al.*, 1988). The objective of these studies was to evaluate the development and yield of intensively managed cotton soil treated with soil-applied N fertilizer under several irrigation methods.

BACKGROUND INFORMATION

Over- and under-fertilization may result in delayed maturity and reduced yield, respectively (Maples and Keogh, 1971). Adequate soil moisture is also necessary for cotton to achieve optimum yields. If the soil becomes either too wet or too dry, cotton plants will undergo stress and begin to shed fruit (Guinn *et al.*, 1981).

RESEARCH DESCRIPTION

This study was conducted at the Southeast Research and Extension Center, Rohwer Division, on an Hebert silt loam soil. The experimental design was a split block with irrigation methods as the main blocks. Nitrogen rates were tested within each irrigation method. Five irrigation methods were used from 1988 to 1993 (Table 1), but only three methods were used in 1994. Six different N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested with different application timings used for the higher (90 to 150 lb N/acre) N rates.

RESULTS

During the last five years, irrigation generally increased cotton yields except during a season when early season rainfall resulted in standing water that delayed the

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irrigated plants; or when Verticillium wilt was prevalent (1994) (Table 2). The method of irrigation to maximize lint yield varied year-to-year and appeared to be less important than irrigation usage most years.

Generally, lint yield was found to increase with increasing N fertilization (Table 3). The N treatments that usually resulted in the greatest lint yields were applications of 60 to 150 lb N/acre, depending upon the irrigation treatment and year. Exceptions were found for the 150 lb N/acre treatment (75 lb N/acre preplant and 75 lb N/acre at first square) which was found to decrease lint yield in some irrigation blocks, and the High Frequency Center Pivot block in 1992 and 1994. The yields of the High Frequency block during those years were significantly influenced by Verticillium wilt. The disease was more virulent in the plots receiving higher N rates, thereby reducing yields with increasing N.

PRACTICAL APPLICATIONS

Irrigated cotton was generally found to be higher yielding than cotton grown under dryland conditions unless Verticillium wilt affected the crop. Fertilizer N requirements of cotton for maximum yield tended to be greater under irrigated production conditions than under to dryland production conditions. Fertilizer N requirements of cotton for maximum yield tended to be greater for furrow-irrigated cotton than for center pivot-irrigated cotton.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

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Table 1. Duration, tensiometer thresholds, and depths and water application rates for five irrigation methods.

Irrigation method	Duration	Tensiometer threshold	Tensiometer depth	Water applied
		----- cbar -----	----- in. -----	----- in. -----
High frequency	Planting to P.B.[z]	35	6	0.75
Center pivot	P.B. to Aug. 15	35	6	1.00
Mod. frequency	Planting to			
Center pivot	Aug. 15	55	6	1.00
Low frequency	First Irrigation	55	12	1.00
Center pivot	Until Aug. 15	55	6	1.50
Furrow flow	Until Aug. 15	55	12	Not Precise
Dryland	Not Irrigated	----	----	----

[z] P.B. = Peak Bloom

Table 2. Lint yield response of cotton to five irrigation methods from 1993 to 1997.

Method	1993	1994	1995	1996	1997
	lb/acre				
High frequency center pivot	1103	1317	1113	1344	1400
Moderate frequency center pivot	1342	----[z]	----	----	----
Low frequency center pivot	1112	----	----	----	----
Furrow flow	1241	1478	1217	1463	1458
Dryland	1067	1353	892	1057	1521
LSD(0.05)	66	83	59	108	99

[z] Treatment not included.

Table 3. Lint yield response of cotton to 10 nitrogen (N) fertilization rates and splits under five irrigation methods from 1993 to 1997.

N rate							
PP[z]	FS	FF	LF[y]	MF	HF	FI	DL
------ lb N/acre -----			------------------------------- lb lint/acre -------------------------------				
1993							
75	75	0	1179 a	1262 cd	1152 a-c	1324 a-c	1095 bc
50	50	50	1164 a	1267 bc	1181 a-c	1345 ab	1144 a-c
30	60	60	1156 a	1269 cd	1097 c	1391 a	1191 ab
60	60	0	1171 a	1394 a-c	1156 a-c	1347 ab	1073 b-d
40	40	40	1177 a	1465 ab	1126 bc	1339 ab	1271 a
45	45	0	1150 a	1525 a	1245 a	1248 bc	1139 a-c
30	30	30	1146 a	1429 ab	1212 ab	1377 ab	1104 bc
30	30	0	1092 a	1346 bc	1121 bc	1198 c	1032 cd
15	15	0	1032 b	1255 cd	992 d	1027 d	949 d
0	0	0	863 c	1185 d	833 e	784 e	966 c
LSD (0.05)			98	143	103	136	114
1994							
75	75	0	----[x]	----	1264 c	1600 a-c	1328 a-c
50	50	50	----	----	1256 c	1643 ab	1513 ab
30	60	60	----	----	1283 c	1633 ab	1501 ab
60	60	0	----	----	1312 bc	1602 a-c	1643 a
40	40	40	----	----	1467 a	1695 a	1559 a
45	45	0	----	----	1441 ab	1492 c	1359 a-c
30	30	30	----	----	1384 a-c	1549 bc	1381 a-c
30	30	0	----	----	1515 a	1482 c	1226 b-d
15	15	0	----	----	1313 bc	1215 d	1085 cd
0	0	0	----	----	1073 e	873 e	931 d
LSD (0.05)			----	----	132	137	322
1995							
75	75	0	----	----	1127 a	1393 a	954 a-c
50	50	50	----	----	1166 a	1373 ab	1039 a
30	60	60	----	----	1193 a	1369 ab	971 ab
60	60	0	----	----	1162 a	1376 ab	879 b-d
40	40	40	----	----	1213 a	1360 ab	1032 a
45	45	0	----	----	1107 a	1236 bc	946 a-c
30	30	30	----	----	1149 a	1280 ab	947 a-c
30	30	0	----	----	1198 a	1098 cd	852 cd
15	15	0	----	----	964 b	980 d	781 d
0	0	0	----	----	838 c	704 e	532 e
LSD (0.05)			----	----	106	146	114

continued

Table 3. Continued.

N rate							
PP[z]	FS	FF	LF[y]	MF	HF	FI	DL
------ lb N/acre -----			------------------------------- lb lint/acre -------------------------------				
1996							
75	75	0	----	----	1315 c	1630 a	1067 a
50	50	50	----	----	1411 a-c	1543 a	1116 a
30	60	60	----	----	1331 bc	1572 a	1078 a
60	60	0	----	----	1383 a-c	1522 a	1035 a
40	40	40	----	----	1431 ab	1576 a	1174 a
45	45	0	----	----	1382 a-c	1495 a	1050 a
30	30	30	----	----	1440 ab	1527 a	1059 a
30	30	0	----	----	1461 a	1633 a	1059 a
15	15	0	----	----	1309 c	1167 d	1048 a
0	0	0	----	----	979 d	868 c	752 b
LSD (0.05)			----	----	114	251	155
1997							
75	75	0	----	----	1491 a	1739 a	1682 ab
50	50	50	----	----	1491 a	1679 a	1777 ab
30	60	60	----	----	1384 a	1576 ab	1867 a
60	60	0	----	----	1528 a	1547 a-c	1629 b
40	40	40	----	----	1491 a	1751 a	1799 ab
45	45	0	----	----	1507 a	1582 ab	1615 b
30	30	30	----	----	1420 a	1368 c	1754 ab
30	30	0	----	----	1477 a	1457 bc	1338 c
15	15	0	----	----	1157 a	1102 d	1067 d
0	0	0	----	----	1086 b	764 e	683 e
LSD (0.05)			----	----	159 b	207	217

[z] Preplant (PP), first square (FS) and first flower (FF).
[y] Low frequency (LF), moderate frequency (MF), high frequency (HF), furrow-irrigated (FI), dryland (DL).
[x] Treatment not applied.

TIMING OF EARLY-SEASON NITROGEN FERTILIZATION OF COTTON[1]

J. Scott McConnell and William H. Baker[2]

RESEARCH PROBLEM

The recommended timing of early-season nitrogen (N) fertilizer to meet the needs of a developing cotton (*Gossypium hirsutum* L.) crop has not been well established (Bonner, 1995). Recommended N rates vary with soil test results, field history, and the development of the crop. The objective of these studies was to determine the optimum time for early-season N applications to cotton.

BACKGROUND INFORMATION

Arkansas cotton producers have traditionally met early-season N requirements of the crop with a preplant N application. The first soil application of N fertilizer to cotton is sometimes delayed until stand establishment due to inclement weather or seedling disease pressure (Minter Applebury, personal communication). It is speculated that delaying the first N application might result in early-season N deficiency and possible yield loss.

RESEARCH DESCRIPTION

A study of early-season soil-applied N fertilization and irrigation of cotton was used to determine the impact of delaying N fertilization. Five soil-applied N splits of 100 lb N/acre and a 0 lb N/acre control were tested. The experiment was duplicated under both furrow-irrigated and dryland conditions. First N applications are made approximately two to four weeks preplant. Second applications were made after the crop emerged (two to four true leaves). The third application was made when the crop reached first square.

RESULTS

Yields were slightly higher under irrigated conditions than under dryland in 1995 but much greater in yield 1996. This trend was reversed in 1997 due to standing water in the irrigated block. Although yields were very high in 1997, greatest yields were found in the dryland block (data not shown).

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[1] This manuscript reprinted from: W.E. Sabbe (ed.). Arkansas Soil Fertility Studies 1998. University of Arkansas Agricultural Experiment Station Research Series 463:45-47.

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Trends in the response to the N treatments were similar in the irrigated and dryland blocks in 1995, the irrigated block in 1996, and in both blocks again in 1997 (Table 1). Treatments did not significantly affect yields in dryland cotton in 1996. The unfertilized control was the lowest yielding treatment. The 100 lb N/acre preplant treatment was the next lowest yielding and not significantly different from the unfertilized control in 1995. The other four N treatments were not significantly different in yield.

A trend of higher yield was observed with treatments that included a first square N application. This trend is consistent with small yield increases from the 100 lb N/acre preplant treatments. One possible explanation for the ineffectiveness of the preplant treatments was the adverse spring weather conditions. Rainy, wet weather probably increased the likelihood of denitrification and leaching of nitrate. These two processes, denitrification and leaching, remove N from the soil and reduce plant uptake, and may have caused the preplant treatments to be less effective than N-fertilizer applied later in the growing season.

PRACTICAL APPLICATIONS

Preliminary results indicate that early-season N applications shortly after emergence and at first square were more effective in meeting the N nutritional needs of cotton than preplant N applications. Because these are preliminary results, testing should be continued before final conclusions are drawn.

ACKNOWLEDGMENTS

Support for this research was provided by the Arkansas Fertilizer Tonnage Fee.

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Table 1. Lint yield response of cotton grown with early-season soil-applied nitrogen (N) treatments under furrow irrigation and dryland conditions in 1995 and 1996.

Soil N rate			1995		1996		1997	
PP[z]	AE	FS	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland
----- lb N/acre -----			--------lb lint/acre --------					
0	50	50	1068	909	1747	1308	1699	2011
50	0	50	990	877	1721	1263	1634	1967
0	0	100	1086	915	1602	1293	1565	1947
0	100	0	1020	869	1475	1203	1524	1958
100	0	0	714	718	1267	1336	1379	1811
0	0	0	707	681	983	1069	952	1153
LSD (0.05)			158	145	173	NS	261	173

[z] Preplant (PP), After Emergence (AE), First Square (FS).

EFFECT OF POULTRY LITTER FOR DRYLAND COTTON ON CLAY SOIL

Earl D. Vories, Robert E. Glover, and Tate A. Castillo[1]

RESEARCH PROBLEM

Approximately 1 million tons of poultry litter are produced annually in Arkansas, most of which is applied to nearby pastures. The objective of this study was to determine the effectiveness of poultry litter as a nitrogen (N) source for cotton (Gossypium hirsutum L.) on a Sharkey silty clay soil. This was part of a larger study examining the benefits of poultry litter in combating runoff on clay soils.

BACKGROUND INFORMATION

Arkansas leads all states in poultry production with an inventory of over 1 billion broilers. Use of poultry litter as a fertilizer in row crop production would encourage litter transport from the poultry growing regions to the Delta. In Alabama studies, broiler litter has been effectively used as a source of N for cotton. Rates as high as four tons per acre had no negative effects on cotton yields and the cotton did not show excessive vegetative growth. Research in southern Arkansas showed poultry litter used as a soil amendment significantly increased cotton yields; however, additional N fertilizer was also used.

RESEARCH DESCRIPTION

Experiments were conducted on nonirrigated (irrigated once in 1998) cotton cultivar 'Suregrow 125' in 1996, 1997, and 1998 on a Sharkey silty clay at the Northeast Research and Extension Center (NEREC) in Keiser. Plots consisted of 32 rows (38-in. spacing) approximately 500 ft in length. Treatments consisted of preplant incorporated applications of broiler litter vs. conventional liquid fertilizer (URAN-32% N) applied preplant (75 lb N/acre) and at late square (50 lb N/acre) with three replications. Broiler litter was applied on 23 May 1996, 13 May 1997, and 18 May 1998. Planting dates were 23 May 1996, 21 May 1997, and 19 May 1998. The center 24 rows of each plot were harvested for a harvest area of approximately 0.9 acres.

To investigate a possible buildup of nutrients, soil cores were taken from every plot in 6-in. increments to a 36 in. depth prior to spring fertilization.

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RESULTS

Broiler litter treatments produced significantly lower seedcotton yields in 1996 (Fig. 1) even though 233 lb N/acre was applied. Increased litter rates in 1997 produced yields equivalent to conventionally-fertilized treatments (Fig. 1). In 1998, the N content of the litter was lower than in the other two years, resulting in lower N application. The broiler litter fertilized plots were again significantly lower in yield. In contrast to Alabama findings, equivalent N rates did not produce equivalent seedcotton yields in this study. In 1997, the only year the litter-fertilized crop did not yield significantly less, over twice the rate of N as broiler litter was applied to produce yields equivalent to conventionally-fertilized plots.

Soil test data collected after one application of litter and subsequent growing season indicated that soil phosphorus (P) content of litter plots was significantly higher than for conventionally-fertilized plots at the 0 to 6 in. depth (Fig. 2, LSD 0.05 = 30 for 0 to 6 in. depth). Data collected after a second litter application and subsequent growing season indicated that soil P content of litter plots was again significantly higher than for conventionally-fertilized plots at the 0 to 6 in. depth (Fig. 3, LSD 0.05 = 31 for 0 to 6 in. depth), and higher than the previous year. The possible buildup of P could eventually become a concern, however, continued monitoring of the soil should indicate whether the use of broiler litter could present an environmental danger.

PRACTICAL APPLICATION

Broiler litter treatments produced significantly lower seedcotton yields in 1996 and 1998. Increased litter rates in 1997 produced yields equivalent to conventionally-fertilized treatments. In contrast to findings in other studies, equivalent N rates did not produce equivalent seedcotton yields in this study. In addition, soil P content of litter fertilized plots was higher than that of conventionally-fertilized plots at the 0 to 6 in. depth. Continued monitoring of the soil is needed to show whether the use of broiler litter could present a possible environmental danger.

Table 1. Total nutrient application to poultry litter fertilized plots[z] from poultry litter study at Northeast Research and Extension Center, Keiser.

	1996	1997	1998
Total Litter Application (tons/acre)	3.2	4.1	3.8
Litter Nutrient Content (lb/ton)			
N	72.9	62.7	40.2
P_2O_5	54.0	64.7	66.0
K_2O	55.2	57.3	47.8
Total Nutrient Application (lb/acre)			
N	233	257	153
P_2O_5	173	265	251
K_2O	177	235	182

[z] Conventionally-fertilized plots received only nitrogen at 125 lb N/acre.

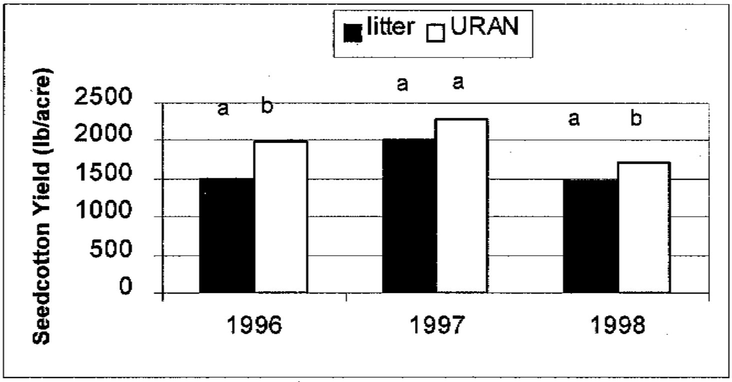

Fig. 1. Seedcotton yields from poultry litter study at the Northeast Research and Extension Center, Keiser. Yields within a given year with the same letter were not significantly different at the α=5% level.

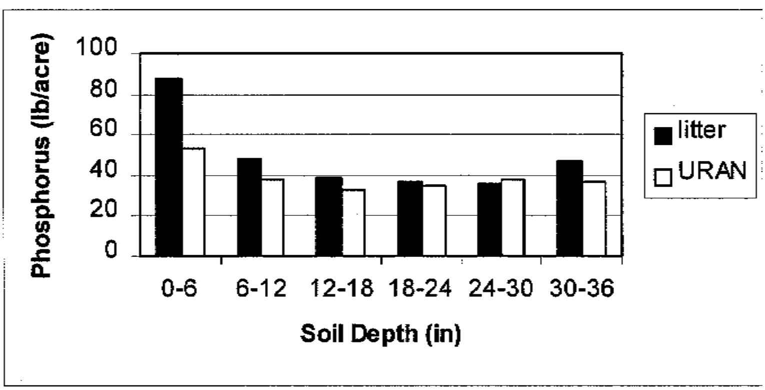

Fig. 2. Soil phosphorus levels from 1997 poultry litter study at the Northeast Research and Extension Center, Keiser.

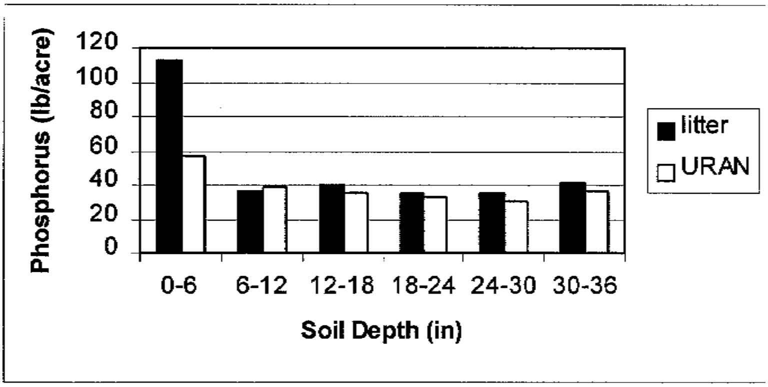

Fig. 3. Soil phosphorus levels from 1998 poultry litter study at the Northeast Research and Extension Center, Keiser.

POSTEMERGENCE WEED CONTROL OPTIONS IN COTTON

Marilyn R. McClelland and James L. Barrentine[1]

RESEARCH PROBLEM

Although postemergence over-the-top herbicides are a valuable tool in cotton weed control programs, there is question whether a postemergence program without a soil-applied residual herbicide will consistently give adequate weed control for all species. The objective of this research was to evaluate efficacy of three over-the-top herbicides with and without standard preemergence (PRE) herbicides.

BACKGROUND INFORMATION

The development of selective postemergence (POST) herbicide technology for broadleaf weed control in cotton has provided producers with a versatile weed management tool for conventional- and conservation-tillage cotton (Hayes, 1996; Wilcut *et al.*, 1998). Staple® (pyrithiobac) can be used on standard cotton cultivars and has both soil and foliar activity. Buctril® (bromoxynil) used with BXN transgenic cultivars has no residual activity and can be applied to cotton at any stage. Roundup Ultra® (glyphosate) is used with transgenic Roundup Ready® cotton and can be applied over-the-top through the 4-leaf cotton stage. Although these herbicides can be used in total POST programs, most researchers recommend careful consideration of weed problems and management practices before eliminating residuals completely (Laws, 1998). Control of extremely heavy weed populations or difficult to control weeds, such as morningglory (*Ipomoea)* species, may be more consistent with some residual herbicide (Laws, 1998).

RESEARCH DESCRIPTION

This experiment was conducted at Marianna on a silt loam soil. Each plot consisted of four 38-in. rows 40 ft long. Beds were hipped and leveled in early April 1998. The test area was overseeded with weed seed before leveling. Appropriate cotton cultivars (Roundup Ready, BXN, and DPL) were planted 16 May into the stale seedbeds, and paraquat was applied as a burndown. Herbicides were applied at 20 gpa with a tractor-mounted or backpack sprayer. Treatments were applied in a factorial arrangement (five POST programs by three levels of preemergence [PRE]) on a randomized complete block design with four replications (Table 1). In addition to post-directed

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treatments listed, a maintenance treatment of Bladex + MSMA was applied post-directed 1 July to all plots. Roundup Ultra was applied with a hooded sprayer as needed to control weeds in row middles, and Assure II was applied with Buctril and Staple treatments. Plots were rated for percent weed control three times during the season and were harvested for seedcotton yield. Data were analyzed by ANOVA, and means were separated by LSD at the 0.05 level.

RESULTS AND DISCUSSION

A heavy weed population was present. Averaged over POST herbicide programs, a PRE application increased control of large crabgrass and smooth pigweed compared to no PRE (Table 2). The labeled PRE rate enhanced prickly sida control, but there was no difference between no PRE and reduced-rate PRE. Level of the PRE component did not affect control of pitted morningglory (86 to 81%). Strengths and weaknesses of POST programs are shown in Table 3. Grass control was poor with the BXN and RU/PYR programs when no PRE was used. The heavy infestation of grass in plots without PRE was difficult to control with POST alone. The RU program controlled grass without PRE. PRE was necessary for smooth pigweed control with the BXN program (34% control without PRE). Tank-mixing Staple with Buctril (PYR/BXN program) controlled pigweed adequately (96%). Prickly sida control was poorest with the RU/PYR program because it was too large to be controlled by the later application of pyrithiobac.

Pitted morningglory control was fair to good (80 to 89%) with all programs except RU/PYR without PRE. Plants had 2 to 4 leaves at EOT and 4 to 6 leaves at LOT and DIR. Rainfall prevented earlier application, which might have increased control. Seedcotton yields did not differ among POST programs when a PRE was applied (Table 3). A PRE application with BXN, PYR, and RU/PYR POST programs increased yield.

PRACTICAL APPLICATION

Weeds in cotton can be controlled with total POST herbicides programs. However, residual soil (PRE) applications provide more flexibility in timing of POST applications. In this experiment, earlier POST timing would probably have increased control with a total POST program.

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Table 1. Treatments and designations.[z]

Treatment	Designation
(lb/acre)	
POST Program:	
Buctril (0.5) EOT (19-in band) fb DIR	BXN
Roundup Ultra (0.75) EOT (broadcast) fb Roundup Ultra, DIR	RU
Staple (0.063) + NIS, 0.25%, EOT (19-in. band) fb DIR	PYR
Staple (0.063) + Buctril (0.38) EOT + NIS, 0.25% (19-in band) fb DIR	PYR/BXN
Roundup Ultra (0.75) EOT (broadcast) fb Staple (0.063) LOT + NIS, 0.25% (19-in band)	RU/PYR
PRE factor: Prowl (pendimethalin) + Cotoran (fluometuron) + Gramoxone Extra (paraquat)	
Labeled rate PRE (1.0 + 1.5 + 0.63 lb/acre)	
Reduced rate PRE (0.5 + 0.75 + 0.63 lb/acre)	
No PRE (paraquat only)	

[z] EOT = early over-the-top (2-leaf cotton); LOT = late over-the-top (7-leaf cotton); DIR = post-directed 7-leaf cotton (Bladex + MSMA); NIS = non-ionic surfactant. Roundup Ultra was applied with a hooded sprayer on all treatments except Roundup Ultra EOT fb DIR.

Table 2. Percent weed control two weeks after final POST application averaged over POST program[z]**.**

PRE rates	DIGSA	AMACH	SIDSP	IPOLA
	(%)			
Labeled PRE	95	99	100	86
Reduced PRE	92	97	92	82
No PRE	77	83	89	81
LSD (0.05)	6	5	6	NS[y]

[z] Maintenance post-directed not yet applied.
[y] Not significant.

Table 3. Percent weed control two weeks after POST program and seedcotton yield following PRE (labeled rate) and no PRE[z].

	DIGSA		AMACH			IPOLA		Seedcotton yield	
POST program	PRE	no PRE	PRE	no PRE	SIDSP[y]	PRE	no PRE	PRE	no PRE
	(%)							(lb/acre)	
BXN	90	62	93	34	95	84	87	1880	520
RU	99	99	100	98	100	89	86	1630	1460
PYR	99	83	100	98	95	89	81	2000	1430
PYR/BXN	96	78	100	96	98	87	88	1900	1720
RU/PYR	91	63	100	88	80	80	61	1870	1440
LSD (0.05)	- 13 -		- 13 -		8	- 11 -		- 390 -	

[z] Maintenance post-directed not yet applied.
[y] Interaction not significant.

ROUNDUP RATE AND TIMING FOR WEED CONTROL IN ROUNDUP READY® COTTON

Marilyn R. McClelland[1]

RESEARCH PROBLEM

Roundup Ultra® (glyphosate) is a valuable postemergence tool in Roundup Ready® cotton weed control programs, but because weed susceptibility differs, it is important to determine the rate and timing of Roundup Ultra that will control even the more tolerant weed species. The objective of this experiment was to compare rates and timing of Roundup Ultra application for optimum control of common weeds in Roundup Ready cotton.

BACKGROUND INFORMATION

The use of Roundup Ultra (glyphosate) in transgenic, Roundup Ready cotton is a valuable tool in cotton weed control programs because of the broad spectrum of weeds controlled postemergence. Although Roundup Ultra is considered a non-selective herbicide, some weeds are more difficult to control than others (Laws, 1998; McClelland, 1998). A single application of Roundup Ultra at the 3- to 4-leaf cotton stage was not sufficient to control morningglory (*Ipomoea)* species, hemp sesbania (*Sesbania exaltata*), or sicklepod (*Senna obtusifolia*) because weeds were too large (McClelland, 1998). The Roundup Ultra label allows two over-the-top applications between cotton emergence and the 4-leaf stage of cotton growth (with a 10-day interval between applications required) and two post-directed applications, with any single application not to exceed one quart of product. Roundup Ultra cannot be applied over-the-top after the 4-leaf cotton stage because of potential boll loss, lower yields, or delayed maturity (Anonymous, 1998). Because of weather conditions, it may be difficult to get two applications of Roundup Ultra on before the fifth cotton leaf. It is important, therefore, to determine whether higher rates or later applications can be sufficient for difficult-to-control weeds such as morningglory.

RESEARCH DESCRIPTION

The experiment was conducted at Fayetteville, in 1998. 'Paymaster 1220RR' cotton (transgenic, Roundup Ready cotton) was planted 18 May in 27-ft plots. The test area was overseeded with weed seed and incorporated lightly before cotton planting. Early over-the-top (EOT) treatments were applied 2 June, late over-the-top (LOT) treat-

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ments were applied 13 June, post-directed treatments at 10-in. cotton (DIR) were applied 28 June, and post-directed layby treatments (LAYBY) were applied to 20-in. cotton 8 July. All applications were applied in 15 gal/acre carrier with a backpack sprayer. The weed population was uniform and dense. Most weeds had two true leaves at EOT and three to eight leaves at LOT. Size of weeds in plots with DIR treatments varied according to control with previous applications. Plots were rated for percent weed control four times during the season, and data were analyzed by ANOVA, with means separated by LSD at the 5% level of significance. Only the final rating is reported here.

RESULTS AND DISCUSSION

Control of large crabgrass and smooth pigweed was at least 98% with Roundup Ultra applied either EOT or LOT followed by (fb) DIR at either 0.5 or 1.0 lb/acre (Table 1). However, control of morningglory species was poor (55 to 68%) if application was delayed until LOT, especially with 0.5 lb/acre. Hemp sesbania was controlled better with 1.0 lb/acre than with 0.5 lb/acre if application was delayed until LOT. However, a LAYBY treatment increased hemp sesbania control to at least 98%. Control of prickly sida and velvetleaf was 98 to 100% with all except Roundup Ultra LOT fb DIR (90 and 89%, respectively). A treatment of Staple (pyrithiobac) + Cotoran (fluometuron) preemergence (PRE) fb Staple LOT and Bladex + MSMA DIR gave excellent control (99 to 100%) of weeds, but cotton was stunted 15 to 23% until mid-July (data not shown). Cotton was not visibly injured with any Roundup Ultra treatment.

In general, broad-spectrum control was possible when Roundup Ultra was applied EOT and then followed by LOT or DIR and a LAYBY application. Waiting until LOT to initiate application severely restricted control of morningglory species, and to a lesser extent control of hemp sesbania, prickly sida, and velvetleaf.

PRACTICAL APPLICATION

This, and other research conducted with Roundup Ready cotton systems (McClelland, 1998), shows that the first application of Roundup Ultra should be applied at the cotyledonary to 2-leaf cotton stage when weeds are still small. Delaying application until the 3- to 4-leaf stage will reduce control of morningglory species.

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Table 1. Midseason weed control with glyphosate in Roundup Ready cotton, Fayetteville, 1998[z].

	Control of weed species with glyphosate at 0.5 and 1.0 lb ai/acre[y]													
	DIGSA		AMACH		IPOLA		IPOHG		SIDSP		ABUTH		SEBEX	
Roundup timing[x]	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0	0.5	1.0
	(% control)													
EOT/DIR	100	100	99	100	83	96	81	96	100	100	99	100	96	100
LOT/DIR	99	100	90	98	55	68	53	66	90	100	89	98	79	94
EOT/LOT/DIR	99	100	100	100	90	100	89	99	100	100	99	100	100	100
EOT/LOT/ DIR/LAYBY	100	100	100	100	94	99	93	99	100	100	100	100	100	100
LOT/DIR/ LAYBY	100	100	97	100	66	82	60	82	99	100	99	100	96	100
LSD (0.05)	--- NS[w] ---		--- 3 ---		--- 6 ---		--- 6 ---		--- 2 ---		--- 2 ---		--- 7 ---	

[z] Rated 27 July, approximately 4 weeks after DIR and 3 weeks after LAYBY treatments were applied.

[y] DIGSA = large crabgrass; AMACH = smooth pigweed; IPOLA = pitted morningglory; IPOHG = entireleaf morningglory; SIDSP = prickly sida; ABUTH = velvetleaf; SEBEX = hemp sesbania.

[x] EOT = early over-the-top (coty.- to 1-lf cotton); LOT = late over-the-top (3- to 4-lf cotton); DIR = post-directed (10-in. cotton); LAYBY = post-directed (20-in. cotton).

[w] Not significant.

ARKANSAS SPIDER MITES, THEIR WILD HOST PLANTS, AND CHEMICAL CONTROL

Donald C. Steinkraus, Jon Zawislak, Gus Lorenz, and Jeff Welch[1]

RESEARCH PROBLEM

Every year some fields in Arkansas, particularly fields in the the northeast, have spider mite problems. Spider mite problems will undoubtedly increase during boll weevil eradication in Arkansas because mite outbreaks are frequently initiated by application of insecticides to cotton (Gonzales *et al.*, 1982). Little is known about the sources of mite infestations in Arkansas cotton. Identification of the most important weed hosts of spider mites may help Arkansas growers reduce mite colonization of cotton fields. The objectives of this study were to identify the weed species surrounding Arkansas cotton fields colonized by mites, and to test selected miticides in the field for control of spider mites in Arkansas cotton. A long-term goal of this project is to determine why certain areas and fields in Arkansas are prone to mite infestation.

MATERIALS AND METHODS

Survey of Mites in Arkansas Weeds

Two commercial fields located in northeast Arkansas near Lepanto in Poinsett County were chosen because of their annual outbreaks of spider mites. Field 1 was planted 16 May and Field 2 was planted 20 May 1998, both with 'Stoneville BXN-47' cotton. Counts of mites on weeds surrounding the cotton fields were made weekly from 2 June, when the cotton was in the cotyledon stage, until 23 July 1998. Fields were very dry and dusty throughout most of the observation period. Weeds growing within 25 meters of the edges of the cotton fields were identified and inspected for spider mites. When possible, at least five specimens of each weed species and five leaves on each plant were examined with 10X hand lenses and the number of mites counted.

Miticide Test

A test was conducted in a commercial cotton field heavily infested with mites, near Blakemore, Lonoke County, to compare the efficacy of six miticides on spider mites. Cotton (Stoneville BXN-47) was planted 27 April in 38-in. rows in Rilla silt loam. Plots, 4 rows by 30 ft long, were marked with flags in the field. Each plot was separated

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by four rows on the sides and 15 ft on the ends. Treatments were arranged in a randomized complete block design with four replications. Miticides were applied on 17 June 1998 with a six-nozzle handboom CO_2-charged backpack sprayer calibrated to deliver 10.5 gpa at 40 psi with TX-6 nozzles. The six miticides selected for these tests and the rates applied were: Capture at 6.4 oz/acre; Comite at 2 pt/acre; Curacron at 1 pt/acre; Kelthane at 3 pt/acre; Pirate at 4.2 oz/acre; Pirate at 6.4 oz/acre; and Zephyr at 6 oz/acre. Water was used as a treatment for the control plots. The plants were an average height of 12 nodes on 17 June. No rain fell during the test providing excellent conditions for evaluating the miticides. Mite counts were made prior to treatment and at 3, 7, and 14 DAT on 10 randomly-selected leaves from the center two rows of each plot using mainstem leaves six nodes beneath the first fully expanded leaf. Counts were made by placing a linen tester immediately to the left of the midrib vein on the underside of each leaf and counting all live immature and adult mites within a 1.5 cm^2 area. Data were analyzed by ANOVA and LSD t-tests (SAS 1988).

RESULTS AND DISCUSSION

Survey of Mites in Arkansas Weeds and Cotton

A total of 29 weed species were identified and examined for mites adjacent to cotton fields. Of these, only nine species were found hosting mites. Two-spotted spider mites were first found on 3 June on Palmer amaranth (a pigweed) about three weeks before they were found on cotton. The most important weed host on all dates was Palmer amaranth, *Amaranthus palmeri*. When goosegrass (*Eleusine indica*), curly dock (*Rumex crispus*), and hedge bindweed (*Convolvulus arvensis*) occurred in close proximity to infested Palmer amaranth, they also supported mite populations. Overall, an average of 2.2 mites per leaf (n=418) were found on Palmer amaranth between 2 June and 23 July. On 18 June and 10 July, means of 10.1 (n=18) and 16.4 (n=25) mites per leaf were found on Palmer amaranth. Frequently small (1 in.), inconspicuous individuals of Palmer amaranth supported heavy mite populations. It appeared that mites left heavily-colonized Palmer amaranth and moved onto other weed species and onto cotton. This suggests that early-season control of Palmer amaranth might lessen mite infestations in cotton. Road and field dust is known to reduce natural enemies, resulting in mite outbreaks along dusty roads (Bartlett, 1951) and appeared to be a factor in the development of mite populations on weeds and cotton in Arkansas.

Miticide Test

All miticides significantly reduced mite numbers at 3 and 7 DAT compared with the water-treated check plots (Table 1). Overall, Kelthane, Zephyr, Comite, and Pirate all provided good control of spider mites on cotton, with Capture providing intermediate control, and Curacron appearing to flare mite numbers. In California, the use of pyrethroids and organophosphates for mite control on cotton is not recommended (Godfrey *et al.*, 1996). They report that these materials frequently result in short-term population reductions followed by rapid resurgence of mite populations exceeding pretreatment levels. Because Capture (bifenthrin) is a pyrethroid and Curacron (prophenofos) is an organophosphate, these materials may flare mites in Arkansas.

PRACTICAL APPLICATION

The survey of weed species surrounding cotton fields in Poinsett County revealed that Palmer amaranth, possibly in conjunction with dusty conditions, is an important host of the two-spotted spider mite. Early season control of this weed by herbicides or physical methods may help reduce mite infestations in cotton. This information could enable growers and scouts to identify and destroy potential mite habitats before mite populations develop and subsequently enter cotton fields. Early season border sprays with Zephyr, Comite, or Kelthane, or other efficacious miticides, may also reduce mite colonization of cotton. Zephyr, Comite, and Kelthane all provided excellent control of spider mites for two weeks. In this test, Curacron appeared to have the potential to flare mite populations. The results of this miticide test enable Arkansas growers to make informed decisions regarding which commercial chemicals to use when treating fields for infestations of spider mites.

ACKNOWLEDGMENT

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Table 1. Mean number of live mites observed per 1.5 cm^2 area of cotton leaf, after treatment with selected miticides in 1998.

			Live mites		
Treatment	Rate/acre[y]	AI/acre[x]	3 DAT	7 DAT	14 DAT
			---- (mean no. live mites/1.5 cm^2)[z] ---		
Capture 2 EC	6.4 oz	0.1	0.57 c	1.25 c	1.80 c
Comite 73.6%	2 pt 1.6	1.02 c	0.65 c	0.40 cd	
Curacron 8 EC	1 pt 1.0	2.87 b	5.27 b	11.10 a	
Kelthane 35 MF-B	3 pt 1.5	0.25 c	0.12 c	0.17 d	
Pirate 3 SC	4.2 oz	0.1	0.30 c	0.70 c	1.55 cd
Pirate 3 SC	6.4 oz	0.15	0.55 c	0.47 c	1.52 cd
Zephyr 0.15 EC	6 oz 0.009	3.22 b	0.15 c	0.20 d	
Control	water	—	6.32 a	7.15 a	4.72 b
LSD (P = 0.05)			1.0	1.1	1.4
F			29.2	43.9	52.4
$P > F$			0.0001	0.0001	0.0001

[z] All live mites were counted in a 1.5 cm^2 leaf area to left of midvein beneath leaf, on 10 randomly chosen mainstem leaves six nodes below first fully expanded leaf per plot.

[y] Formulation/acre.

[x] Means within a column followed by the same letter(s) are not significantly different (LSD, $P < 0.05$).

EVALUATION OF INSECTICIDES AND COMBINATIONS FOR COTTON APHID CONTROL IN SOUTHEAST ARKANSAS

Marwan S. Kharboutli and Charles T. Allen[1]

RESEARCH PROBLEM

Much of the information in the literature about the effectiveness of the available cotton aphid insecticides in Arkansas is five to six years old. Numerous scientists have reported poor aphid control with many organophosphate insecticides, rapid aphid resurgence following insecticide treatments, and aphid induced fruit shed due to plant stress. The purpose of this study was to examine the efficacy of various insecticides on aphid populations.

BACKGROUND INFORMATION

Cotton aphids (*Aphis gossypii* Glover) occur each year on Arkansas cotton. Infestations of moderate to high levels may have a great impact on lint yield and quality. Aphids may or may not be present long enough or in high enough populations to cause economic damage to the crop. Often, cotton aphid populations reach high levels and then quickly disappear due to infections by an aphid parasitic fungus, *Neozygites fresenii*. Cotton aphids reproduce rapidly and are capable of developing resistance to insecticides very quickly. When populations reach damaging levels and treatment is needed, growers need current information as to how well the available aphid insecticides work.

RESEARCH DESCRIPTION

These aphicide efficacy studies werecarried out over a three-year period; 1996, 1997, and 1998. The 1996 test was conducted on the Scott Day farm near Winchester, the 1997 test was conducted on the Paul Johnson farm near Grady, and the 1998 test was conducted on the Mike Norris farm near Dumas. In all three tests, cotton was maintained using standard production practices and sprayed using a CO^2-charged hand boom sprayer (63 to 72 gallons total spray per acre). Randomized complete block designs with four replications were used. Data collected were analyzed using ANOVA and Duncan's Multiple Range Test at the 5% level of significance.

The 1996 test was conducted on irrigated NuCotn 33B planted on 27 April 1996. Pretreatment counts (12 July 1996) indicated an average of 460 aphids per leaf. The

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test was terminated after 15 July 1996 because the aphid parasitic fungus, *Neozygites fresenii*, had decimated the aphid populations in all plots.

The 1997 test was conducted on irrigated 'Deltapine NuCotn 33B' planted on 3 May 1997. Pretreatment counts (23 July 1997) averaged 316 aphids per leaf. The test was terminated on 26 July 1997 due to the outbreak of the aphid fungus which greatly reduced aphid numbers in the field.

The 1998 test was conducted on irrigated 'Stoneville BXN 47' planted on 9 May 1998. Pretreatment counts (21 July 1998) indicated aphid population to exceed 1000 aphids per leaf. The test was terminated on 24 July 1998 due to aphid population reduction from the parasitic fungus.

RESULTS AND DISCUSSION

All treatments, except in 1998, significantly reduced aphid numbers compared with the untreated check (Tables 1, 2, and 3). Because of the swift crash of aphid population in 1998, only knock down could be assessed. Furadan 4F was consistently a strong aphid control treatment in these studies and gave quick and substantial aphid control. Even with the massive outbreak of the fungus in 1998, Furadan exhibited strong aphid knock down. However, doubling the rate of Furadan 4F from 8 to 16 oz did not yield significantly greater aphid control. Chemicals that also proved effective against aphids were Lannate and Bidrin + Ovasyn. Dimethoate and Orthene + Lorsban gave the poorest control. Provado seemed to give good aphid control but not until two or more days after treatment, indicating slow action.

The outbreak of the aphid fungus limited our ability to study the residual effects of treatments most years and may have been an especially important limitation with slow-acting products. Beside the lethal effect of Provado on sucking insects, its sublethal antifeeding effects have been examined by numerous scientists. Nauen (1995) reported on the sublethal antifeeding effect of Provado on aphids and found that the antifeeding effects may not be noticed until yields are taken. Therefore, aphid counts in plots treated with Provado may not accurately reflect the effect of their abundance on cotton yield.

This study suggests that in the absence of the insect pathogenic fungus, adequate aphid control may be obtained with several insecticides.

PRACTICAL APPLICATION

Furadan provides excellent cotton aphid control in southeast Arkansas. Its use has been limited by the triggering Section 18 labeling it has been under and the lengthy reentry intervals during which protective clothing is required. Lannate (a Bidrin-Ovasyn combination), Provado, and Bidrin can be used to obtain satisfactory aphid control. These products and combinations are legal for aphid control in cotton and have less restrictive reentry intervals than Furadan.

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Table 1. Average number of aphids per leaf (top and middle canopy leaves)[z] following treatment with various insecticides. Winchester, 1996.

Treatment	Rate/acre	Number of aphids: 1-DPT[y]	3-DPT	Summary of 1 & 3
	oz form. (lb ai)	------------------ (No. aphids/leaf) ----------------		
Check		547 a	97 a	322 a
Orthene 90S +	8.0 (0.45) +			
Lorsban 4E	8.0 (0.25)	293 b	84 a	188 b
Dimethoate 4EC	8.0 (0.25)	230 b	56 ab	143 bc
Bidrin 8	4.0 (0.25)	108 c	53 ab	80 cd
Provado 1.6 F	2.0 (0.025)	112 c	8 bc	60 cd
Bidrin 8	8.0 (0.5)	94 c	25 bc	60 cd
Lannate LV	6.7 (0.126)	65 c	20 bc	43 d
Provado 1.6 F	3.75 (0.047)	72 c	9 bc	40 d
Bidrin 8 +	8.0 (0.5) +			
Ovasyn	10.7 (0.125)	48 c	10 bc	29 d
Lannate LV	13.2 (0.248)	22 c	15 bc	19 d
Furadan 4F	4.0 (0.125)	18 c	1 c	10 d
Furadan 4F	8.0 (0.25)	18 c	1 c	9 d

[z] Means in columns followed by the same letter(s) are not significantly different (5% level of significance).
[y] DPT = Day(s) Post Treatment.

Table 2. Average number of aphids per leaf (top and middle canopy leaves)[z] following treatment with various insecticides. Grady, 1997.

Treatment	Rate/acre	Number of aphids 1-DPT[y]	3-DPT	Summary of 1 & 3
	oz form. (lb ai)	-------------------- (No. aphids/leaf)		---------------------
Check		165 a	111 a	80 a
Provado 1.6 F	2.08 (0.026)	106 b	13 b	11 b
Provado 1.6 F	3.75 (0.047)	81 bc	16 b	8 b
Bidrin 8	4.0 (0.25)	50 cd	9 b	8 b
Bidrin 8	8.0 (0.50)	41 cd	7 b	4 b
Provado 1.6 F	5.84 (0.073)	33 d	13 b	3 b
Lannate LV	8.0 (0.15)	19 d	9 b	8 b
Lannate LV	16.0 (0.30)	17 d	3 b	6 b
Furadan 4 F	8.0 (0.25)	13 d	0.7 b	0.7 b
Furadan 4 F	16.0 (0.50)	12 d	0.2 b	0.1 b

[z] Means in columns followed by the same letter(s) are not significantly different (5% level of significance).
[y] DPT = Day(s) Post Treatment.

Table 3. Average number of aphids per leaf (top and middle canopy leaves)[z] following treatment with various insecticides. Dumas, 1998.

Treatment	Rate/acre	Number of aphids 1-DPT[y]	3-DPT	Summary of 1 & 3
	oz form. (lb ai)	--------------- (No. aphids/leaf)		----------
Bidrin 41 WP	16.0 (0.4)	28.5 a	11.3 a	22.8 a
Bidrin 8 E	6.4 (0.4)	19.2 ab	22.3 a	20.2 ab
Provado 1.6 F	2.0 (0.026)	16.0 ab	14.4 a	15.4 ab
Lannate 2.4 L	8.0 (0.15)	11.2 ab	13.4 a	11.8 ab
Check		7.7 ab	10.5 a	8.6 ab
Lannate 2.4 L	16.0 (0.30)	5.2 b	4.2 a	4.9 ab
Lorsban 4 E +				
methyl parathion 4E	16.0 (0.5) +			
8.0 (0.25)	3.5 b	5.4 a	4.2 ab	
Furadan 4 F	8.0 (0.25)	0.5 b	1.1 a	0.7 b

[z] Means in columns followed by the same letter(s) are not significantly different (5% level of significance).
[y] DPT = Day(s) Post Treatment.

1998 BOLLWORM AND TOBACCO BUDWORM CONTROL STUDIES

Marwan S. Kharboutli, Charles T. Allen, Charles Capps, Jr., and Larry Earnest[1]

RESEARCH PROBLEM

Bollworm and tobacco budworm have developed resistance to all classes of insecticides to which they have been repeatedly exposed. Alternating insecticides and developing new ones is important in slowing down resistance development. Also, research is needed to test the efficacy of new insecticides and compare economic benefits with the old ones.

BACKGROUND INFORMATION

The cotton bollworm, *Helicoverpa zea*, and the tobacco budworm, *Heliothis virescens*, are well established as two of the most important cotton pests in the United States (Luttrell, 1995). Insecticide resistance is a major factor responsible for our inability to manage these two insects (Sparks *et al*., 1993). There is a continual need for new insecticides with new modes of action. The purpose of this study was to examine the efficacy of several new insecticides with novel modes of action as compared to traditional insecticides against cotton bollworm and tobacco budworm.

MATERIALS AND METHODS

Five tests were conducted in 1998 at the Southeast Research and Extension Center, Rohwer Division, to evaluate the efficacy of several chemicals on cotton bollworm and tobacco budworm. Tests were done using small plots and randomized complete block designs with four replications. Tests were initiated when eggs or small worm densities were at or approaching threshold levels. The sprays were applied at 40 PSI and 10 gallons of finished spray per acre with appropriate rates of surfactants. Post-treatment counts were made three days after treatment by examining 25 terminals, 25 squares, and 25 bolls per plot and recording number of eggs, worms, and damaged parts. Lint yields were determined by machine harvesting the middle two rows of the plots. Data were processed using the Pesticide Research Manager 5 (PRM) and CoStat (CoStat Statistical Software). Analysis of Variance was run and the Least Significant Difference (LSD) was used to separate the means.

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Tests I and II

The primary worm pest in these tests was cotton bollworm. For Test I 'Suregrow 125' was planted on 9 June 1998 and for Test II 'Stoneville 474' was planted on 5 May 1998. Treatments were applied on 17 July and 27 July 1998 using a two-row backpack sprayer with two Tx4 hollow cone nozzles / row. Cotton was harvested on 30 September 1998.

Tests III, IV, and V

Tobacco budworm was the predominant worm pest in Tests III and V. The tests were conducted on Suregrow 125 planted on 9 June 1998. Treatments in Test III were applied on 10 August, 17 August, and 24 August 1998, those in Test IV were applied on 15 August, 21 August, and 29 August 1998, and those in Test V were applied on 11 August, 17 August, and 22 August 1998. Insecticides were applied using a high clearance sprayer. Cotton was harvested on 6 November 1998.

RESULTS AND DISCUSSION

Bollworm Control

All treatments in Test I significantly reduced bollworm counts and square and boll damage (Table 1). Data from terminals, squares, and bolls showed similar efficacy trends. New compounds such as Tracer and Steward were as effective in reducing worm counts and damage as Baythroid. In Test II, Baythroid at 0.037 lb ai / acre appeared to be quite effective against the bollworm.

Tobacco Budworm Control

Worm counts and terminal, square, and boll damage tended to be numerically low in plots treated with Tracer or Pirate (Table 2). Worm counts and damage in plots treated with pyrethroids were relatively high, indicative of the 90% tobacco budworm population in the test. Worm reduction and damage prevention trends with Steward were good, but consistently trended higher than Tracer. Confirm, in Test V, was somewhat more effective than Karate on tobacco budworm, although, increasing the Confirm rate did not result in an increased measure of control.

Lint Yield

In Test I against bollworms, only a combination treatment of Baythroid and Tracer (1 / 2x rate), provided a significant increase in lint yield compared to the check (Table 1). The treatment combination of Baythroid and Tracer, Baythroid and Pirate, in addition to the Steward treatments produced the highest numerical yields in this test. Plots treated with Steward yielded numerically higher (150 lb more cotton lint) than all but the most effective tank-mixes. Steward also had good efficacy on plant bugs and beet armyworm (Kharboutli *et al.*, 1999). This may have contributed to the numerically higher yield in the Steward-treated plots. All the pyrethroids used in Test II tended to produce more cotton than did the check plots.

In Tests III and IV where tobacco budworm was the dominant worm pest, lint yield in plots treated with Steward ranked among the highest for all treatments

(Table 2). Plots treated with Tracer had numerically the lowest worm count and damage but did not produce similarly high yields, possibly due to the presence of other yield influencing insects in plots such as plant bugs. In Test V, plots treated with Confirm at 0.125 lb ai/acre produced more cotton than did the check plots. Yields in pyrethroid-treated plots were not different from those in check plots.

PRACTICAL APPLICATION

Pyrethroids are still effective against cotton bollworm. Among the new insecticides, Tracer is highly efficacious against bollworm as is Pirate in combination with Baythroid. Steward also provides good control of bollworm.

Tracer and Steward appear to be the chemicals of choice against tobacco budworm. In addition to having good worm activity, Steward is a broad-spectrum insecticide with activity on insects such as plant bug and beet armyworm. Significant increases in lint yields were obtained in plots treated with Steward compared to other treatments used in this study.

ACKNOWLEDGMENTS

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Table 1. Cotton bollworm survival following insecticidal sprays as indexed by insect count, damage, and lint yield[z], Rohwer.

Treatment	Rate	Bollworms[y]			Damage[y]			Lint Yield
		Term.	Squares	Bolls	Term.	Squares	Bolls	
	(lb ai/acre)							(lb/acre)
Test I								
Check		1.40 a	0.88 a	1.40 a	2.80 a	4.40 a	3.30 a	648 b
Steward 1.25SC	0.11	0.38 ab	0.13 b	0.00 b	1.10 ab	0.63 b	0.25 b	817 ab
Tracer 4SC	0.067	0.13 ab	0.13 b	0.00 b	0.50 b	0.75 b	0.50 b	800 ab
Baythroid 2EC	0.033	0.13 ab	0.00 b	0.63 b	0.38 b	0.50 b	0.75 b	742 ab
Pirate 3SC + Baythroid 2EC	0.2 + 0.028	0.13 ab	0.00 b	0.13 b	0.63 b	0.00 b	0.25 b	713 ab
Steward 1.25SC	0.09	0.00 b	0.25 b	0.13 b	0.25 b	0.38 b	0.88 b	798 ab
Pirate 3SC + Baythroid 2EC	0.25 + 0.028	0.00 b	0.00 b	0.00 b	0.50 b	0.63 b	0.00 b	834 ab
Tracer 4SC + Baythroid 2EC	0.031 + 0.028	0.00 b	0.00 b	0.25 b	0.00 b	0.00 b	0.25 b	847 a
Test II								
Check		1.90 a	0.38 a	0.38 a	1.90 a	2.50 a	2.80 a	649 b
Karate Z 2.08 EC	0.033	0.25 b	0.50	0.00 a	0.50 a	0.75 b	0.38 b	860 ab
Fury 1.5 EC	0.039	0.13 b	0.00 a	0.00 a	0.75 a	0.50 b	0.50 b	834 ab
Decis 1.5 EC	0.025	0.13 b	0.00 a	0.13 a	0.75 a	0.75 b	0.63 b	912 a
Baythroid 2 EC	0.037	0.00 b	0.00 a	0.00 a	0.38 a	0.00 b	0.75 b	851 ab

[z] Means in columns followed by the same letter(s) are not significantly different at the 5% level of significance.
[y] Worm count and damage are seasonal means of averages of 25 plant parts three days after treatments (two applications).

Table 2. Tobacco bollworm (TBW) survival following insecticidal sprays as indexed by insect count, damage, and lint yield[z], Rohwer.

		Bollworms[y]			Damage[y]			
Treatment	Rate	Term.	Squares	Bolls	Term.	Squares	Bolls	Lint Yield
	(lb ai/acre)							(lb/acre)
Test III								
Baythroid2 EC	0.03	3.00 a	1.80 abc	1.30 abc	5.40 abc	2.80 ab	1.80 a	808 cde
Check		2.10 ab	2.30 a	1.70 ab	6.7 a	3.7 a	2.1 a	708 de
Steward 1.25 SC	0.11	1.80 bc	0.84 abc	0.92 a-d	2.90 d	1.70 ab	1.30 ab	1041 a
Baythroid 2 EC + Orthene 90 S	0.03 + 0.5	1.70 bcd	2.10 ab	1.80 a	6.20 ab	3.30 a	2.00 a	920 abc
Pirate 3 SC + Curacron 8 L	0.25 + 0.5	1.60 bcd	1.20 abc	1.20 a-d	5.80 abc	3.40 a	1.40 ab	770 cde
Pirate 3 SC	0.35	1.50 bcd	0.58 bc	0.58 bcd	5.30 abc	1.80 ab	1.10 ab	673 e
Baythroid 2 EC + Pirate 3 SC	0.03 + 0.35	1.40 bcd	1.60 abc	0.66 a-d	4.40 bcd	2.60 ab	1.10 ab	894 abc
Steward 1.25 SC	0.09	1.20 bcd	1.00 abc	1.10 a-d	5.30 abc	1.50 ab	1.20 ab	1011 ab
Pirate 3 SC + Curacron 8 L	0.2 + 0.5	0.75 cd	1.75 abc	1.30 abc	4.80 a-d	3.10 ab	2.00 a	718 de
Baythroid 2 EC + Steward 1.25 SC	0.03 + 0.09	0.67 cd	1.20 abc	1.00 a-d	4.10 bcd	1.80 ab	1.40 ab	1048 a
Baythroid 2 EC + Tracer 4 SC	0.03 + 0.031	0.59 cd	0.33 c	0.42 cd	3.90 cd	1.10 b	0.25 b	870 bcd
Tracer 4 SC	0.063	0.42 d	0.33 c	0.10 d	2.90 d	1.50 ab	0.25 b	728 de
Test IV								
Karate 1 EC	0.03	2.00 a	1.50 ab	2.50 a	6.6 a	3.20 a	3.50 a	689 b
Baythroid 2 EC	0.03	1.90 a	2.10 a	2.00 ab	4.6 ab	3.80 a	2.80 ab	626 b
Check		1.60 ab	1.50 ab	1.40 abc	6.3 a	3.30 a	2.80 ab	648 b
Steward 1.25 SC	0.11	1.50 ab	0.92 ab	1.00 bc	4.6 ab	2.70 a	1.90 bc	996 a
Steward 1.25 SC	0.09	1.30 ab	1.20 ab	1.50 abc	5.3 ab	2.10 ab	2.00 bc	781 ab
Tracer 4 SC	0.067	0.17 b	0.33 b	0.42 c	3.3 b	0.67 b	0.75 c	821 ab
Test V								
Check		3.0 a	2.2 a	1.5 abc	5.9 a	3.2 ab	2.3 ab	694 b
Karate 2 SC	0.033	3.0 a	2.1 a	2.5 a	7.4 a	4.2 a	3.6 a	742 ab
Confirm 2 F	0.0625	2.8 a	1.5 a	1.1 c	6.5 a	2.4 b	1.5 b	785 ab
Confirm 2 F	0.125	2.6 a	2.0 a	1.3 bc	5.6 a	2.7 b	1.4 b	824 a
Confirm 2 F + Karate 2 SC	0.125 + 0.033	2.4 a	2.0 a	2.3 ab	5.5 a	4.1 a	2.8 ab	768 ab

[z] Means in columns followed by the same letter(s) are not significantly different at the 5% level of significance.
[y] Worm count and damage are seasonal means of averages of 25 plant parts three days after treatments (two applications).

THRIPS CONTROL IN ULTRA-NARROW-ROW COTTON

Charles T. Allen, Marwan S. Kharboutli, Larry Earnest, and Charles Capps, Jr.[1]

RESEARCH PROBLEM

Ultra-narrow-row (UNR) production systems may have the potential to compete with soybeans, corn, and rice on soils previously considered unsuitable for cotton production. Managing production costs prudently is essential in an economically successful UNR system. Insecticide sprays, which constitute a sizable expense in the conventional system, must be kept at a minimum. Much work is needed on insect management of UNR cotton because the nature of insect injury on UNR cotton is largely unknown. While high stand counts and earliness are critical to success in UNR production, cost control is equally critical. Questions such as "are thrips control treatments needed?" are important and unresolved.

BACKGROUND INFORMATION

The poorly drained clay soils of southeast Arkansas are a challenge to farmers in the area. Production of soybeans, corn, and other crops on some of these marginal soils has been economically disappointing for many growers. The development of effective new herbicides and herbicide systems for cotton has made narrow-row and ultra-narrow-row (drilled) cotton possible for these marginal fields. To be profitable, the UNR production system must be managed as a low input system. Tillage costs are reduced and insecticide savings are made possible by the shortened UNR cotton growing season. Still, efforts must be directed at keeping insect control costs at a minimum in UNR production. The need for control measures against thrips is unresolved. Although cotton plants can compensate for the early season damage inflicted by thrips if sufficient heat units are available, numerous reports have indicated that feeding by thrips reduces leaf area, plant height, stand count, plant root development, early square set, and yield in conventionally-grown cotton (Micinski *et al.*, 1990; Herbert, 1995; Roberts and Rechel, 1996). In the UNR system, later planting dates can be used because of the shortened fruiting period and are believed to be appropriate to avoid the need for expensive treatments for seedling diseases. Seedling health and rapid growth in the warm soils available at the later planting dates may allow the crop to escape

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serious thrips damage without treatment or allow growers to use short residual inexpensive foliar treatments for thrips control. This study was conducted to compare various thrips control methods in the UNR system.

RESEARCH DESCRIPTION

This study was conducted over a two-year period, 1997 to 1998. In both years, a John Deere 750 no till grain drill was used to place seeds in 7.5-in. rows at a rate of about 3 seeds per ft (42.6 lb / acre). Research plots were maintained with practices conducive for the UNR production system.

In 1997, 'Stoneville 474' was planted on 15 May 1997 in plots that were 10 ft wide by 240 ft long. Five thrips control treatments plus an untreated check were arranged using a randomized complete block design with four replications. Two of the six treatments (Gaucho and Orthene) were seed treatment insecticides that had been applied to the seed when it was processed. Temik 15G (10 lb / acre) and Thimet 20G (11 lb / acre) comprised our in-furrow granular treatments which were applied using the grass seed hopper on the planter. Orthene 90S (0.225 lb / acre) was applied as liquid foliar treatment in 5.76 gallons per acre on 12 June (rained off) and 16 June 1997.

Thrips samples were taken on 2 June and 19 June 1997 by cutting 10 plants per plot about an inch above the soil line and placing the plants in Ziplock plastic bags. The samples were then washed thoroughly using soapy water and filtered onto 11-cm diameter filter paper. Thrips were then counted under 10 and 20X magnification in the laboratory. Stand counts were made by counting all plants in 9 ft^2 on 5 June and 9 July 1997. Height measurements were taken for 10 plants per plot on 9 July 1997. Plants were visually rated for appearance on 9 July 1997 on a scale of 0 to 10 with 10 being a perfect plant. Yield data were collected on 10 October 1997 by hand harvesting the seedcotton from 9 ft^2 sections of each plot.

In 1998, 'Stoneville 373' was planted on 4 June 1998. The study was conducted using an Unreplicated Strip Test with four subplots / treatment. Each subplot was 10 ft wide and 40 ft long. Seven treatments plus a check were used. Gaucho and Orthene were two seed treatment insecticides which had been applied to the seed when it was processed. Temik 15G (7 and10 lb / acre) and Thimet 20G (10 lb / acre) comprised our in-furrow granular treatments which were applied using a grass seed hopper. Orthene 90S was applied foliarly in 10 GPA on 16 June 1998 in combination with Orthene ST.

Thrips samples were taken on 15 June, 19 June, 22 June, 29 June, and 7 July 1998 by cutting 10 plants per subplot about an inch above the soil line and placing the plants in Ziplock plastic bags. The thrips were washed from the plants in the plastic bags using soapy water and isopropyl alcohol. Thrips were then collected onto 7-cm filter paper using Buchner funnels. A vacuum pump was used to facilitate rapid filtration of the thrips from the wash solution. Thrips were then identified and counted under 10 and 20X magnification in the laboratory. Stand counts were made by counting all plants in 3 row ft on 8 July 1998. Heights of 5 plants per subplot were taken on 23 July 1998. Lint cotton yield was determined by hand harvesting the seed cotton from 9 ft^2 sections of each subplot on 21 October 1998. Data were analyzed using ANOVA (1997) and

Kruskall-Wallis (1998) and means were separated by the Least Significant Differences at the 5% level of significance.

RESULTS AND DISCUSSION

In 1997, no significant differences in thrips counts were observed among treatments (Table 1). However, Temik, Thimet, and Gaucho tended to give long-term thrips suppression and positive plant responses in growth and appearance. Orthene seed treatment and the foliar Orthene treatment appear to have given briefer periods of thrips suppression based on thrips counts, plant heights, and visual rating data. No significant differences in stand counts were observed. Plant heights tended to be numerically higher in the Orthene foliar-treated plots and lower in Orthene seed treatments plots (Table 1). Lint yield, however, did not follow the thrips count and plant damage pattern. Lint yields were highest in the Orthene seed-treatment plots, the treatment which had numerically the highest thrips counts and one of the poorest visual ratings. Regression analysis showed no significant relationship between thrips numbers, plant height, fruit per plant,visual ratings, or yield. Plant population was significantly correlated with yield (R^2=.91). Yields from plots with plant population of about 110,000 plants/acre were higher than yields from plots with plant populations of above 130,000 or 140,000 plants/acre.

In 1998, all treatments significantly reduced thrips counts compared to the untreated check (Table 2). Temik, Thimet, and the combination treatments gave the best control of all treatments while Gaucho ST and Orthene ST appeared to be the weakest of all control methods. All treatments produced similar stand counts to the check (Table 2). The combination treatment of Orthene ST+Orthene foliar produced the highest stand counts while Orthene ST produced the lowest. None of the treatments significantly affected the first fruiting node position (Table 2). All treatments produced similar plant heights to the untreated check (Table 2). Plant heights were highest in plots treated with Temik (1.5 lb ai/acre) and lowest in the Orthene ST+Orthene foliar plots. All treatments produced similar lint yields to the untreated check (Table 2). Thimet produced numerically the highest yield while Gaucho ST produced the lowest lint yield (Table 2).

PRACTICAL APPLICATION

Thrips caused plant injury and slowed growth in UNR cotton as in conventional cotton. Temik, Thimet, and Gaucho ST seemed to provide good thrips control and plant protection, however, thrips counts and damage did not correlate well with lint yield. The data indicate thrips treatments may not be necessary on UNR cotton.

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Table 1. Thrips control, plant response, and lint yield following thrips control treatments in ultra-narrow-row cotton[z], Rohwer.

Treatment	Rate	Thrips 2 June	Thrips 19 June	9 July Plants	9 July Height	9 July Plant rating[y]	10 October Lint yield
	(lb ai/acre)	----- (no./plant) -----		(no./acre)	in)		(lb/acre)
Check	-	0.95 a	2.2 a	142,780 a	22 b	4.1 b	840 b
Orthene ST	-	0.58 a	2.5 a	110,715 a	23 a	4.1 b	1017 a
Gaucho ST	-	0.35 a	1.1 a	135,520 a	23 a	6.0 a	988 a
Thimet 20G IF	2.0	0.33 a	1.3 a	142,780 a	23 a	6.0 a	889 ab
Temik 15G IF	1.65	0.03 a	0.9 a	136,125 a	24 a	5.5 a	966 ab
Orthene 90S F[x]	0.225	-	0.5 a	145,805 a	19 b	4.1 b	851 b

[z] Means in columns followed by the same letter are not significantly different (P = 0.05).
[y] Rating scale of 1 to 10 with 10 being a perfect plant.
[x] Foliar Orthene applied on 12 June (rained off) and 16 June 1997.

Table 2. Thrips control, plant response, and lint yield following thrips control treatments in ultra-narrow-row cotton[z], Rohwer,1998.

Treatment	Rate	Thrips	8 July Plants	23 July Height	28 July First fruit node	21 October Lint yield
	(lb ai/acre)	(no./plant)	(no./acre)	(in.)		(lb/acre)
Check	-	12.9 a	139,392 ab	20.6 ab	5.8 a	1091 ab
Gaucho ST	-	8.0 b	133,584 ab	19.6 b	5.9 a	825 b
Orthene ST	-	6.7 bc	121,968 b	20.1 ab	6.1 a	982 ab
Gaucho ST + Orthene ST	-	5.0 cd	162,624 ab	21.3 ab	6.0 a	998 ab
Orthene ST + Orthene 90S[x]	0.2	4.4 cd	209,088 a	19.1 b	5.8 a	1113 ab
Thimet 20G	2.0	3.6 d	168,432 ab	19.4 b	5.5 a	1152 a
Temik 15G	1.05	2.8 d	156,816 ab	21.2 ab	5.6 a	923 ab
Temik 15G	1.5	2.4 d	180,048 ab	22.5 a	5.7 a	993 ab

[z] Means in columns followed by the same letter are not significantly different (P = 0.05).
[y] Seasonal mean counts of five sampling date.
[x] Orthene applied on 16 June 1998.

INSECTICIDE TERMINATION REGIMES IN SOUTHEAST ARKANSAS

Charles T. Allen and Marwan S. Kharboutli[1]

RESEARCH PROBLEM

Insecticides are needed for the economical production of cotton (Gossypium hirsutum L.) in southeast Arkansas. However, they are an expensive input and add to the cost of producing the crop. Until recently, there has not been a reliable system to help farmers terminate insecticide use as early as possible without sacrificing yield.

BACKGROUND INFORMATION

The COTMAN (COTton MANagement) system provides a technique for monitoring cotton growth and fruit development during the season and assisting with end-of-season management decisions (Oosterhuis *et al*., 1996). Due to its indeterminate growth habit, an optimum balance of fruit and vegetative growth needs to be maintained for maximum cotton yield. COTMAN can be used to provide information to help keep cotton plant growth and fruit loads in balance.

COTMAN uses Nodes Above White Flower (NAWF) as the basis to determine crop maturity. Research has shown NAWF is closely related with variations in canopy photo-synthesis (Oosterhuis *et al*., 1992) and the economic value of flowers rapidly decreases at NAWF < 5 (Bourland *et al*., 1992; Lammers, 1996). The date that a crop attains NAWF= 5 is the flowering date of the last effective boll population (Oosterhuis *et al*., 1996). Beyond that point, the number of heat units accumulated forms the basis on which to predict the date on which the last effective boll population will be safe from insect injury and insecticide applications can be safely terminated. Research has shown that cotton bolls which have accumulated 350 heat units (DD60s) or more since bloom are safe from significant loss by bollworm / budworm or boll weevil damage. Therefore, COTMAN recommends insecticide termination at NAWF=5 + 350 heat units, unless beet armyworm or fall armyworm infestations are present. However, farmers in fear of late-season damage to bolls often continue insecticide applications beyond the COTMAN termination date. The available research indicates that there is no economic advantage to using insecticides after the COTMAN termination date, but few studies have been conducted in southeast Arkansas. This study was conducted to examine the effect of insecticide termination date on yield and economic returns.

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RESEARCH DESCRIPTION

Two termination tests were carried out in 1998 in Desha County. One test was conducted on the Steve Stevens farm near Backgate, and the other test was run on the Pickens Plantation, Pickens.

The Stevens test was done on 80 acres of irrigated 'Deltapine 51' planted on 7 May 1998 and maintained using standard production practices. The test was conducted using a randomized complete block design with four replications. Plots were 4 rows wide and ran across the field (average length = 1721 ft). Two insecticide termination regimes were compared: NAWF=5 + 350 heat units and the standard system, NAWF=5 + 450 heat units. NAWF=5 occurred on 2 August 1998 and NAWF=5 + 350 heat units occurred on 18 August 1998. After 18 August 1998, standard termination plots were treated with Karate (3.87 oz/acre) + Lannate LV (16.0 oz/acre) on 21 August 1998. Foliar insecticide treatments in-season were made both by ground and by aerial equipment. Prior to harvest, the plants were mapped and their height was recorded. Lint yields were determined by machine harvesting all four rows of the plots on 30 September 1998.

The test on Pickens Plantation was done on 56.9 acres of irrigated 'Stoneville 373'. Orthene-treated seed were planted on 7 May 1998 and the crop was maintained using standard production practices. The test was a randomized block design with two replications. Plots were 60 rows wide and ran across the field (average length = 822 ft). As in the Stevens test, two insecticide termination regimes were compared: NAWF=5 + 350 heat units (early termination), and NAWF=5 + 450 heat units (standard termination). NAWF=5 occurred on 17 July 1998 and NAWF=5 + 350 heat units occurred on 1 August 1998. A subsequent application, Larvin (25.6 oz/acre) was made on 10 August 1998 on the standard termination plots only. As in the Stevens test, in-season foliar insecticide applications were made using both ground and aerial equipment. Prior to harvest, the plants were mapped and their height was recorded. Lint yields were determined by machine harvesting 4 rows in each plot on 23 September 1998.

Data collected in both tests were analyzed using ANOVA and Duncan's Multiple Range Test. Variables analyzed were plant height, percent open bolls, percent green bolls, percent total bolls, lint yield, and net return. For economic comparisons, 63 cents per pound was applied to the lint yields.

RESULTS

Boll Retention

Boll retention was similar in early termination and standard termination plots (Table 1). Boll retention in the top half of the plant indicated that neither the accumulative boll retention rates nor boll retention rates for individual nodes were significantly different between the two termination regimes. There was a general trend for plants under the traditional termination system to have numerically more bolls than the system advocated by COTMAN. The only significant differences in boll retention that existed between the two termination systems were those for green bolls. Where significant differences existed, green boll retention rates were significantly higher under the traditional termination system than the early one. However, green bolls made up only a small percentage of total bolls in both tests and made little contribution to harvest.

Lint Yield

Plots in the traditional termination regime produced similar lint yield in both tests to those under the early termination system recommended by COTMAN (Table 2). The traditional termination system produced 18.5% more bolls than the early termination system but yielded only 4.5% more cotton.

Economic Assessments

In both the Stevens and Pickens farm tests, the economic returns after treatment costs were similar. Standard insecticide termination did not translate into higher yields or profits as compared with the early termination regime as determined by COTMAN (Table 2).

PRACTICAL APPLICATION

Insecticide termination dates as recommended by COTMAN have been validated in this study. There were no economic advantages for extending protection period from insect damage any further than that recommended by COTMAN. Plots in which insecticide applications were terminated early (at NAWF=5 + 350 heat units) were similar in boll counts, lint yields, and economic returns to plots in which insecticides were terminated in a more traditional manner (i.e., NAWF=5 + 450 heat units).

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Table 1. Boll retention in early and standard termination plots[z], Desha County, 1998.

	Node number - from top of plant[y]						
Insecticide termination	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9
Stevens Farm							
Early termination[x]	1.0 a	7.4 a	9.5 a	10.9 a	12.4 a	15.1 a	16.9 a
Standard termination[w]	3.4 a	8.5 a	12.3 a	14.8 a	15.8 a	17.3 a	19.0 a
Pickens Plantation							
Early termination[x]	4.8 a	12.3 a	9.9 a	12.0 a	17.7 a	20.8 a	25.6 a
Standard termination[w]	1.6 a	9.0 a	20.7 a	22.3 a	33.6 a	25.3 a	30.6 a

[z] Means in columns followed by the same letter are not significantly different ($P < 0.05$).
[y] Plant mapping done on 28 September and 29 September 1998 at the Stevens Farm; 17 September 1998 at the Pickens Plantation.
[x] NAWF = 5 + 350 DD60 heat units.
[w] NAWF = 5 + 450 DD60 heat units.

Table 2. Effect of insecticide termination system on lint yield and return in southeast Arkansas[z], Desha County, 1998.

Insecticide termination	Lint yield	Gross revenue[y]	Cost of extra protection	Net return
	(lb/acre)	-------------------------	($/acre)	-------------------------
Stevens Farm				
Early termination[x]	844 a	531.43 a	—	531.43 a
Standard termination[w]	888 a	559.60 a	15.75	543.85 a
Pickens Plantation				
Early termination[x]	778 a	490.14 a	—	490.14 a
Standard termination[w]	807 a	508.10 a	13.80	494.30 a
Combined data				
Early termination[x]	820.30 a	516.76 a	—	516.76 a
Standard termination[w]	861.30 a	542.60 a	15.10	527.50 a

[z] Means in columns followed by the same letter are not significantly different ($P < 0.05$).
[y] 63 cents per pound applied to lint yield.
[x] NAWF = 5 + 350 DD60 heat units.
[w] NAWF = 5 + 450 DD60 heat units.

INSECTICIDE RESISTANCE IN TOBACCO BUDWORM AND COTTON BOLLWORM IN SOUTHEAST ARKANSAS

Charles T. Allen, Marwan S. Kharboutli, and Kenneth R. Williams[1]

RESEARCH PROBLEM

Tobacco budworm and cotton bollworm have developed (or are developing) resistance to all classes of insecticides to which they have been repeatedly exposed. This resistance has made it harder for farmers to control these pests. Resistance can be slowed and control failures reduced in number if producers are aware of the status of resistance development in their area. A successful resistance management strategy depends, in part, on monitoring responses of cotton pests to insecticides for an early detection of any changes in susceptibility that may occur.

BACKGROUND INFORMATION

Cotton bollworm and tobacco budworm are two of the most damaging and difficult to manage insect pests of cotton (Gossypium hirsutum L.). Pyrethroid insecticides have for many years been used to keep the two pests under check. However, failure with tobacco budworm field control frequently occurs due to the development of insecticide resistance. Pyrethroid resistance in tobacco budworm was documented during the late 1980s in Arkansas (Plapp *et al.*, 1987) and in other states triggering the initiation of pyrethroid resistance management strategies. Widespread monitoring of male tobacco budworm moths for pyrethroid resistance has been conducted using the glass vial technique (Plapp *et al.*, 1987) commonly referred to as the adult vial test (AVT). A five-year study showed that pyrethroid resistance in tobacco budworm in southeast Arkansas has progressed to the point of basically no control from 1994 to 1998 (Williams, 1999). Tobacco budworm has also developed resistance to other insecticides, and by 1993, it had developed resistance to the three major insecticide classes (Organophosphate, Carbamates, and Pyrethroids) used against it. Susceptibility of cotton bollworm to pyrethroids has always been high although recent reports (Bagwell *et al.*, 1998) indicate that susceptibility may be changing. The purpose of this study was to examine the susceptibility of tobacco budworm and cotton bollworm moths to cypermethrin, profenofos (Curacron), and Tracer in southeast Arkansas.

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MATERIALS AND METHODS

This study was conducted over a three-year period from 1996 to 1998. Wire cone traps baited with artificial sex pheromone lures were used to collect male tobacco budworm and bollworm moths from May through September. Traps were placed on cotton field borders in Drew, Desha, and Ashley counties in southeast Arkansas. Moths were collected from 14 locations in Drew/Desha counties and 10 locations in Ashley County. Moths from a one-night capture were removed from the traps early in the morning to prevent excessive heat stress and transported to an air-conditioned lab for testing. Only moths that appeared young and healthy were used in resistance tests.

Pretreated glass scintillation vials (20 ml) coated inside with a residual film of technical-grade cypermethrin (5 and10 µg "micrograms" per vial), Curacron (20 and 25 µg per vial), or Tracer (15 µg per vial) were used for tobacco budworm. For cotton bollworm, vials coated inside with a residual film of technical-grade cypermethrin (2.5 and 10 µg per vial) were used. These doses separated the resistant moths from the susceptible moths. Mortality was recorded after 24 hours of exposure. All data were corrected for control mortality using Abbott's formula (Abbott, 1925).

RESULTS AND DISCUSSION

Tobacco Budworm

Comparing the mean seasonal responses of tobacco budworm moths bioassayed at 10 µg cypermethrin per vial during 1996, 1997, and 1998 to that determined for the period of 1987 to 1995 (Bagwell *et al.*, 1998) revealed that: 1) the overall level of pyrethroid resistance in tobacco budworm is still increasing; and 2) pyrethroid resistance levels were substantially higher from 1996 to 1998 than had been reported in previous years (Tables 1, 2, and 3). In Drew/Desha counties, percent survival in June 1996, 1997, and 1998 was 52.6, 60.3, and 56.2%, respectively. Previously, the highest level of survival observed in June between 1987 and 1996 was 29% (Bagwell *et al.*, 1998). Overall (seasonal) survival at 10 µg cypermethrin was 52.4, 68.8, and 61.3% in 1996, 1997, and 1998, respectively. In Louisiana, survival rate was 15% in 1987,16% in 1988, 25% in 1989, 37% in 1990, 36% in 1991, 40% in 1992, 48% in 1993, and 39% in 1994, 1995, and 1996 (Bagwell *et al.*, 1998). There was a general pattern in our study of increasing resistance to cypermethrin as the cotton growing season progressed. There was also a correlation with increased usage of insecticides. Across counties, pyrethroid resistance (percent survival) tended to be lowest early in the season (60.5% survival rate in June) then increased dramatically in July (70.4%) and remained high through August and September (Tables 1, 2, and 3).

Responses of tobacco budworm moths to profenofos are given in Tables 1, 2, and 3. Mean survival rates varied by county and dose and ranged from 1.4 to 31.2%. Comparing survival rates among years shows that resistance to profenofos in tobacco budworm increased from 1996 to 1998. Resistance to profenofos also tended to be higher late than early in the season. Tobacco budworm resistance to Tracer was low (Table 3).

Cotton Bollworm

Percent survival of bollworm moths at 2.5 and 10 µg of cypermethrin per vial is shown in Tables 4 and 5. Survival rates at the 2.5 µg cypermethrin dose averaged 33 and 21% in 1997 and 1998, respectively. At the 10 µg dose, survival rates averaged 18.7 and 2.9% in 1997 and 1998, respectively. Survival rates in this study were similar (for the same dose and period) among years and to those from previous years. In general, bollworm tolerance to cypermethrin tended to increase as the season progressed. Percent survival of bollworms increased moderately between July and August 1997 but not in 1998. Survival was highest during July and August.

PRACTICAL APPLICATION

These data document the continued presence of resistance in tobacco budworm to pyrethroid and organophosphate insecticides. Resistance levels to pyrethroids in tobacco budworm in 1996 to 1998 was the highest documented since monitoring was first initiated in 1987. Mid- to late-season pyrethroid resistance is believed to be worsened by use of pyrethroids in June, therefore, the use of pyrethroids is not recommended in June. Pyrethroids have the best opportunity to work against the predominantly bollworm and boll weevil pest complex present 1 July through 27 July. After 27 July, pyrethroids should not be used because worm populations normally shift to predominantly tobacco budworm. Alternative controls such as Bt cotton, spinosad, or other new chemistries should be used instead of pyrethroids against tobacco budworm. Rotation of insecticides is a good way to manage resistance to insecticides and lengthen their usefulness.

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Table 1. Percent survival of male tobacco budworm moths after 24-hour exposure to residues of insecticides in 20-ml glass vials[z], Arkansas, 1996.

County	Treatment	June	July	August	September	Season mean
		(% survival)				
Desha/Drew	Cypermethrin 5 µg/vial	24.1	71.0	76.1	63.3	58.6
Desha/Drew	Cypermethrin 10 µg/vial	52.6	68.0	43.0	46.0	52.4
Desha/Drew	Curacron at 25 µg/vial	2.5	0.6	2.3	0	1.4

[z] 389 moths tested at each dose and the check treatment.

Table 2. Percent survival of male tobacco budworm moths after 24-hour exposure to residues of insecticides in 20-ml glass vials[z], Arkansas, 1997.

County	Treatment	June	July	August	September	Season mean
		(% survival)				
Ashley	Cypermethrin 10 µg/vial	—	77.3	67.2	72.6	72.4
Ashley	Curacron at 25 µg/vial	—	5.1	24.6	19.2	16.3
Desha/Drew	Cypermethrin 5 µg/vial	75.0	77.1	83.5	90.0	81.4
Desha/Drew	Cypermethrin 10 µg/vial	60.3	74.3	67.2	73.3	68.8
Desha/Drew	Curacron at 25 µg/vial	12.5	0	8.6	0	5.3

[z] Number of moths tested not available.

Table 3. Percent survival of male tobacco budworm moths after 24-hour exposure to residues of insecticides in 20-ml glass vials, Arkansas, 1998.

County	Treatment	June	July	August	September	Season mean
		(% survival)				
Ashley	Cypermethrin 10 µg/vial[z]	65.0	73.0	—	—	69.0
Ashley	Tracer 15 µg/vial[y]	—	1.9	6.5	5.3	4.6
Ashley	Curacron at 20 µg/vial[x]	17.0	22.2	47.9	37.8	31.2
Desha/Drew[w]	Cypermethrin 5 µg/vial	—	67.0	65.2	64.3	65.5
Desha/Drew	Cypermethrin 10 µg/vial	—	56.2	61.9	65.7	61.3
Desha/Drew	Curacron at 25 µg/vial	—	15.0	19.2	21.7	18.6

[z] 195 moths tested.
[y] 1208 moths tested.
[x] 1228 moths tested (1169 moths tested in the check treatment).
[w] Number of moths tested not available.

Table 4. Percent survival of male cotton bollworm moths after 24-hour exposure to residues of insecticides in 20-ml glass vials, Arkansas, 1997.

County	Treatment	July	August	Season mean
		-------------- (% survival)	----------------	
Ashley	Cypermethrin 2.5 µg/vial[z]	27.7	38.2	33.0
Ashley	Cypermethrin 10 µg/vial[y]	15.0	22.3	18.7

[z] 369 moths tested.
[y] 297 moths tested (400 moths tested in the check treatment).

Table 5. Percent survival of male cotton bollworm moths after 24-hour exposure to residues of insecticides in 20-ml glass vials, Arkansas, 1998.

County	Treatment	May	June	July	August	Season mean
		----------------------	---------------------- (% survival)	----------------------		
Ashley	Cypermethrin 2.5 µg/vial[z]	0	32.3	33.9	17.6	21.0
Ashley	Cypermethrin 10 µg/vial[y]	—	—	5.8	0	2.9

[z] 899 moths tested.
[y] 330 moths tested (862 moths tested in the check treatment).

SPIDER MITE CONTROL IN SOUTHEAST ARKANSAS

Charles T. Allen, Marwan S. Kharboutli, and Larry Earnest[1]

RESEARCH PROBLEM

Miticides are sometimes needed to help protect cotton (Gossypium hirsutum L.) in southeast Arkansas from two-spotted spider mite damage. However, acaricide resistance in spider mites has been reported. Limited information is available on the effectiveness on the various miticide products. This study was conducted to examine the efficacy of various compounds used for mite control.

BACKGROUND INFORMATION

The two-spotted spider mite, *Tetranychus urticae* Koch, is an important cause of lost revenue to cotton producers in Arkansas and across the U.S. Cotton Belt. Losses for Arkansas were estimated at 1,692 bales in 1997 with a value of some $528,000 (Williams, 1998). Treatment costs for spider mite control in Arkansas were estimated at $817,000. The resulting cost to producers from spider mites, lost yield, and control costs was about $1.3 million in Arkansas in 1997. In spite of these impacts on cotton profitability, few studies on spider mite control in cotton have been published from the Mid-South region.

MATERIALS AND METHODS

This paper summarizes data from three tests conducted in 1996, 1997, and 1998 against the two-spotted spider mite, *T. urticae*.

The 1996 test was conducted on the Southeast Research and Extension Center, Rohwer Division. The test was conducted on 'Suregrow 125' cotton planted on 2 May 1996 and grown using standard production practices. This test was treated on 17 July 1996 using a John Deere high clearance sprayer applying 10 gallons of finished spray per acre. Plots were 140 ft long by 8 rows wide and were unreplicated. Five subplots were established per treatment.

The 1997 test was conducted on the Randy Eagle Farm near Grady. The test was conducted on 'Deltapine Nucotn 33B' cotton planted on 6 May 1997 and grown using standard production practices. The test was treated using a CO_2 charged backpack sprayer in 13.6 gallons of finished spray per acre. In this test, plots were 25 ft long by 2 rows

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wide with one border row between treated plots. The test was conducted using a randomized block design with four replications of each treatment.

The 1998 test was conducted on the Mike Norris Farm near Pickens. The test was conducted on a field of 'Stoneville 474' cotton planted on 5 May 1998 and grown using standard production practices. The test was treated using a CO_2 charged backpack sprayer in 10.0 gallons of finished spray per acre. Plots were 25 ft long by 2 rows wide with one border row between treated plots. The test was conducted using a randomized block design with four replications.

Data were collected on each posttreatment sampling date by collecting five main stem leaves (four nodes below the terminal) per plot (five leaves per subplot in the 1996 test). The leaves were placed in Ziplock plastic bags, held on ice, and transported to the laboratory. In the lab, one 20X microscope field (4.5 mm^2) containing the central leaf vein was examined and the live spider mites were counted. Data from each plot (subplot in 1996) were averaged and the plot or subplot means were analyzed. Kruskal-Wallis and LSD were used to analyze the 1996 test, and ANOVA and LSD were used with the 1997 and 1998 data.

RESULTS AND DISCUSSION

Results are shown in Tables 1 to 3. The 1996 data (Table 1) showed relatively good separation of the treatments two days after treatment (2 DAT), but at 6 DAT a fungal pathogen had reduced spider mite populations in all treatments. Two days after treatment, Pirate at 0.15 lb ai/acre provided statistically superior reduction of mite populations. Curacron 1.0 lb ai/acre was the only other treatment which lowered mite numbers significantly below the level in the untreated check 2 DAT.

The 1997 data (Table 2) showed good treatment separation at 2 and 5 DAT, but non-significant trends only by 6 DAT. At 2 DAT, all miticides significantly reduced mite numbers below the average level in the untreated check plots. Ovasyn 0.5 lb ai/acre had higher mite survival than did the other treatments. Lorsban 1.0 lb ai/acre and Pirate 0.1 and 0.15 lb ai/acre treated cotton had low mite survival. By 5 DAT, Lorsban-treated plots had increased considerably in mite numbers. The only treatments which significantly lowered mite populations below those seen in the untreated check 5 DAT were the two rates of Pirate. By 6 DAT, Pirate-treated plots showed only a nonsignificant trend toward lower mite levels.

The 1998 data (Table 3) showed strong separation of the treatments at 1, 2, and 3 DAT. At 1 DAT, only Curacron 1.0 lb ai/acre and Pirate at all three rates gave significant reductions in mite numbers as compared to the untreated check. Ovasyn 0.25 lb ai/acre, Curacron, and all three rates of Pirate produced fewer mites than were seen in the untreated check 2 DAT. At 3 DAT, only Ovasyn and the three rates of Pirate had significantly fewer mites than were in check plots.

PRACTICAL APPLICATION

Pirate 3SC, at all three rates tested, provided strong control of two-spotted spider mite populations with no indications (in this data) of short-term population rebound.

Lorsban at both 0.75 and 1.0 lb ai/acre showed less consistent initial control and at 1.0 lb ai/acre, mite populations tended to rebound following treatments. Curacron at both 1.0 and 0.75 lb ai/acre provided good initial population suppression, but mite population rebound was seen in the 1998 data. Studebaker (1997) reported similar population rebound after Curacron and Lorsban treatment in a 1996 miticide trial conducted near Keiser. In that study, he showed good miticidal activity from both Pirate and Kelthane 4MF.

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Table 1. Live spider mites after miticide application[z], Rohwer, 1996.

Miticide	Rate	Mites/microscope field	
		2 DAT	6 DAT
	(lb ai/acre)	------------------(no./microscope field)-----------	
Check	---	5.3 a	1.9 a
Lorsban 4E	0.75	3.6 ab	1.2 a
Curacron 8E	1.0	2.1 b	0.7 a
Zephyr 0.15EC	0.0094	3.1 ab	0.9 a
Pirate 3SC	0.15	0.4 c	0.5 a

[z] Means in columns followed by the same letter are not significantly different at the 5% level of significance.

Table 2. Live spider mites after miticide application[z], Grady, 1997.

Miticide	Rate	Mites/microscope field		
		2 DAT	5 DAT	6 DAT
	(lb ai/acre)	-------------------------(no./microscope field) ---------------		
Check	---	6.0 a	6.2 a	4.2 a
Ovasyn 1.5	0.5	3.4 b	2.0 ab	0.4 a
Curacron 8E	0.75	1.2 c	1.5 ab	0.9 a
Lorsban 4E	1.0	0.8 c	3.3 ab	0.6 a
Pirate 3SC	0.1	0.4 c	0.2 b	0.1 a
Pirate 3SC	0.15	0.4 c	0.1 b	0.1 a

[z] Means in columns followed by the same letter are not significantly different at the 5% level of significance.

Table 3. Live spider mites after miticide application[z], Pickens, 1998.

Miticide	Rate	Mites/microscope field		
		2 DAT	5 DAT	6 DAT
	(lb ai/acre)	------------------------- (no./microscope field) ---------------		
Check	---	8.5 a	11.0 a	9.6 a
Curacron 8E	1.0	1.9 b	4.0 c	8.8 ab
Lorsban 4E	1.0	5.6 ab	8.5 ab	6.2 abc
Ovasyn 1.5	0.25	5.0 ab	4.8 bc	4.3 bc
Pirate 3SC	0.05	3.7 b	1.8 c	1.8 c
Pirate 3SC	0.1	2.3 b	1.1 c	1.3 c
Pirate 3SC	0.15	3.8 b	1.1 c	1.1 c

[z] Means in columns followed by the same letter are not significantly different at the 5% level of significance.

TRANSGENIC AND CONVENTIONAL INSECT AND WEED CONTROL SYSTEMS

Charles T. Allen, Marwan S. Kharboutli, Kelly J. Bryant, Fred M. Bourland, Larry Earnest, Charles Capps, Jr., and George Palmer[1]

RESEARCH PROBLEM

Transgenic cotton varieties have been developed and marketed to provide growers with options for insect and weed control. Studies have been conducted to evaluate the insect control, weed control, and yields provided by these varieties. However, comparisons of conventional and transgenic varieties produced under appropriate systems and compared by evaluating economic returns are not available.

BACKGROUND INFORMATION

Bollgard™ cotton varieties have been genetically altered to produce a toxin from the bacterium *Bacillus thuringiensis* (Benedict, 1996). Bollgard cotton varieties became commercially available to growers in 1996. Roundup Ready™ cotton varieties have been genetically altered to produce EPSPS synthase. This enzyme protects cotton from damage when it is sprayed with herbicides containing the active ingredient glyphosate (Johnson, 1996). Roundup Ready varieties were commercially available for the first time in 1997. Cotton varieties with both Bollgard and Roundup Ready traits became commercially available for the first time in 1998. These technologies provide options which can be incorporated into a grower's cotton production system. Studies evaluating these systems are needed so that growers can make informed decisions about their use.

MATERIALS AND METHODS

This study was composed of nine treatments, each replicated four times. The treatments were conventional and transgenic seed from two parental lines 'Paymaster 1220' and 'DPL 5415' (Bt / Roundup Ready, Bt / conventional herbicide, conventional insecticide / Roundup Ready, and conventional insecticide / conventional herbicide). 'Stoneville 474' was used as a conventional insecticide / conventional herbicide check. This arrangement was planted at Rohwer in southeast Arkansas on 5 May 1998 and at Keiser

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in northeast Arkansas on 9 May 1998 in plots 40 ft long by 4 rows wide arranged in a randomized complete block design. Standard weed control, insect control, fertilization, and irrigation timing were used. Standard harvest aid and harvesting methods were also used. Seedcotton samples from both tests were ginned with a plot gin located at Keiser, and lint samples were submitted to the LSU Cotton Fiber Laboratory for HVI classing. Loan values for the lint were established using the 1998 CCC Loan Values provided by Staplcotn at Greenwood, Mississippi.

Weed Control Program

In the Roundup Ready plots, a PPI herbicide program was used first and then Roundup Ultra was used for the remainder of the season. The conventional program was a grower standard approach.

Foliar Insecticide Program

Early-season insect control applications (thrips, boll weevils, and plant bugs) and late-season applications (boll weevils and defoliators) were made at both locations across all plots. Midseason application decisions were made on an as needed, plot-by-plot basis.

Data Collection and Processing

Percent weed control ratings were made on 19 June and 21 September 1998 at Rowher. Three days after midseason insecticide treatments at Rohwer, pest and damage counts were taken (25 terminals, 25 squares, and 25 bolls examined per plot). Net returns (after weed and insect control costs) were calculated for each plot. Technology fees for the transgenic varieties were considered as control costs. Weed control ratings, insect damage, yield, and net return data were processed using ANOVA and LSD at the 5% level of significance.

RESULTS AND DISCUSSION

Weed Control Efficacy

Few significant differences in weed control among varieties / systems were seen.

Worm Damage

Fruit damage was generally low. Bollgard cotton had 3.6-fold greater terminal damage and 2.6-fold higher boll damage than sprayed non-Bt cotton (worm damage taken three days after non-Bt cotton was sprayed).

Lint Yields

Across locations, the high yielding treatments were St 474, DPL 5415 and PM 1220 BG. Conventional weed control systems yielded significantly more lint / acre than did Roundup Ready weed control systems at Rohwer but not at Keiser or across locations (Table 1). The comparison of insect control systems produced no significant differences in lint yield.

Net Returns

Net returns of the variety / system treatments (Table 2) were very similar to the lint yield data (Table 1). Across locations, net returns were higher in the St 474, DPL 5415, PM 1220 BG, and DPL 5415 BG treatments.

Conventional herbicide systems gave significantly higher net returns at Rohwer, and similar trends were seen at Keiser and in the combined data (Table 2). No statistical differences or consistent trends in net returns (after weed and insect control costs were paid) were seen in the comparison of insect control systems.

PRACTICAL APPLICATION

The Roundup Ready system provided weed control at about the same level as in the conventional system. Consistent trends and statistically significant differences supported the conclusion that the Roundup Ready system produced lower yields and net returns than did the conventional system. Cotton in the conventional insect control systems had less worm damage than did cotton in untreated Bollgard systems, but no yield or net return advantage was seen. Stoneville 474 conventional gave, numerically, the highest yield and net return at Rohwer as well as the combined location data. At Keiser, the DPL 5415 line did well with DPL 5415 BGxRR providing, numerically, the highest yield and net return after weed and insect control costs were paid.

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Table 1. Lint yield of varieties/systems tested[z], Rohwer and Keiser, 1998.

Variable	Rohwer	Keiser	Combined
	(lb/acre)		
Variety			
St 474	911 a	1046 ab	978 a
DPL 5415	789 ab	1082 ab	935 ab
PM 1220 BG	798 ab	1057 ab	927 ab
DPL 5415 BG	712 b	1102 a	907 abc
DPL 5415 RR	696 b	1075 a	885 abcd
PM 1220	781 ab	984 ab	883 abcd
DPL 5415 BGxRR	521 c	1150 a	835 bcd
PM 1220 BGxRR	637 bc	918 bc	778 cd
PM 1220 RR	690 b	855 c	773 d
Weed Control System[y]			
Conventional	770 a	1056 a	913 a
Roundup Ready	636 b	999 a	817 a
Insect Control System[y]			
Conventional	739 a	999 a	869 a
Bollgard	667 a	1056 a	862 a

[z] Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[y] Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.

Table 2. Net returns of varieties/systems tested[z, y], Rohwer and Keiser, 1998.

Variable	Rohwer	Keiser	Combined
	($/acre)		
Variety			
St 474	442.35 a	583.93 ab	513.14 a
DPL 5415	359.56 ab	608.23 a	483.90 ab
PM 1220 BG	370.42 ab	574.02 ab	472.22 ab
DPL 5415 BG	312.28 b	604.19 a	458.23 ab
PM 1220	353.78 ab	542.03 abc	447.90 abc
DPL 5415 RR	305.05 b	590.26 a	447.66 abc
DPL 5415 BGxRR	190.96 c	623.61 a	407.59 bc
PM 1220 RR	300.97 b	441.12 c	371.04 c
PM 1220 BGxRR	269.67 bc	466.46 bc	368.06 c
Weed Control System[x]			
Conventional	349.01 a	582.12 a	465.59 a
Roundup Ready	266.66 b	530.36 a	398.51 a
Insect Control System[x]			
Conventional	329.84 a	543.16 a	437.63 a
Bollgard	285.83 a	567.07 a	426.45 a

[z] Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[y] Net returns over insect and weed control costs.
[x] Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.

PESTS AND DAMAGE ON SELECTED BOLLGARD COTTON CULTIVARS IN SOUTHEAST ARKANSAS

Charles T. Allen, N. Philip Tugwell, Marwan S. Kharboutli, Charles Capps Jr., and Larry Earnest[1]

RESEARCH PROBLEM

Bt cotton is a new technology to control worms. Bt cotton, however, is not completely immune to worm damage, and often insecticide applications are needed to prevent worm damage. Little work has been done on insect pest management of Bt cotton. Recent introduction by the industry of more Bt cultivars has given farmers the option to select from among several available Bt lines. Cotton growers need information on the performance and pests management of the Bt cultivars.

BACKGROUND INFORMATION

Transgenic cotton which has the insecticidal endotoxin protein of *Bacillus thurengiensis* (Bt cotton) is one of the newly available and promising technologies for control of damaging worm populations. The Bt genes are expressed in leaves, squares, and bolls (Perlak *et al*., 1990). When targeted pests feed on Bollgard cotton, a lethal dose of the protein is consumed and the pest dies before significant damage is done to the crop (Deaton, 1995; Meyers *et al*., 1997).

In the Mississippi River Delta, Bt cotton is best suited for use in areas which are historically infested with high to moderate tobacco budworm populations. Bt toxins are more effective on tobacco budworm than on bollworm. Cheap and effective insecticides are available for bollworm control while less effective and more expensive chemical controls are required for budworm control. Therefore, the cost of purchasing Bt technology in areas more heavily infested with budworm is often appropriate, while use of non-Bt varieties may be more suitable for areas which are traditionally more likely to have bollworms. The objective of this study was to evaluate the insect control strategies of several Bt cotton cultivars under irrigated southeast Arkansas growing conditions.

RESEARCH DESCRIPTION

This study was carried over a three-year period from 1996 to 1998. All tests were conducted on the Southeast Research and Extension Center, Rohwer Division. Plots

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were 4 rows by 40 ft and arranged in a randomized complete block design with six replications in 1996 and four replications in 1997 and 1998. A factorial arrangement of treatments was used in all three years. Plots were either sprayed or unsprayed. COTMAN data (plant mapping) were collected on each plot to determine fruit set, node development, cutout, and spray termination. Standard production practices were used to produce the crop.

In 1996, five Bt varieties and one non-Bt variety were planted on 22 May 1996. COTMAN termination strategy was used to make insecticide termination decisions. Insect control sprays were terminated in each plot at NAWF=5+350 heat units or at NAWF=5+650 heat units. An unsprayed treatment was also assigned to each variety. Tracer was applied to appropriate plots at 2 oz/acre on 26 August, 30 August, and 4 September 1996. Insect and damaged fruit data were taken by observing 10 terminals (top of plant to bloom),10 blooms, and 20 bolls per plot. Standard harvest preparations were used and based on 850 heat units after NAWF=5. The field was picked on 24 October 1996.

In 1997, six Bt varieties were planted on 13 May 1997. Karate was applied to appropriate plots at 3.8 oz/acre on 4 August 1997. Insect and damaged fruit data were taken by observing 10 terminals (top of plant to bloom), 10 blooms, and 20 small bolls per plot. Standard harvest preparations were used and based on percent open bolls (at least 60% for all varieties). The field was picked on 1 October 1997.

In 1998, nine Bt and one non-Bt variety were planted on 9 May 1998. Baythroid was applied at 2 oz/acre on 18 July and 28 July 1998. Insect and damaged fruit data were taken by observing 25 terminals (top of plant), 25 squares (top one-third of plant), and 25 small bolls per plot. The field was picked on 24 September 1998.

Plant mapping data were processed using COTMAN and data were analyzed in all three years using ANOVA and Duncan's Multiple Range Test (CoStat Statistical Software) with a 5% level of significance.

RESULTS AND DISCUSSION

Worm Counts

Worm counts in 1996 were significantly lower on Bt than on unsprayed non-Bt cultivars (Table 1). Worm counts were similar on sprayed non-Bt and unsprayed Bt cultivars. Since the non-Bt variety received three insecticide applications, worm count data from the 1996 study showed that Bt varieties with no insecticide applications exerted control pressure on worms that was equal to three insecticide applications on non-Bt varieties under the light worm pressure experienced in 1996. Insecticide sprays in 1996 significantly reduced worm numbers on non-Bt cotton but not on Bt cultivars. Worm pressure in 1997 was not high enough to collect meaningful worm count or damage data. In 1998, no significant differences in worm counts existed between non-Bt and Bt cultivars (Table 2). Worm counts, however, tended to be numerically lower on Bt than non-Bt cotton. When data were analyzed across spraying regimes, worm counts in 1996 were significantly lower on Bt than non-Bt varieties, but such differences were not seen in 1998 (Table 3).

Worm Damage

No significant differences existed in 1996 for worm damage between Bt and non-Bt cultivars, whether sprayed or unsprayed (Table 1). However, a strong trend existed for Bt cultivars to suffer less worm damage than non-Bt cultivars, especially in the unsprayed non-Bt plots. In 1998, worm damage was significantly lower in sprayed Bt plots than in unsprayed non-Bt plots (Table 2). In 1996 and 1998, insecticides tended to have more affect in reducing damage on non-Bt than Bt varieties. When data were analyzed across spraying regimes, worm damage in 1996 were significantly lower on Bt than non-Bt varieties but no such differences were seen in 1998 (Table 3).

Plant Bugs

No differences were found in this study for plant bug counts between Bt and non-Bt cotton cultivars, regardless of insecticidal treatment (Table 1, 2, and 3). Bt cotton neither suppressed nor enhanced plant bug numbers in comparison with non-Bt cotton.

PRACTICAL APPLICATION

This study indicates that Bt cottons, though not immune to worm damage, are resistant to damage. Economic benefits can be gained, however, by scouting and spraying Bt cotton as needed. This study suggests that insecticide applications on Bt cotton cultivars could be terminated at NAWF=5 + 350 heat units, as is the case for non-Bt cotton cultivars.

Growers should carefully weigh the value of Bt cotton cultivars in their production systems. One of the most important factors farmers need to keep in mind when considering using Bt cotton cultivars is the worm population composition. Cotton bollworm is less susceptible to the Bt toxin than tobacco budworm and cheap and effective insecticides are available to control cotton bollworm. Therefore, Bt cotton is a better fit in budworm dominated areas.

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Table 1. The efficacy of insecticidal sprays on abundance of worms and plant bugs infesting Bt and non-Bt cotton in southeast Arkansas[z], Rohwer, 1996.

Variety	Insecticides	Worm count[y]	Worm damage[y]	Plant bug count[y]
DPL 50	Unsprayed	2.00 a	3.7 a	3.0 a
DPL 50	Sprayed[x]	0.67 b	1.7 a	3.5 a
All Bt's	Unsprayed	0.42 b	1.6 a	3.9 a
All Bt's	Sprayed[x]	0.25 b	0.9 a	2.7 a

[z] Means in columns followed by the same letter(s) are not significantly different (P=0.05).
[y] 10 terminals, 10 white blooms, and 20 small bolls per plot.
[x] Sprayed plots protected with insecticides to NAWF 5 + 650 heat units.

Table 2. The efficacy of insecticidal sprays on abundance of worms and plant bugs infesting Bt and non-Bt cotton in southeast Arkansas[z], Rohwer, 1998.

Variety	Insecticides	Worm count[y]	Worm damage[y]	Plant bug count[y]
DPL 50	Unsprayed	2.00 a	4.80 a	0.88 a
DPL 50	Sprayed[x]	0.50 a	1.90 ab	0.00 a
All Bt's	Unsprayed	0.78 a	2.90 a	1.20 a
All Bt's	Sprayed[x]	0.13 a	0.42 b	0.78 a

[z] Means in columns followed by the same letter(s) are not significantly different (P=0.05).
[y] 25 terminals, 25 squares. and 20 small bolls per plot.
[x] Sprayed plots treated with Baythroid on 18 July and 28 July 1998.

Table 3. Worm and plant bug abundance on Bt and non-Bt cotton in southeast Arkansas[z], Rohwer, 1996 and 1998.

	Worm count[y]		Worm damage[y]		Plant bug counts[y]	
Variety	1996	1998	1996	1998	1996	1998
Non-Bt Cotton	1.80 a	1.30 a	3.2 a	3.3 a	3.3 a	0.44 a
Bt Cotton	0.26 b	0.45 a	1.2 b	1.7 a	3.1 a	1.00 a

[z] Means in columns followed by the same letter(s) are not significantly different (P=0.05).
[y] 1996: 10 terminals, 10 white blooms, and 20 small bolls per plot; 1998: 25 terminals, 25 squares, and 20 small bolls per plot. Data combined for sprayed and unsprayed plots.

IN-FURROW INSECTICIDES FOR THRIPS CONTROL IN SOUTHEAST ARKANSAS

Charles T. Allen and Marwan S. Kharboutli[1]

RESEARCH PROBLEM

Insecticides are the major tools used in controlling thrips in cotton (Gossypium hirsutum L.). There is a continual need to compare the efficacy of new and old compounds so farmers can make an intelligent choice when selecting chemicals for thrips control. The objective of this study was to examine the efficacy of various insecticides and application methods for thrips control.

BACKGROUND INFORMATION

Thrips cause losses to early-season cotton each year in Arkansas. These insects feed on the sap of young, tender tissues of the newly emerged seedlings causing discoloration and malformation in leaves as well as stunted plants. Feeding on the terminal bud may cause it to be aborted resulting in excessive branching possibly delaying crop maturity and reducing yield (Micinski *et al.*, 1990). Although cotton plants are able to outgrow and compensate for some thrips injury, infestations can sometimes reach high levels and can reduce yield if left unchecked (Herbert, 1995; Roberts and Rechel, 1996). Estimated yield loss in Arkansas due to thrips damage in 1997 was about 23,042 bales (Williams, 1998). Concerns related to thrips at planting treatments are the length of time thrips are controlled, the cost of treatment, phytotoxicity, and plant stand loss effects. In addition, newer compounds are periodically introduced for thrips control and comparisons of old and new compounds are needed.

RESEARCH DESCRIPTION

This study was carried out in 1998 at the Southeast Research and Extension Center, Rohwer Division. 'NuCotn 33B' was planted on 6 May 1998 and maintained using standard production practices. The test was conducted using a randomized complete block design with four replications. Plots were 40 ft long and 4 rows wide. Liquid and granular insecticides and seed treatments employed. The seed treatment insecticides used in this study were Gaucho and Orthene. The granular insecticides tested, Thimet 20G and Temik 15G, were dropped in-furrow using the granular applicator on the John Deere Maxemerge planter. Three rates of Temik were used: 0.525, 0.75, and 1.05 lb ai/acre while Thimet was used at the rate of 1.0 lb ai/acre. Admire, Di-Syston, and Orthene

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were applied as liquid in-furrow treatments at planting on 6 May 1998.

Thrips samples were taken on 19 May, 26 May, and 3 June 1998 by cutting 10 plants per plot about an inch above the soil line and placing the plants in Ziplock plastic bags. The thrips were washed from the plants in the plastic bags using soapy water and isopropyl alcohol. Thrips were then collected onto 7 cm filter paper using Buchner funnels. Thrips were then counted under 10 and 20X magnification in the laboratory. Damage due to thrips injury was visually evaluated on 28 May 1998 by rating each plot for plant height, vigor, and foliage distortion. Plots were rated visually for thrips damage using a rating scale of 0 to 10 where 0 indicated no damage and 10 indicated severe damage. Phytotoxicity ratings were taken on 28 May 1998. Plots were rated visually by assigning a numerical value 0 to 10 where 0 indicated no visible phytotoxicity and 10 indicated severe damage. Stand counts were made by counting all plants in 6 ft of row on 9 June 1998.

Lint cotton yield was determined by machine harvesting the middle two rows of the plots on 30 September 1998. Data were processed using the Pesticide Research Manager 5 (PRM) and CoStat. Analysis of Variance was run and Least Significant Difference (LSD) was used to separate the means.

RESULTS AND DISCUSSION

All treatments significantly reduced thrips counts compared with the check on 19 May 1998, the first week of sampling (Table 1). Temik 15G at 0.75 lb ai/acre, Orthene seed treatment (ST) and in-furrow Admire 2F + Orthene 90S (0.0375 and 0.5 lb ai/acre, respectively) were very effective in controlling thrips on the 19 May 1998 sampling date. Admire 2F at both rates used and Thimet 20G at 1 lb ai/acre, however, had numerically higher thrips counts than other treatments in the 19 May 1998 sampling. A consistent trend in subsequent sampling (on 26 May and 3 June 1998) showed Temik (at all three rates used), in-furrow Orthene 90S, Orthene ST and all multi-product treatment combinations to effectively control thrips populations.

All treatments significantly reduced thrips damage compared to the check (Table 1). Thrips damage was correlated positively with thrips counts ($P<0.001$, $r^2=0.84$, 0.84, and 0.59 for the three sampling dates, respectively). Highly effective treatments such as Temik had the least thrips damage while less effective treatments such as Admire and Thimet had significantly higher thrips damage.

Phytotoxicity ratings were high in plots treated with Thimet and the high rate of Temik (Table 2). Increasing the rate of Temik resulted in higher phytotoxicity effect on cotton seedlings (nonsignificant, positive correlation). Stand counts reflected the phytotoxic effects of chemicals on plants. Stand counts were significantly lower in plots treated with Temik 15G at 1.05 lb ai/acre than in any other treatment illustrating the negative impact exerted by Temik at high rates on cotton seedlings. Increasing the rate of Temik tended to reduce cotton stand density. A strong negative correlation existed in plots treated with Temik between phytotoxicity rating and stand count ($P=0.043$, $r^2=0.99$). Gaucho ST, Admire 2F (at the two rates used), and Orthene ST tended to have the least level of phytotoxicity and highest plant stand count (Table 2).

No significant differences existed in lint yields among the treatments used in this study (Table 2). Admire 2F (0.05 lb ai/acre) produced numerically the highest yield while the Thimet 20G treatment produced the least. The apparent paradox in results with Admire, poorer thrips control (and resulting thrips damage) yet numerically high yield, is not well explained in this study and deserves further research. Furthermore, the apparent negative dosage response of Admire on thrips control, yet positive dosage response of Admire on yield is also puzzling. Plant compensation for early season thrips damage/phytotoxic effects undoubtedly obscured any effects insecticide treatments might have had on yield. Unmeasured effects of Admire on other insect pests may have explained some of the contradictions in the data. Yield did not significantly correlate with any of the parameters examined in this study. However, when data from the Temik plots were analyzed separately, a strong negative correlation between yield and thrips damage (P=0.024, r^2=0.99) was observed.

PRACTICAL APPLICATION

Temik 15G is an effective thrips treatment but, at high rates, it has negative effects on seedling establishment and plant populations. The low rate of Temik affords reasonable thrips control with minimum phytotoxic effects. The effect of chemical treatments on insect pests and cotton plants may not translate to differences in lint yield due to the ability of plants to compensate for early season damage. However, we would expect to see yield losses under conditions of severe thrips populations and damage.

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Table 1. Thrips counts and damage ratings[z] following at planting insecticide and seed treatments for thrips control, Rohwer, 1998.

		Thrips/plant[y]			Thrips damage[x]
Treatment	Rate	19 May	26 May	3 June	28 May
	(lb ai/acre)				
Check		1.50 a	12.73 a	13.53 ab	6.0 a
Temik 15G	0.525	0.20 bc	1.53 cd	1.98 e	1.3 e
Temik 15G	0.75	0.05 c	0.88 cd	4.23 e	1.4 e
Temik 15G	1.05	0.20 bc	0.48 d	2.53 e	1.4 e
Thimet 20G	1.0	0.60 bc	7.03 a-d	7.03 cde	3.7 bc
Gaucho ST		0.18 bc	6.38 a-d	10.90 a-d	2.7 cde
Admire 2F	0.05	0.88 b	8.88 ab	12.73 abc	4.5 b
Admire 2F	0.0375	0.45 bc	7.80 abc	15.03 a	3.1 cd
Admire 2F +	0.0375				
Orthene 90S	0.5	0.10 c	3.85 bcd	3.88 e	2.7 cde
Admire 2F +	0.0375				
Di-Syston 8	0.5	0.13 bc	2.20 bcd	3.0 e	1.7 de
Orthene ST +					
Admire 2F	0.0375	0.20 bc	5.55 bcd	5.35 de	1.7 de
Orthene ST +					
Admire 2F	0.05	0.18 bc	1.80 cd	2.93 e	1.7 de
Orthene 90S	1.0	0.18 bc	1.83 cd	3.98 e	1.8 de
Gaucho ST +					
Orthene ST		0.30 bc	2.03 bcd	7.88 b-e	2.1 de
Orthene ST		0.08 c	2.33 bcd	3.33 e	2.6 cde

[z] Means in columns followed by the same letter are not statistically different ($P = 0.05$).
[y] Adult and immature thrips.
[x] Damage rating 0 to 10 where 0 = no damage and 10 = severe damage and dead plants.

Table 2. Phytotoxicity rating, stand count, and lint yield[z] following various at planting and seed treatments for thrips control, Rohwer, 1998.

Treatment	Rate	Phytoxicity rating[y]	Plants[x]	Lint yield
	(lb ai/acre)		(no./acre)	(lb/acre)
Check		2.1 c	61900 ab	766.4 a
Temik 15G	0.525	2.5 bc	59149 abc	788.3 a
Temik 15G	0.75	2.6 bc	58003 abc	767.3 a
Temik 15G	1.05	3.0 ab	63047 c	768.2 a
Thimet 20G	1.0	3.3 a	64193 ab	716.1 a
Gaucho ST		2.2 c	63047 ab	795.6 a
Admire 2F	0.05	2.1 c	64193 ab	809.3 a
Admire 2F	0.0375	2.1 c	64881 ab	781.0 a
Admire 2F	0.0375			
Orthene 90S	0.5	2.2 c	60295 ab	783.8 a
Admire 2F +	0.0375			
Di-Syston 8	0.5	2.8 abc	61442 ab	744.5 a
Orthene ST +				
Admire 2F	0.0375	2.4 bc	61900 ab	739.9 a
Orthene ST +				
Admire 2F	0.05	2.4 bc	63734 ab	771.9 a
Orthene 90S	1.0	2.3 c	56169 bc	741.7 a
Gaucho ST +				
Orthene ST		2.6 bc	59149 abc	732.6 a
Orthene ST		2.1 c	67632 a	768.2 a

[z] Means in columns followed by the same letter are not statistically different ($P = 0.05$).
[y] Rating was done on 28 May 1998 on a scale 0 to 10 where 0 = no visible phytotoxicity and 10 = severe damage and dead plants.
[x] Taken on 9 June 1998.

YIELD AND ECONOMICS OF SELECTED BOLLGARD COTTON CULTIVARS WITH AND WITHOUT WORM SPRAYS

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RESEARCH PROBLEM

Bt cotton varieties are becoming a very important part of the cotton industry. Although the emphasis for these varieties has been their ability to control worms, they must provide high yields and economic returns to be adopted widely in cotton production systems in southeast Arkansas. The value of spraying Bt cotton varieties for worm control needs to be investigated.

BACKGROUND INFORMATION

Transgenic cotton which has the insecticidal endotoxin protein of *Bacillus thurengiensis* (Bt cotton) is one of the newly available and promising technologies that can be used to provide control of bollworm and insecticide resistant tobacco budworm populations. The Bt genes are expressed in leaves, squares, and bolls (Perlak *et al.*, 1990). When targeted pests feed on Bollgard cotton, a lethal dose of the protein is consumed and the pest dies before significant damage is done to the crop (Deaton, 1995; Meyers *et al.*, 1997).

In the Mississippi River Delta, Bt cotton is best suited for use in areas historically infested with high to moderate populations of tobacco budworm. This is primarily because cheap and effective insecticides are available for bollworm control while much less effective chemical controls are available at higher costs for budworm control. The objective of this study was to evaluate the yield potential and economics of several Bt cotton cultivars under irrigated southeast Arkansas growing conditions.

RESEARCH DESCRIPTION

This study was carried out over a three-year period from 1996 to 1998. All tests were conducted on the Southeast Research and Extension Center, Rohwer Division. Plots were 4 rows by 40 ft and were arranged in a randomized complete block design with six replications in 1996 and four replications in 1997 and 1998. A factorial arrangement of treatments was used. Two factors were incorporated in this study: variety and insecticide spray termination date. Plots were either sprayed or unsprayed.

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COTMAN data collection (plant mapping) was done on each plot to determine fruit set, node/internode development, cutout, and spray termination. Standard production practices were used to produce the crop.

In 1996, five Bt varieties and one non-Bt variety were planted on 22 May 1996. COTMAN termination strategy was used to make insecticide termination decisions. Insect control sprays were terminated in each plot at NAWF=5+350 DD60 heat units or at NAWF=5+650 DD60 heat units. An unsprayed treatment was also assigned to each variety. Tracer was applied to appropriate plots at 2 oz/acre on 26 August, 30 August, and 4 September 1996. Standard harvest preparations were used and based on 850 DD60 heat units after NAWF=5. The field was picked on 24 October 1996.

In 1997, six Bt varieties were planted on 13 May 1997. Karate was applied to appropriate plots at 3.8 oz/acre on 4 August 1997. Standard harvest preparations were used and based on percent open bolls (at least 60% for all varieties). The field was picked on 1 October 1997. In 1998, nine Bt and one non-Bt varieties were planted on 9 May 1998. Baythroid was applied at 2 oz/acre on 18 July and 28 July 1998 to appropriate plots. The field was picked on 24 September 1998.

Insect control costs included the cost of the insecticides, application costs, and a $32/acre technology fee for Bt cotton lines. Plant mapping data were processed using COTMAN and data were analyzed in all three years using ANOVA and Duncan's Multiple Range Test (CoStat Statistical Software) with a 5% level of significance.

RESULTS AND DISCUSSION

Lint Yields

In 1996, insecticide sprays and termination dates had no effect on lint yield of Bt varieties. Insecticide sprays had a significant effect on yield of the non-Bt variety but termination date did not (Table 1). Comparing Bt varieties individually (Table 2), cotton yield in 1996 was not significantly affected by insecticide sprays nor termination date for any of the varieties tested, except for 'Deltapine 90Bt' where the lowest lint yield was produced in plots terminated at NAWF= 5 + 650 heat units. Termination date had no significant effect on yield of the non-Bt variety (Table 2). Higher yields were not obtained by continued late-season sprays of Bt or non-Bt cotton.

Similarly, in 1997, insecticide application had no effect on lint yield for any variety except Deltapine 90 Bt which produced significantly more cotton in sprayed than unsprayed plots (Table 3).

In 1998, however, four of the nine Bt varieties produced more lint in sprayed than unsprayed plots (Table 4). The non-Bt variety, 'Stoneville 373', also produced more lint in sprayed than unsprayed plots. When data from all three years were analyzed, use of insecticide sprays as needed on Bt cotton cultivars produced a significant increase of 79 lb/acre more lint than did untreated Bt cotton (Table 5).

Economic Assessments

In 1996, the highest returns after insect control costs were realized from the 'Deltapine 50Bt' unsprayed plots while Deltapine 90Bt produced the least returns (Table

2). Sprayed Bt cotton in which sprays were terminated at NAWF=5+350 heat units produced approximately $15 / acre more revenue after insect control costs than did unsprayed Bt cotton in 1996.

In 1997, sprayed 'Paymaster 1330 BG' produced the highest returns after worm control expenses while unsprayed Deltapine 90Bt produced the lowest returns (Table 3). However, the returns for sprayed Paymaster 1330 BG were just $1 greater than for sprayed NuCotn 33B. This represents a $28 / acre advantage associated with applying worm control insecticides as needed to Bt cotton.

In 1998, 'Deltapine 428' produced the highest returns after insect control costs while unsprayed 90B, 20B, and St 373 (non-Bt) produced the lowest returns (Table 4). This represented a $54 / acre advantage associated with applying worm control insecticides as needed to Bt cotton in 1998.

The economic advantage of spraying Bt cotton as needed for worm control (across all cultivars and years) was about $32 / acre. This advantage was observed even though all three years of this study could be characterized as light worm years at this test site.

PRACTICAL APPLICATION

Economic benefits can be gained by using Bt cotton in southeast Arkansas. This study suggests that insecticide applications on Bt cotton cultivars could be terminated on Bt cotton at NAWF=5 + 350 heat units, as is the case for non-Bt cotton cultivars.

Growers should carefully weigh the value of Bt cotton cultivars in their production systems. Cost, performance, insect pressure, and proximity to towns, schools, or other sensitive sites are important components of the decision to plant a Bt or a non-Bt cultivar.

When a decision has been made to use a Bt cultivar, growers need to be aware of the variation in the yield potential of the various Bt cotton cultivars available. A careful assessment of the yield potential of the available cotton cultivars is essential before making a decision on which to use. Scouting and spraying Bt cultivars as needed was shown in this study to produce consistently stronger yields and net returns than using the Bt varieties without midseason worm sprays.

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Table 1. Lint yield of Bt and non-Bt cotton varieties as influenced by insecticidal sprays and termination date[z], Rohwer, 1996.

Insecticide / termination	Lint yield: Bt varieties[y]	Lint yield: DPL 50 (Non-Bt)
	(lb/acre)	(lb/acre)
NAWF=5 + 350 heat units	1061.5 a	1233.5 a
NAWF=5 + 650 heat units	1055.0 a	1228.4 a
Unsprayed	1017.3 a	1067.3 b

[z] Means in columns followed by the same letter(s) are not significantly different (*P* =0.05).
[y] Yield data combined across Bt varieties.

Table 2. Lint yield, gross returns, worm control costs, and returns after worm control costs of all Bt and non-Bt cotton varieties as influenced by insecticidal sprays and termination date[z], Rohwer, 1996.

Variety	Insecticide/ Termination	Lint yield	Gross return	Worm control cost[y]	Net return
		(lb/acre)	($/acre)	($/acre)	($/acre)
DP 50 Bt	Unsprayed	1312.8 a	918.96 a	32.00	886.96 a
DP 50 Bt	350 H.U.[x]	1303.6 a	912.49 a	46.28	866.21 a
DP 50 Bt	650 H.U.	1290.7 a	903.49 a	74.84	828.65 ab
NC33b	650 H.U.	1263.4 a	884.41 a	74.84	809.57 ab
DP50	350 H.U.	1233.6 ab	863.50 a	0.00	863.50 a
DP50	650 H.U.	1228.3 ab	859.81 ab	42.84	816.97 ab
NC33b	350 H.U.	1225.7 ab	857.99 ab	46.28	811.71 ab
NC33b	Unsprayed	1203.7 ab	842.56 ab	32.00	810.56 ab
DP 20 Bt	650 H.U.	1095.8 bc	767.03 bc	74.84	692.19 cd
DP50	Unsprayed	1067.1 c	747.00 c	0.00	747.00 bc
DP 20Bt	Unsprayed	1055.4 c	738.79 c	32.00	706.79 cd
DP 20Bt	350 H.U.	1045.0 c	731.53 c	60.56	670.97 cde
MON 531	650 H.U.	996.9 cd	697.86 cd	74.84	623.02 de
MON 531	350 H.U.	968.3 cd	677.78 cd	32.00	645.78 de
MON 531	Unsprayed	873.5 de	611.42 de	32.00	579.42 e
DP 90Bt	350 H.U.	765.6 ef	535.94 ef	60.56	475.38 f
DP 90Bt	Unsprayed	640.8 fg	448.55 fg	32.00	416.55 fg
DP 90Bt	650 H.U.	627.8 g	439.43 g	74.84	364.59 g

[z] Means in columns followed by the same letter(s) are not significantly different (*P* =0.05).
[y] Insecticide cost plus $3.00 per acre (application cost).
[x] Heat units accumulated past NAWF = 5.

Table 3. Comparison of lint yield, worm control costs, gross and net returns of Bt cotton varieties as influenced by insecticidal treatment in 1997 transgenic cotton trials[z], Rohwer.

Variety	Insecticide	Lint yield	Gross return	Worm control cost[y]	Net return
		(lb/acre)	-------------------- ($/acre)	------------------------	
PM 1330 BG	Sprayed[x]	1352.9 a	906.43 a	41.98	864.45 a
PM 1330 BG	Unsprayed	1330.9 abc	891.73 abc	32.00	859.73 ab
NC 32 Bt	Sprayed	1351.0 ab	905.20 ab	41.98	863.22 ab
NC 32 Bt	Unsprayed	1276.1 a-d	855.01 a-d	32.00	823.01 abc
NC 33b	Sprayed	1307.2 abc	875.82 abc	41.98	833.84 ab
NC 33b	Unsprayed	1257.0 cd	842.16 cd	32.00	810.16 abc
DP 20 Bt	Sprayed	1288.0 abc	862.97 abc	41.98	820.99 abc
DP 20 Bt	Unsprayed	1303.6 abc	873.38 abc	32.00	841.38 ab
PM 1215 BG	Sprayed	1262.4 a-d	845.83 a-d	41.98	803.85 abc
PM 1215 BG	Unsprayed	1187.5 de	795.64 de	32.00	763.64 cd
DP 90 Bt	Sprayed	1258.8 bcd	843.38 bcd	41.98	801.40 bc
DP 90 Bt	Unsprayed	1125.4 e	754.02 e	32.00	722.02 d

[z] Means in columns followed by the same letter(s) are not significantly different (P =0.05).
[y] Insecticide cost plus $3.00 per acre (application cost).
[x] Average of 350 heat units + 650 heat units.

Table 4. Comparison of lint yield, worm control costs, and gross and net returns of all Bt and non-Bt cotton varieties as influenced by insecticidal treatments[y], Rohwer, 1998.

Variety	Insecticide	Lint yield	Gross return	Worm control Cost[y]	Net return
		(lb/acre)	--------------------	($/acre)	----------------------
DP 428	Sprayed	949.2 a	597.98 a	49.89	548.09 a
NC 32B	Sprayed	913.3 ab	575.38 ab	49.89	525.49 ab
DP 50B	Sprayed	900.1 abc	567.06 abc	49.89	517.18 abc
DP 20B	Sprayed	837.5 a-d	527.59 a-d	49.89	477.71 a-d
DP 90B	Sprayed	835.2 a-d	526.15 a-d	49.89	476.26 a-d
NC 32B	Unsprayed	821.7 a-e	517.64 a-e	32.00	485.64 a-d
DP 458	Sprayed	810.1 b-e	510.35 b-e	49.89	460.46 b-e
DP 428	Unsprayed	767.4 c-f	483.43 c-f	32.00	451.43 b-f
NC 35B	Sprayed	750.3 def	472.71 def	49.89	422.82 d-g
DP 655	Sprayed	749.9 def	472.45 def	49.89	422.57 d-g
DP 50B	Unsprayed	737.2 def	464.41 def	32.00	432.40 c-g
NC 33B	Sprayed	735.9 def	463.62 def	49.89	413.73 d-g
NC 33B	Unsprayed	735.0 def	463.07 def	32.00	431.07 c-g
ST 373 (non-Bt)	Sprayed	722.6 def	455.26 def	17.89	437.37 c-g
DP 655	Unsprayed	714.2 def	449.93 def	32.00	417.93 d-g
NC 35B	Unsprayed	687.3 efg	433.02 efg	32.00	401.01 d-g
DP 458	Unsprayed	685.8 efg	432.04 efg	32.00	400.04 d-g
DP 90B	Unsprayed	664.4 fg	418.56 fg	32.00	386.56 efg
DP 20B	Unsprayed	640.7 fg	403.61 fg	32.00	371.61 fg
ST 373 (non-Bt)	Unsprayed	562.2 g	354.17 g	0.00	354.17 g

[z] Means in columns followed by the same letter(s) are not significantly different (*P*=0.05).
[y] Insecticide cost plus $3.25 per acre (application cost).

Table 5. Lint yield of Bt varieties as influenced by insecticidal treatments in 1996, 1997, and 1998 combined[z], Rohwer.

Insecticide	Yield
Sprayed[y]	1014 a
Unsprayed	935 b

[z] Means in columns followed by the same letter(s) are not significantly different (*P*=0.05).
[y] Combined for all insecticide termination regimes.

A TWO-YEAR EVALUATION OF BAIT STICKS IN AN AREA WITH LOW BOLL WEEVIL POPULATION DENSITIES IN NORTHEAST ARKANSAS

Tina G. Teague and N. Philip Tugwell[1]

RESEARCH PROBLEM

The combination of 1) sparse overwintering habitat, 2) winter conditions, and 3) the emphasis of farmers on crop earliness, generally results in low boll weevil pest pressure in much of northeast Arkansas. Low cost and low risk approaches for eradication may be appropriate for this region. One approach would include extensive use of attract-and-kill devices using the powerful boll weevil pheromone.

BACKGROUND INFORMATION

Boll weevil eradication in the southeastern and Mid-South states has included 8 to 13 insecticide sprays for fall diapause control in the first one to two years of the program. These insecticide applications result in significant reductions in boll weevil population densities. Following these reductions, eradication is accomplished with extensive use of traps in conjunction with the boll weevil pheromone. The use of malathion does not eradicate the boll weevil; it's purpose is to reduce numbers sufficiently for the pheromone and traps to eliminate the pest. Where population numbers are already low, it may be possible to eliminate diapause sprays and substitute alternative suppression tactics. The bait stick is a pheromone-based tactic that may have use as a low-cost alternative.

This research project was begun in spring 1996 to evaluate the effectiveness of bait sticks in suppressing boll weevil populations in low infestation areas. The study was conducted in northeast Arkansas in fields with historically low boll weevil population densities. We have previously reported on results from the 1997 crop year (Teague and Tugwell, 1998). Here we summarize those findings and add the results from the 1998 evaluation.

MATERIALS AND METHODS

The experiment was conducted in three adjacent fields at five sites (replications) in Craighead, Mississippi, and Poinsett counties. Site selection for the study required that each test field must be at least 50 acres with low to medium quality overwintering habitat on one or two sides only (Teague and Tugwell, 1998). There were three bait-

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stick treatments: 1) standard bait sticks (BWACT, Plato Industries, Houston, Texas) baited with 60 mg pheromone, 2) brown sticks with 60 mg pheromone (non-painted & no toxicant), and 3) no sticks or pheromone. Since each site had at least 1500 ft adjacent to overwintering habitat, there were at least 15 sticks/treatment/site--1 stick per 100 ft. A buffer area of at least 200 ft was left between treatments. Treatments were installed in early April 1996, and new sticks with pheromone were set every four weeks through October. In April 1997, old sticks from 1996 were removed and pheromone traps were installed at 100-ft intervals for each treatment. Trapping continued for five weeks. In the third week of May, traps were removed and bait-stick treatments were reinstalled for 1997 in the same configuration as 1996. Monthly rotations continued through October 1997. In spring 1998, all old sticks were once again removed and traps installed as done in 1997[1]. Trapping continued for five weeks.

RESULTS

Weevil infestations were low in experimental sites in 1996 and 1997. Moderate to high weevil fall dispersal was observed in the fields after local cotton had reached cutout, but these infestations were of no economic significance to the crops. Effects of the 1996 treatments assessed in 1997 pheromone trapping indicated that significantly ($P < 0.05$, AOV) lower numbers of boll weevils were associated with fields treated with bait sticks, with or without toxin (Fig. 1). Similar trends were observed in 1998 trapping, although overall weevil numbers in 1998 were higher than in previous years because of mild 1997/98 winter conditions and higher than normal survival of overwintered weevils. Once again significantly fewer boll weevils ($P < 0.05$) were associated with fields treated with bait sticks, with or without toxicant.

PRACTICAL APPLICATION

Results from this experiment indicate that both bait-stick treatments significantly reduced boll weevil numbers. The mechanism by which pheromone alone (brown sticks, no toxicant) resulted in reductions in insect numbers is unknown. Explanations for these results can be only speculative without further research, but with eradication now progressing through the state, ample time for that research is not available. Regardless of mechanisms, we believe that bait-stick technology shows promise for use in eradication programs in low population density areas. This pheromone-based technology integrated with other suppression tactics that focus on weevil control at the border of the hibernation quarters could be an important component of a total eradication program for the low infestation zones in Arkansas.

ACKNOWLEDGMENTS

Funding for this project was provided through Cotton Incorporated. We thank the following cooperating growers and their crews: Snowden and Cole Hawkins, Billy Baker, Jim Moon, Jr., Gary Beard, Eric Boling, Dennis Gathright, and Danny Finch. We also acknowledge Mike Gibson of the Judd Hill Foundation for his assistance.

[1] One site was dropped in spring 1998 after a fire destroyed the overwintering habitat adjacent to treatments.

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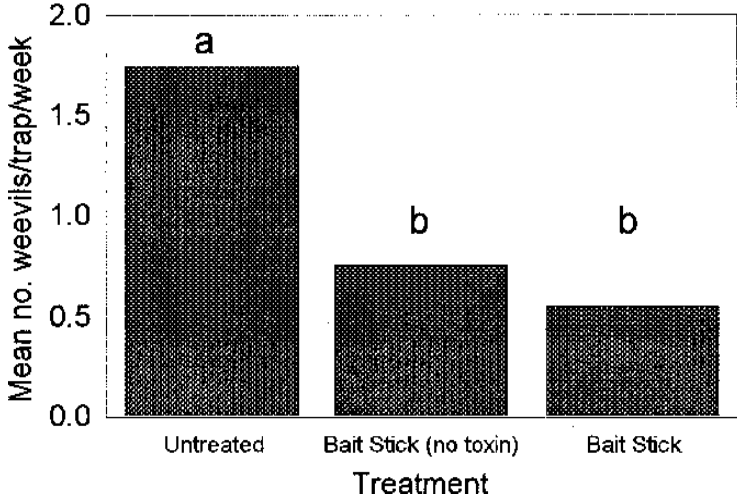

Fig. 1. Mean number of boll weevils per trap collected in pheromone traps in April to mid-May 1997 in evaluations of 1996 bait-stick treatments.

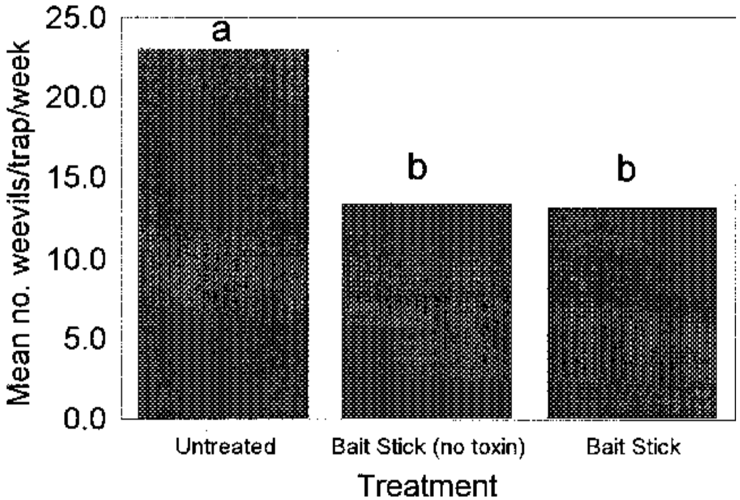

Fig. 2. Mean number of boll weevils per trap collected in pheromone traps in April to mid-May 1998 in evaluations of 1997 bait-stick treatments.

MORTALITY OF BOLL WEEVIL (*Anthonomus grandis* Boheman) ON SEEDLING COTTON TREATED WITH IN-FURROW INSECTICIDES AND NEMATICIDES

Tina G. Teague, N. Philip Tugwell, Gus Lorenz, and Terry L. Kirkpatrick[1]

RESEARCH PROBLEM

One goal in Arkansas boll weevil eradication programs is to prevent boll weevil colonization of cotton fields in the spring and early summer. Pesticides applied at planting directed at thrips or nematode control can also reduce numbers of "pioneer" boll weevils invading presquaring cotton. This research was designed to compare survival of overwintered boll weevils fed seedlings treated with commonly used in-furrow insecticides / nematicides.

BACKGROUND INFORMATION

In-furrow applications of Temik (aldicarb) have been shown to reduce populations of weevils (Bariola *et al.*, 1971); however, levels of control resulting from other insecticides are less understood. Research results in 1997 showed no difference in survival of boll weevils fed cotton seedlings grown from Gaucho (imidacloprid)-treated seed compared to non-treated seed (Teague and Tugwell, 1998). In that same study, cotton seedlings treated with in-furrow applications of Temik 15G (5 lb formulation / acre) were toxic to boll weevils with mortality as high as 90%. This work was expanded in 1998 to include additional rates of Temik and other commonly used at-planting insecticides / nematicides.

MATERIALS AND METHODS

Cotton cultivar 'Stoneville 474' was planted 10 May in 4 rows wide, 25 ft long plots on a commercial farm near Holly Grove. Treatments were arranged in a randomized complete block design with three replications. Insecticide / nematicide treatments were applied at planting; these included Temik 15G at 3 rates, Admire, Admire + Nemacur and Disyston 15G.

Seedlings (cotyledon and 1-leaf stage) from these plots were collected on 22 May. Ten weevils were placed in 1-gallon glass jars containing three *bouquets* consisting of 4 to 6 seedlings from the appropriate treatment plot and held in 3-oz. plastic capped cups filled with water. After three days, new seedlings were collected to replace the old

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plants. Mortality was assessed at seven days. Boll weevils collected from pheromone traps placed on the University of Arkansas Cotton Branch Station in Marianna were used for the bioassays.

RESULTS

Mortality ranged between 95 and 100% when boll weevils were fed Temik-treated seedlings. This was significantly greater mortality compared to that observed with untreated or Admire-treated seedlings (Table 1). Addition of Nemacur to Admire increased boll weevil mortality to a level comparable to Disyston.

PRACTICAL APPLICATION

In-furrow Temik applications can reduce survival of pioneer boll weevils invading seedling cotton. During years and in locations where boll weevil emergence occurs relatively early in spring, mortality from in-furrow applications could have significant negative impact on first generation weevils. This has been observed in late-planted Texas cotton (Bariola *et al.*, 1971).

Boll weevils whose spring emergence time is synchronized with availability of squaring cotton will be most successful in colonizing fields. One goal of Arkansas Eradication Programs will be to control these colonizing weevils near the field border and reduce the need for field-wide spring malathion applications. We assume that an additional benefit of elimination of early emerging pioneer weevils (and the pheromone they produce) in presquaring cotton is to decrease their interference with pheromone-based suppression tactics aimed at keeping weevils aggregated near the field border where they are controlled with traps, bait sticks, or malathion border sprays.

ACKNOWLEDGMENTS

We thank Mr. Mike Richardson of Holly Grove for his cooperation in this trial. We appreciate Mr. Alan Beach's assistance with the trial.

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Table 1. Mean percent mortality of boll weevils after seven days feeding on cotton seedlings treated with in-furrow insecticides/nematicides.

Treatment & formulation/acre	% Mortality
Untreated	7.4
Temik 3.5 lb	100.0
Temik 5.0 lb	100.0
Temik 7.0 lb	95.8
Admire 3.2 oz	18.5
Admire 3.2 oz + Nemacur 1qt	59.3
Disyston 15 G 6.5 lb	51.0
$P > F$ (AOV)	0.005
LSD (0.05)	38.52

SUMMARY OF INSECTICIDE PERFORMANCE FOR BOLL WEEVIL (*Anthonomus grandis*) CONTROL IN ARKANSAS COTTON

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RESEARCH PROBLEM

Boll weevil control has been a major concern of cotton producers in Arkansas. The use of insecticides is presently the only effective means of control, however, insecticidal performance varies among products. Studebaker and Johnson (1991) reported that the pyrethroid insecticides performed well, usually keeping damage levels below 20%, while Guthion or azinphosmethyl gave little control. In general, malathion has performed well as a ultra low volume (ULV) formulation in the boll weevil eradication (Jones *et al.*, 1996), but performed poorly in a water based spray.

BACKGROUND INFORMATION

Organophosphates, pyrethroids, tank-mixes, and other insecticides were compared for efficacy against the boll weevil in Lonoke County over a nine-year period. Results from all of these tests have been compiled and summarized to show each treatment's relative performance. Boll weevil control was calculated from damage levels in the treated plots compared to the untreated. Each insecticidal treatment was grouped into one of six categories based upon its chemical makeup. The best performing groups included: fipronil (Regent), averaging 64% control; pyrethroids, averaging 65% control; and tank-mixes, averaging 66% control. Other groups included organophosphates, averaging 36% control; endosulfan (Phaser/Thiodan), averaging 45% control; and oxymyl (Vydate) averaging about 48% control.

RESEARCH DESCRIPTION

Insecticide tests for boll weevil control were conducted from 1989 through 1997 in Lonoke County. Insecticidal treatments were started when 10 to 20% of squares were damaged by weevil punctures (usually mid-August) and terminated in September. Cotton plots were 12 rows wide by 50 ft long and on 38-ft row spacing. Treatment plots were replicated four times. One row of cotton between each plot was mowed down to suppress migration from plot to plot.

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Insecticides were applied with a John Deere Hi-Cycle 6000 equipped with a CO_2-mounted spray system with TSX-6 hollow cone nozzles spaced on 19-in. center. Insecticide treatments were applied at approximately 10 GPA and 50 PSI. Insecticide treatments began when damage to squares reached an average of 12 to 20%. Treatments were applied on a three- to five-day interval and were evaluated by inspecting 25 squares in each plot two to three days after treatments were applied. Boll weevil control was calculated from damage levels in the treated compared to the untreated cotton using the Abbot's formula (Abbott, 1925).

RESULTS

Pyrethroids

The pyrethroids were the best performing class of insecticides for boll weevil control (Table 1), averaging 65% control of infestations. Of the pyrethroids, Asana XL, Baythroid, Capture, and the new formulation of Karate, Karate Z 2.09, were the most effective for controlling boll weevils. Baythroid controlled boll weevils well at the most common field rates (0.028 to 0.040 lb ai/acre), averaging from 74 to 97% control. Baythroid at the 0.22 lb/acre rate was less effective, averaging only 48% control. Capture (0.050 lb ai/acre) also performed well on boll weevils, averaging 78% control. Increasing the rate did not increase boll weevil control. Control of boll weevils with Asana XL increased with higher rates. Plots sprayed with Asana XL at 0.030, 0.036, and 0.042 lb ai/acre gave 65, 72, and 89% control, respectively. A new formulation of Karate (Karate Z, 2.09E) had good boll weevil control, averaging 83% control. Karate Z should be available to growers this year. Decis, Fury, Karate, and Scout X-tra gave fair boll weevil control (50-65%).

Organophospates

In general, organophosphate insecticide performance was fair for boll weevil control (Table 2), averaging 36%. The best organophosphate treatments were Bidrin (0.5 lb ai/acre), Guthion (0.5 lb ai/acre), Penncap M (0.5 lb ai/acre), and Cythion RTU (0.8 lb ai/acre), which averaged 62, 52, 50, and 48% boll weevil control, respectively.

Oxymyl, Endosulfan, and Fipronil

Regent (a fipronil) provided good boll weevil control (averaged up to 67%). Vydate and Phaser/Thiodan (Oxymyl and endosulfan) gave fair control with 48 and 45% control (Table 3).

Tank-Mixes

Combining insecticide products in a tank-mix usually provided very good boll weevil control (Table 4). Insecticides applied as tank-mixes averaged 66% control overall. In general, tank-mixes had similar or better control levels than pyrethroids. In particular, tank-mixes Scout X-tra with Vydate, Karate with Vydate, Decis with Thiodan, and Asana with Vydate showed improved control (averaging 75 to 93% control) than the tank-mix partner used by itself.

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Table 1. Pyrethroid insecticide control of the boll weevil.

Trade Name	Common name	Rate	No. of trials	Control
		(lb ai/acre)		(%)
Asana XL 0.66E	esfenvalerate	0.030	6	65.0
		0.036	2	71.8
		0.042	1	79.4
Baythroid 2E	cyfluthrin	0.022	2	47.5
		0.025	1	74.4
		0.028	7	81.4
		0.030	2	74.2
		0.040	1	86.7
Capture 2E	bifenthrin	0.050	1	78.0
		0.060	1	74.2
Decis 1.5 E	deltamethrin	0.020	4	54.0
Fury 1.5E	zeta-cypermethrin	0.038	4	56.9
Karate 1E	lambda-cyhalothrin	0.025	7	62.5
		0.028	2	63.5
		0.030	1	58.4
		0.033	2	64.4
Karate Z 2.09E	lambda- cyhalothrin	0.025	2	83.0
Scout X-tra 0.9E	tralomethrin	0.018	3	50.4
		0.020	1	61.0
		0.024	4	61.7
All pyrethroids				64.7

Table 2. Organophosphate insecticide control of the boll weevil.

Trade Name	Common name	Rate	No. of trials	Control
		(lb ai/acre)		(%)
Cythion RTU	malathion	0.80	1	47.6
Guthion 2E	azinphosmethyl	0.25	8	24.5
		0.38	1	41.0
		0.50	1	51.6
Imidan 50WP	phosmet	0.05	1	25.2
		0.075	1	3.3
		1.00	1	25.1
Methyl Parathion 4E	methyl parathion	0.50	2	34.5
Penncap M 2E	methyl parathion	0.25	4	33.7
		0.35	1	44.6
		0.50	2	50.4
Bidrin	dicrotophos	0.50	2	62.4
All pyrethroids				36.0

Table 3. Oxamyl, endosulfan, and fipronil control of the boll weevil.

Trade name	Common name	Rate	No. of trials	Control
		(lb ai/acre)		(%)
Vydate CLV 3.77	oxamyl	0.25	2	42.0
		0.50	2	53.6
	All Oxamyls			47.8
Phaser/Thiodan 3E	endosulfan	0.25	1	45.0
		0.375	1	39.7
		0.50	1	50.7
	All Endosulfans			45.2
Regent 80WG	fipronil	0.050	1	66.8
		0.068	1	62.1
Regent 2.5E	fipronil	0.050	1	64.7
		0.068	1	60.9
	All Fipronils			63.6

Table 4. Tank-mix insecticide control of the boll weevil.

Trade name	Common name	Rate	No. of trials	Control
		(lb ai/acre)		(%)
Methyl Parathion 2E	methyl parathion	0.250		
Thiodan 3E	endosulfan	0.375	2	49.0
Scout X-tra 0.9E	tralomethrin	0.900		
Vydate CLV 3.77E	oxamyl	0.250	1	76.5
Baythroid 2E	cyfluthrin	0.028		
Guthion 2L	azinphosmethyl	0.025	1	83.2
Karate 1	lambda-cyhalothrinE	0.025		
Vydate CLV 3.77E	oxamyl	0.250	1	81.1
Axana XL 0.66	esfenvalerate	0.030		
Vydate CLV 3.77E	oxamyl	0.250	1	74.5
Decis 1.5E	deltamethrin	0.023		
Phaser/Thiodan 3E	endosulfan	0.500	1	92.2
Ammo 2.5E	cypermethrin	0.060		
Methyl Parathion 2E	methyl parathion	0.250	1	69.3
Thiodan 3E	endosulfan	0.375		
Orthene 90SP	acephate	0.500		
Vydate CLV 3.77E	oxamyl	0.250	2	47.7
All tank-mix insecticide treatments				66.3

VALIDATION AND ECONOMIC BENEFITS OF COTMAN INSECTICIDE TERMINATION RULES: FOUR YEARS OF RESEARCH

Mark J. Cochran, Diana M. Danforth, Sha Mi, N. Philip Tugwell, N. Ray Benson, and Kelly J. Bryant[1]

RESEARCH PROBLEM

The elimination of late-season insecticide applications when bolls are no longer susceptible to damage by fruit-feeding insects has the potential to save producers money without adversely impacting yields. Research was designed to (1) validate that bolls are no longer susceptible to damage from fruit-feeding insects when they have accumulated 350 heat units (HUs or DD60s) after Nodes Above White Flower equals five (NAWF=5), and (2) define the economic cost savings when this rule is used to terminate unnecessary insecticide applications.

BACKGROUND INFORMATION

The Economic Threshold concept described by Stern *et al.* (1959) has been widely adopted for determining when to initiate insect control in cotton during crop development, but it does not apply when the crop is tolerant and no longer susceptible to damage from pests (Pedigo *et al.*, 1986). To attempt to use thresholds after a crop has become tolerant to pests will result in unnecessary economic and ecological costs. A procedure for defining the end of crop susceptibility and the beginning of boll tolerance to such pests as the boll weevil, bollworm, tobacco budworm, and plant bug has been the focus of recent research. Studies by Wells (1983) and Bourland *et al.* (1992) indicate that the flower date of the last effective boll population, or cutout, could be identified by a slowdown in terminal growth as described by NAWF=5. Bagwell and Tugwell (1992) found evidence suggesting that a crop was no longer susceptible to fruit-feeding insects when bolls accrued 350 HUs. This report uses data collected over a four-year period from 1995 through 1998 in Arkansas, Louisiana, Mississippi, and Texas to validate insecticide termination at 350 HUs and to define cost savings to producers from using this termination rule.

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RESEARCH DESCRIPTION

Small Plot Experiments

Validation experiments in small plots were designed to determine the optimum HUs beyond NAWF=5 when insecticide applications could be terminated without adversely affecting yields. Natural infestations of fruit-feeding pests (excluding leaf-feeding pests) in numbers high enough to threaten damage were required to define optimum HUs for spray termination. Treatments were sprayed until designated HUs for application termination had been reached. Two treatments terminated insecticides at fewer than 350 HUs (0 and 200), one treatment terminated at 350 HUs, and two additional treatments terminated at greater than 350 HUs (500 and 650). Plots were arranged in a randomized complete block design with four replications. Where lint yields were unavailable, seedcotton yields were converted to lint yield / acre assuming a 33% lint turnout. A one-way ANOVA was calculated to test the null hypothesis of no treatment differences in yields.

Large Plot On-Farm Experiments

Large plot treatments also were arranged in a randomized complete block design with replications. The 350 HU termination treatment was compared with a standard full-season grower treatment that was assumed to reflect the spray routine normally used by each grower or advisor. The large plot tests were established in fields where COTMAN data were available and only where threatening fruit-feeding insect infestations were located. The full-season treatments were sprayed as many times as the growers or their advisors thought necessary to protect the crop, but in the other treatment, sprays were terminated at NAWF=5 + 350 HUs. Where lint yields were unavailable, seed cotton yields were converted to lint yield / acre assuming a 33% lint turnout. A one-way ANOVA was calculated to test the null hypothesis of no treatment differences in yields. Gross revenues for each treatment were also calculated by assuming a lint price of 65 cents / lb. Net revenues were then calculated as gross revenue minus costs of insect control after 350 HUs. A one-way ANOVA also was calculated to test the null hypothesis of no treatment differences in net revenues.

RESULTS

Small Plot Experiments

Twenty small plot research trials were conducted in Arkansas, Louisiana, Mississippi, and Texas over the three-year period from 1995 through 1997. In some trials, one or more treatments were eliminated due to weather and other constraints. Those are indicated by dashes in the result tables.

Only 4 of the 20 trials showed significant treatment differences in yield. In 1995, the Asgrow experiment showed significantly higher yield with termination at 200 HUs as compared with termination at cutout (0 HUs), while the station experiment resulted in higher yield at 350 HUs compared with 650 HUs (Table 1). In 1996, no significant differences were found in any of the experiments (Table 2). In 1997, the SJTRM971 experiment showed termination at cutout (0 HUs) to result in significantly lower yields than termination at 350 HUs or higher, while the MRTRM973 experiment showed termination at 200 HUs or lower to result in significantly less yield than at 450 heat units or above (Table 3).

Results from the 20 small plot experiments showed that no yield penalty was ever associated with insecticide termination at 350 HUs from cutout. However, yield penalties were observed at termination earlier than 350 HUs in three of the experiments.

Large Plot On-Farm Experiments

Thirty-three large plot research trials were conducted in Arkansas, Mississippi, and Texas over the four-year period from 1995 through 1998. In those experiments, termination at 350 HUs resulted in (1) no yield difference in 30 cases; (2) significant yield penalty in two cases; and (3) a significant yield increase in one case (Table 4). The 1995 Arkansas large plot trial, Wildy31 showed a yield penalty and involved a field that had substantial replant because of seedling injury following a sandstorm. Based on those results, when fields have a high replant percentage, COTMAN rules now recommend accumulating 450 HUs before terminating insecticides for fruit-feeding insects. In the 1995 Arkansas trial, Young also showed a yield penalty. However, when additional control costs were subtracted, the termination at 350 heat units resulted in $29 more revenue per acre ($F = 99999$, $p > F = .0001$). The high F value and associated probability in statistical tests for yield and net revenue differences are due to identical yield values reported for each replicate in a treatment.

Over all trials, a difference of less than 2 lbs of lint / acre was observed between full-season treatment and termination at 350 HUs. An average of $19.62 / acre was spent on additional control costs not resulting in increased yields.

PRACTICAL APPLICATION

Results indicate that the COTMAN insecticide termination rules work. In three years of research involving 20 small plot trials, a yield penalty was never observed for insecticide termination at 350 HUs beyond NAWF=5. Four years of large plot grower trials compared yields using the COTMAN insecticide termination rule to yields using the growers' normal action thresholds for insecticide applications. In each of the 33 trials, the grower thresholds resulted in additional insecticide applications beyond 350 HUs at an additional cost ranging from $7 to $70 per acre (Table 4). In 32 of 33 trials, insecticide termination at 350 HUs improved farm profits. Overall, an average of less than 2 lbs of lint difference was observed between insecticide termination at 350 HUs and the grower full-season treatment. An average of $19.62 per acre was spent on insect control with no return to yield.

The COTMAN insecticide termination rule is part of the BOLLMAN portion of the program (Danforth and O'Leary, 1998). It uses easy-to-collect NAWF counts starting at first flower and ending at NAWF=5, and requires about 16 to 23 minutes data collection time per field per week (Robertson *et al.*, 1997). COTMAN identifies the date that each field reaches NAWF=5 and then, using current local temperatures, identifies the date that bolls are no longer susceptible to fruit-feeding insects and insecticide applications can be stopped. Research results from different locations and in different years were consistent as to the potential for the COTMAN insecticide termination rule to save the producer money. In fact, if the average savings of $19.62 per acre were applied to the 900,000 harvested cotton acres in 1998, more than $17.5 million in insecticide costs could have been saved by Arkansas producers.

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Table 1. 1995 Small plot research: lint yield by heat units from cutout at insecticide termination.

	Treatment heat unit category					
Experiment	0	200	350	500	650	LSD
	lint yield (lb/ac)					
SJCT9501 (LA)	565	587	564	633	640	134
MRCT9526 (LA)	685	725	710	656	683	87
MRCT9525 (LA)	685	719	710	705	719	47
Marianna (AR)	1357	1361	1309	1288	1338	138
Asgrow (TX) *	698	815	757	738	763	104
TAES (TX)	752	771	773	766	741	98
Station (AR) *	893	--	974	905	859	109

*Significant difference among treatments at $P < 0.05$.

Table 2. 1996 Small plot research: lint yield by heat units from cutout at insecticide termination.

	Treatment heat unit category					
Experiment	0	200	350	500	650	LSD
	lint yield (lb/ac)					
Marianna (AR)	931	1025	1153	1017	1091	141
MRTRM961 (LA)	750	763	801	783	777	65
MRTRM963 (LA)	1143	1150	1228	1420	1343	202
SJTRM961 (LA)	1357	1361	1309	1288	1338	138
MRTRM962 (LA)	351	393	397	395	349	95
BM (MS)	1271	1377	1442	1427	1327	206
PH (MS)	--	1106	1256	1202	--	158

Table 3. 1997 Small plot research: lint yield by heat units from cutout at insecticide termination.

	Treatment heat unit category					
Experiment	0	200	350	500	650	LSD
	lint yield (lb/ac)					
MRTRM971 (LA)	676	711	786	718	698	111
SJTRM971 (LA) *	421	445	458	449	459	26

	Treatment heat unit category				
Experiment	0	200	450	550	LSD
	lint yield (lb/ac)				
MRTRM972 (LA)	--	631	--	599	84
MRTRM973 (LA) *	445	448	518	545	55
MRTRM974 (LA)	180	216	164	229	71

*Significant difference among treatments at $P < 0.05$.

Table 4. Large plot research, 1995-1998: lint yield for insecticide termination at 350 heat units from cutout vs. grower full-season treatment with additional full-season control costs

		Lint yield						Full-season control	
		350 Termination	Full-season	Reps	*SE* of estimate	*F*	*p > F*	Addt'l Applications	Add'l costs
								(#)	($/acre)
Arkansas									
1995	Wildy31	782	819	10	10.92	11.40	0.0082	1	9.29
	Wildy46	691	688	10	13.36	0.04	0.8444	1	9.29
	Wildy49	839	831	10	8.01	0.85	0.3808	1	9.29
	Young	834	843	2	0.00	100000	0.0001	3	35.49
1996	Parten	596	513	2	125.00	0.44	0.6263	1	11.80
	Young	608	652	2	24.50	3.30	0.3204	1	11.80
1997	Steve	958	951	4	24.72	0.07	0.8068	1	32.69
	Wildy	640	599	5	88.62	0.21	0.6618	1	10.50
1998	Edwards	775	745	2	50.69	0.34	0.6625	2	17.95
	Finch	481	489	5	3.94	3.93	0.1186	2	14.69
	Gandy	785	791	3	75.95	0.00	0.9509	1	10.80
	Kimbrall	930	846	4	17.33	23.35	0.0169	1	7.34
	Mizell3	1019	896	4	90.49	1.85	0.2674	2	25.46
	Mizell-T	728	740	4	12.81	0.84	0.4274	2	28.54
	Stuckey	494	503	3	19.38	0.17	0.7167	1	12.83
	Wildy15	867	868	3	15.61	0.00	0.9852	2	20.15
	Wildy89	433	446	7	20.16	0.43	0.5372	2	20.16
Mississippi									
1995	BM3	992	961	1	0.00			4	56.30
	Campbell5	482	474	3	22.71	0.06	0.8103	2	10.38
	Campbell7	590	556	3	19.19	3.15	0.2178	2	10.89
	HN4	743	793	2	26.18	3.60	0.3090	1	17.72
	KP1	1053	1001	3	70.11	0.56	0.5314	1	14.56
	MM1	683	735	3	104.13	0.25	0.6676	1	12.44
	SP2	916	893	3	16.89	1.80	0.3118	2	32.86
1996	BM	1135	1310	3	49.78	12.43	0.0719	2	21.92
	HN	915	989	3	38.34	3.73	0.1932	2	18.60
	JO	727	715	3	21.39	0.31	0.6322	2	31.68
	KP	1417	1430	3	124.45	0.01	0.9242	1	17.01
	LJM	1255	1222	5	32.70	1.00	0.3750	NA	NA
	RO	986	948	3	163.35	0.06	0.3451	5	70.91
Texas									
1995	Edwin	912	949	3	39.98	1.50	0.3957	1	6.88
	Glass	1131	1163	3	57.33	1.14	0.5796	1	6.88
	Marburger	970	1047	3	70.92	1.50	0.3238	1	6.88
Mean[z]	829	831						1.68	19.62

[z] Average of additional costs is calculated excluding Wildy31 and by using $29/acre for Young. Wildy31showed yield difference that supported full-season but the net revenues showed no difference. Young also showed yield difference that supported full-season, but the net revenue under 350 heat unit termination was $29 higher than for full-season. In this case, we used the $29 difference between net revenues for Young instead of the $35 additional cost.

CYTOPLASMIC MALE STERILITY BASED ON *Gossypium sturtianum* CYTOPLASM (CMS-C_1): CHARACTERIZATION AND GENETICS OF RESTORATION

Jinfa F. Zhang and James McD. Stewart[1]

RESEARCH PROBLEM

To exploit heterosis in cotton, an efficient hybrid production system is a necessity. Hybrid seeds in many crops are produced by virtue of a cytoplasmic male sterile (CMS) system. However, the *harknessii* CMS system of cotton has not been particularly successful in hybrid cotton production in the United States because of problems with fertility restoration, possible negative effects on yield potential, and economics of F_1 seed production. With the advent of high-value transgenic seed, the economic factors are changed, but the other problems remain. In addressing these, we are examining a new CMS in cotton based on *Gossypium sturtianum* (C_1) cytoplasm.

BACKGROUND INFORMATION

CMS can arise spontaneously in natural populations or breeding lines following mutagenesis as a result of wide crosses, or by interspecific cytoplasmic replacement. In cotton, no natural CMS mutant has been found. When the cytoplasm of one species is replaced by that of a related but genetically distant species, male sterility conditioned by the new cytoplasm is a common result. The Australian and American wild species of *Gossypium* are most distant from cotton based on chloroplast DNA diversity (Wendel and Albert, 1992) and are the most likely to result in male sterility in alloplasmic lines. Alloplasmic CMS lines with American species *G. harknessii* (D_{2-2}), *G. aridum* (D_4), and *G. trilobum* (D_8) cytoplasms have been developed (Meyer, 1975; Stewart, 1992), however, no CMS cotton based on an Australian wild *Gossypium* species cytoplasm has been reported.

RESEARCH DESCRIPTION

The alloplasmic line (CMS-C_1-57-4) with *G. sturtianum* cytoplasm and Pima 57-4 nuclear background was developed by Stewart (1992) from a genotype containing C_1 cytoplasm obtained from Dr. A.A. Bell. CMS-C_1-57-4 and its recurrent parent, Pima 57-4 were tested in replicated field trials in 1996-1998. Anther number, chlorophyll content, photosynthetic rate, stomatal conductance, and water transpiration rate were

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measured on the fourth leaf from the top of plants during the boll-filling stage each year. Agronomic traits and fiber properties were determined following harvest.

CMS-C_1-57-4 was crossed as female with B418R (D_{2-2} restorer line, D2R) and D8R, the D_8 restorer line, respectively. The F_1's were grown in the greenhouse in the winter of 1995 to generate F_2 populations. During 1996-1998, additional crosses were made and all tested for male fertility (see Table 5).

RESULTS

CMS-C_1-57-4 resembled its recurrent parent, Pima 57-4, in plant growth habit and general vegetative morphological traits; however, as in other CMS lines, flower buds and flowers were smaller than the fertile parent and no pollen was produced. The number of anthers per flower in CMS-C_1 was not significantly different from the 57-4 recurrent parent (Table 1).

Over a three-year period, CMS-C_1 consistently had higher net photosynthetic rate, stomatal resistance, and transpiration rate than 57-4 (Table 2), however, no significant differences were detected in chlorophyll contents (Table 3). CMS-C_1 had significantly lower yield due to lower lint percentage and smaller boll size than 57-4 and fiber length was significantly longer (Table 4).

Cotton lines D_8R and D_2R (restorers of other CMS genotypes) and T582 and T586 (non-restorers) were crossed onto CMS-C_1 to test for fertility restoration (Table 5). D_8R was unable to restore fertility to CMS-C_1 progeny. Testcrosses with T582 and T586 also indicated that upland cotton has no restorer factor(s) for CMS-C_1. However, the F_1 between CMS-C_1 and D_2R were all fertile, and the F_2 had 3 fertile to 1 sterile ratio, indicating that a single D_2R gene (Rf_1) can restore fertility to CMS-C_1. The test-cross between CMS-C_1 and (TM-1 x D_2R)F_1 confirmed that only one restorer gene (Rf_1) is involved in restoration (Table 5).

PRACTICAL APPLICATION

With the advent of high-value transgenic seeds, the potential for hybrid cotton becomes more economically feasible if a suitable male sterile / restorer system can be developed. The existing CMS system based on the cytoplasm of *G. harknessii* suffers from restoration problems and potential yield depression. The CMS-C_1 along with the CMS-D_8 developed at the University of Arkansas offer additional possibilities for hybrid cotton production.

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Table 1. Anther numbers in different CMS systems of cotton[z].

	1996				1998			
Genotype	Set 1	Set 2	Set 3	Mean	Set 1	Set 2	Set 3	Mean
Pima 57-4 (CK)	125.8	131.0	132.0	129.6	150.7	142.7	153.3	148.9
CMS-C_1-57-4	114.5	127.3	137.3	126.4	139.3	139.3	146.7	141.8

[z]Anthers in five to six flowers were counted in each set.

Table 2. Photosynthetic rate and its related traits in CMS-C1[z].

		CMS-C_1-57-4			Pima 57-4		
Date		Net photosynthetic rate	Stomatal conductance	Transpiration rate	Net Photosynthetic rate	Stomatal conductance	Transpiration rate
		(µmol $CO_2 m^{-2}S^{-1}$)	(cm S^{-1})	(mmol CO_2 $m^{-2}S^{-1}$)	(µmol $CO_2 m^{-2}S^{-1}$)	(cm S^{-1})	(mmol CO_2 $m^{-2}S^{-1}$)
1996	7/25	21.98	1.39	5.91	17.79	0.98	5.08
	8/2	17.89	4.04	14.30	15.80	2.36	12.53
	8/6	17.52	1.55	10.77	14.51	1.20	9.33
	8/19	16.87	0.64	2.97	20.44	0.87	3.63
1997	7/30	26.59	1.47	16.71	25.30	1.34	16.57
	8/4	27.29	5.95	26.25	26.33	5.54	25.68
1998	8/17	28.15	1.58	21.93	20.38	0.65	25.58
	8/18	27.42	2.17	22.85	26.52	2.41	17.27
Average		22.96	2.35	15.21	20.88	1.92	22.47
		+9.96%	22.41%	7.57%	0	0	0

[z]One to two leaves per plot were sampled.

Table 3. Chlorophyll contents[z] and in CMS-C_1 and 57-4.

	Chlorophyll content	
Trait	CMS-C_1-57-4	Pima 57-4
	------------------- (mg dm^{-2})	-------------------
Chlorophyll a	2.78	2.97
Chlorophyll b	0.99	1.30
Total chlorophyll	3.77	4.27
Chlorophyll a/ b	2.81	2.57

[z] One disk (0.3848 cm^2/disk) from each of six plants were pooled for chlorophyll extraction in 10 ml of 80% acetone at -4°C for 24 to 48 hours.

Table 4. Agronomic performance of CMS-C_1 compared to the recurrent parent.

Trait		CMS-C_1-57-4	57-4	LSD 0.05
Seedcotton yield (g/10 plts)	1997	124.5	325.1*	101.0
Fiber yield (g/10 plts)	1997	36.8	120.9*	36.0
Lint (%)	1996	28.69	37.44*	1.64
	1997	29.53	37.40*	1.32
Boll size (g)	1996	2.48	3.55*	0.39
	1997	3.12	4.90*	0.66
Fiber length (inch)	1996	1.26	1.13*	0.09
	1997	1.31	1.16*	0.06
Fiber strength (g/tex)	1996	39.30	41.90	5.60
	1997	38.37	35.57	4.07
Elongation (%)	1996	7.13	9.30	1.50
	1997	7.33	9.03	0.79
Micronaire	1996	4.77	4.63	0.37
	1997	4.97	4.40	0.59

Table 5. Fertility segregation in crosses between CMS-C_1 and D_8R and D_2R.

Cross	No. fertile	No. sterile	Expected ratio	P^2 [z]
(CMS-C_1 x D_8R)F_1	0	26	0:1	
(CMS-C_1 x D_8R)F_1 x T582	0	5	0:1	
(CMS-C_1 x D_8R)F_1 x (T586 x D_8R)F_1	0	69	0:1	
(CMS-C_1 x D_2R)F_1	39	0	1:0	
(CMS-C_1 x D_2R)F_2	188	50	3:1	2.03
CMS-C_1 x (TM-1 x D_2R)F_1	52	60	1:1	0.57

[z] P^2 (0.05) = 3.84.

CLONING OF A BIOACTIVE PEPTIDE FOR COTTON TRANSFORMATION

Satyendra Rajguru and James McD. Stewart[1]

RESEARCH PROBLEM

Cotton plants are under constant assault by microbial pathogens and insect pests. Fungal pathogens alone contribute to a major reduction in yield in the United States. Fungicides have been widely used to control the incidence of disease, however, excessive use of fungicides and pesticides challenge fragile ecosystems. An alternative method of dealing with pathogenic microbes is by incorporating disease resistance genes or biocidal genes to impede or kill the invading pathogen. This project emphasizes the incorporation of a gene with antifungal properties into cotton in order to will enhance the resistance of cotton to major fungal diseases.

BACKGROUND INFORMATION

Bioactive peptides have been identified from various organisms. One of the peptides that has emerged as a potential candidate for genetic engineering is magainin. Magainins are small (approximately 23 to 30 amino acids) antibiotic peptides isolated from African clawed frog (*Xenopus laevis*). Two isoforms of magainin have been isolated and named magainin 1 and 2. They possess broad anti-parasitic and antibiotic activities (Zasloff, 1987). Magainin interacts directly with lipid bilayers and ruptures the cellular membrane of target cells thereby disrupting the membrane integrity by forming ion channels across lipid bilayers of microorganisms. Membranes of higher plants and animals are relatively insensitive to the peptide (Duclohier *et al.*, 1989; Cruciani *et al.*, 1992). Kristyanne *et al.* (1996) reported the antifungal activity of magainin on several species of fungi pathogenic on cotton such as *Rhizoctonia solani, Fusarium oxysporum*, *Verticillium dahliae,* and *Thielaviopsis basicola*. Magainin 2 at 0.05 mg/ml completely inhibited hyphal growth of these species. Electron microscopy revealed degradation of the mitochondrial and cytoplasmic matrices, a reduction in the number of ribosomes, and vacuolization of the cytoplasm.

RESEARCH DESCRIPTION

A DNA sequence encoding a transit peptide and the magainin gene were designed. Polymerase chain reaction (PCR) was used to synthesize the chimeric gene. The transit peptide chosen in this case was one which would facilitate secretion of the protein from

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the cells to the extracellular space. Following PCR, the fragment was purified and cloned into pGEM-T vector to facilitate sequencing. White colonies containing the inserts were selected and plasmid DNA was isolated. Presence of the DNA inserts in the plasmids and bacteria were confirmed by PCR. Also, the fragment was excised from the re-isolated plasmid with two restriction enzymes, BamH I and Sac I as additional confirmation of its presence. The fragment was then purified and cloned into a binary vector with a constitutive gene promoter that would control its expression in plant cells. Again, the presence of the insert in the binary vector was confirmed by PCR analysis.

Future research involves the transfer of the gene into *Agrobacterium* and subsequent transformation of tobacco and cotton. Transgenic plants will be tested for the integration and expression of the gene by southern and northern blots. Transformed plants will be tested for resistance against the cotton disease organisms *T. basicola*, *R. solani*, *F. oxysporum*, and *V. dahliae*.

PRACTICAL APPLICATION

Research on bioactive peptides has received considerable attention, and it is worthwhile to consider magainin-like peptides as a potential antibiotics. Preliminary studies indicate that magainin can be included in our arsenal of various antibiotic peptides that show promise in enhancing resistance in crop plants. The use of magainin in cotton and other crops will provide an alternative tool to combat pathogens.

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GENETIC AND MOLECULAR CHARACTERIZATION OF SEMIGAMY EXPRESSION IN COTTON (*Gossypium barbadense*)

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RESEARCH PROBLEMS

Semigamy (*Se*) is a type of facultative apomixis in which male gametes do not fuse with female gametes after entering the embryo sac, leading to production of paternal and maternal haploid progeny. This phenomenon has been found in more than 10 plant species including cotton (*Gossypium barbadense* L.). It provides a potential system to investigate reproductive biology and a convenient way to generate haploids at will in cotton breeding.

BACKGROUND INFORMATION

Even though much research has been done since the *Se* cotton line, 57-4, was isolated from Pima S-1 as a doubled haploid from a natural haploid mutant (Turcotte and Feaster, 1963), many aspects of the mutant are still not known. The genetic and molecular bases for expression of the phenotype are not understood, and there are questions concerning the stability of expression. Additionally, a method for early identification of haploid seeds is needed (Zhang *et al.*, 1998).

RESEARCH DESCRIPTION

The plant materials consisted of Pima S-1, a normal *G. barbadense* (*sese*), and two semigametic lines (*SeSe*), Pima 57-4, which was derived from Pima S-1, and Sev7 which also carried a recessive gene for virescent leaf color. To evaluate the stability of *Se* expression, single-plant selection was followed by two years of progeny testing. To study the inheritance of *Se*, a cross of 57-4 x S-1 was made, and the F_2, and BC_1F_1, i.e. F_1 x both of the parents, were test crossed with Sev7. Genetic differences in photosynthesis and agronomic traits between 57-4 and its putative isoline, S-1, were compared in replicated trials during 1996 to 1998. Fourth main stem leaves from the topmost leaves were sampled for photosynthetic rate and chlorophyll content during the boll-filling stage. Different exotic cytoplasmic lines with 57-4 and Sev7 nuclear backgrounds were compared for haploid production in the same trials. Boll traits and fiber quality were determined at harvest. The genetic dissimilarity between 57-1 and S-1 was also evaluated at the DNA level with molecular markers (RAPDs). To isolate genes related

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to *Se* expression, mRNA differential display was employed to compare cDNA profiles between 57-4 and S-1. The differentially displayed cDNA bands were excised, reamplified, cloned into pGEM-T vectors, and the nucleotide sequence determined.

RESULTS AND ANALYSIS

Genetic Differences Between Pima 57-4 and Pima S-1

Compared with S-1, 57-4 had significantly lower chlorophyll a, b, and total chlorophyll contents in its functional leaves. 57-4 also had consistently lower stomatal conductance and transpiration rate. Seedcotton yield was not significantly different, but 57-4 had significantly higher lint percentage, seed weight, and micronaire (coarser fiber). Boll weight of 57-4 was lower and the fibers were shorter and stronger. Based on 171 RAPD markers generated from 20 informative primers, 57-4 was 93% identical to S-1, while each shared only 57% of the markers with upland cotton (*G. hirsutum*).

In both 57-4 and Sev7 a wide range in seed weight was noted with a substantial portion of the seeds being small. Seed weight was significantly and positively correlated with vigor as measured by germination percentage. Additionally, most small seed produced haploid plants, thus a significant and positive correlation between seed weight and ploidy level exists.

Stability of *Se* Expression

The stability of semigametic lines in producing haploids was evaluated by pedigree selection for three consecutive generations starting from a 1996 base population producing 46.3% and 43.2% haploid plants in 57-4 and Sev7, respectively. In 1997, progeny rows of 57-4 produced an average of 69.9% haploids (range14.3 to 75.5%), while progeny of Sev7 averaged 36.1% haploids (range 0 to 87.5%). In 1998, progeny families of 57-4 averaged 43.9% haploids (range 33.9 to 54.6%), while those of Sev7 averaged 43.6% (range 35.7 to 50.4%). Analysis of variance indicated no genotypic difference, but the majority of variation (68% in 57-4 and 64.6% in Sev7) was due to variance among individual bolls within a plant. In 57-4 and Sev7, 27.7% and 28.8% of total variation, respectively, was among plants within a family, whereas variance among families explained only 4.0% and 7.1% of total variation, respectively. Therefore, *Se* expression in 57-4 and Sev7 is genetically stable, but environmental and developmental factors affect haploid production.

Genetics of *Se*

The F_2 and BC_1F_1 of 57-4 x S-1 were test crossed with Sev7. The F_2 population produced semigametic (80) and non-semigametic progenies (37), which fit to a 3:1 ratio. The (F_1 x S-1) produced 50% semigametic lines (24) and 50% non-semigametic lines (26), while the (F_1 x 57-4) produced 50% higher haploid-producing lines (29) and 50% lower haploid-producing lines (21). The data confirmed that *Se* in cotton is conditioned by one incompletely dominant gene. When 57-4 was used as female parent, the F_1 gave 11.1% haploid, while the reciprocal F_1 produced no haploids. Surprisingly, the F_2 produced only 3.7% haploids. The F_1 as female backcrossed with 57-4 and S-1 produced 13.0% and 4.3% haploids, respectively, while the BC_1F_1 with 57-4 as female produced 15.2% haploids. The results could not be explained by a gametophytic control model in which haploid production is controlled by the genotype of the gamete. However, the data were consistent with a one-gene model based on a combination of sporophytic and gametophytic control.

The inheritance in chlorophyll content was investigated in the cross between lower chlorophyll-containing 57-4 and S-1. One gene was estimated from generation mean analysis. The semigametic F_3 lines also had lower chlorophyll content than the non-semigametic ones. Significant positive correlation between haploid production and chlorophyll content was found.

Cytoplasmic Effect

Alloplasmic lines with cytoplasm from 11 *Gossypium* species (A_2, B_1, C_1, D_{2-2}, D_{3-d}, E_1, F_1, AD_1, AD_3, AD_4, and AD_5) were compared for haploid production in 57-4 or Sev7 background. The results showed that the haploid percentage was much lower in cytoplamic male sterile (CMS) lines (C_1 and D_{2-2}), indicating that semigametic expression is suppressed by CMS.

Molecular Characterization of *Se*

When mRNAs from ovule and anther tissues were compared between 57-4 and S-1, more than 60 differentially expressed cDNAs were detected, cloned, and sequenced by mRNA differential display. Some of the sequences had homology to genes coding for cell division-related proteins. The *Se* gene is likely related with cell division.

PRACTICAL APPLICATION

We first demonstrated that *Se* lines produce a substantial number of small seeds that yield haploid plants. This can be used for early haploid identification in a haploid-breeding program. We also verified that *Se* is genetically stable and controlled by an incompletely dominant gene. Variation in production of haploids was due to environmental and developmental effects. The polymorphic molecular markers between 57-4 and S-1 provide putative molecular markers for tagging the *Se* gene, so that development of new semigametic lines can be facilitated. Our results first established that the genetic systems for controlling *Se* and chlorophyll content were associated, or were likely the same, indicating that the *Se* gene may have other functions. Further studies will provide an in-depth look for the mechanism underlying the relationship in reproductive biology. Gene expression studies associated with *Se* will help understand its molecular mechanism and may eventually lead to isolation of the *Se* gene.

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POTENTIAL FOR ECONOMIC PRODUCTION OF ASIATIC COTTON IN THE DELTA GROWING AREA

James McD. Stewart[1]

RESEARCH PROBLEM

Five to ten thousand bales of Asiatic cotton (*Gossypium arboreum* L.) are imported into the United States each year. The U.S. manufacturing requirements for the fibers of this type of cotton could provide an alternative production option for a limited number of cotton producers. However, no varieties have been developed for production in the United States. The objectives of this research were 1) to evaluate a wide selection of Asiatic cotton varieties for good agronomic and yield potential in the Arkansas Delta, and 2) to determine if the characteristics of Asiatic cotton allow it to be harvested and ginned with upland cotton equipment.

BACKGROUND INFORMATION

High micronaire cotton is used in non-woven applications such as padding in sports equipment and in pads in fashion clothing where resiliency is important. Diploid Asiatic cotton is particularly well suited for these applications because of the high micronaire of the fibers, which ranges between 6 and 8+ depending on the variety. No Asiatic cotton is produced in the United States primarily because of its short fiber length and to the perception that it has low yield relative to upland cotton. Manufacturers using this speciality fiber currently must import it from the countries of South Asia. For a limited number of producers looking to diversify their farming operation (initially, 3,000 to 5,000 acres total), development of a domestic source of this high micronaire cotton may provide one option. However, to be economical, varieties of Asiatic cotton must be identified or developed that are competitive in yield and can be harvested and ginned with existing equipment.

RESEARCH DESCRIPTION

From the *G. arboreum* collection maintained at the University of Arkansas (approximately 250 accessions), 71 accessions (varieties or genotypes) were selected solely on the bases of having fiber micronaire in excess of 7.0 from previous evaluations. In 1996, these were grown in single 40-ft rows spaced 38 in. apart at the Southeast Research and Extension Center, Rohwer Division. The plot received routine management

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typical of upland cotton. Agronomic characteristics of each accession were noted, and yield was estimated from two hand-picked 5-ft sections within the row. Only cotton remaining on the plant was harvested and the samples were ginned on a small laboratory saw gin. In 1997, nine selected lines were grown at the same location under the same conditions except plots consisted of 4 rows each replicated four times. Again management followed upland cotton practices. The plots were harvested with a spindle picker and samples were ginned on a gin stand at the USDA Ginning Laboratory, Stoneville, Mississippi. In 1998, approximately 1-acre plots with 38-ft row spacing and replicated four times were grown of four lines at the Northeast Research and Extension Center (NEREC) at Keiser. Plots were harvested with a stripper and seedcotton ginned on a commercial gin stand.

RESULTS

Agronomic characteristics of the original 71 accessions varied widely in leaf type, plant height, earliness, and other parameters. Major considerations for selection of genetic lines suitable for U.S. production included plant height, earliness, and loc retention. Loc retention was considered to be an important trait because any production in the United States must be amenable to mechanical harvesting to be successful. Asiatic cottons were bred for hand picking so many varieties have a tendency to drop the seedcotton once the boll is open. In these tests estimates of yield did not include seedcotton that had dropped to the ground. Among the 71 accessions, fiber yield ranged from 260 lb / acre to more than 1500 lb / acre among the accessions. Generally the highest yielding accessions were early fruiting with good loc retention.

Nine accessions exceeding 1000 lb / acre lint yield were selected for replicated trials in 1997. Two main conclusions resulted from these trials. First, Asiatic cottons cannot be harvested with a spindle picker because of the short, coarse fiber. The amount of seedcotton that could be picked was not representative of the yield potential of the accessions. Visual observations were used to select the top four lines for further evaluation. Second, the cotton can be ginned on existing gin stands. The seedcotton was taken to the USDA Ginning Laboratory, Stoneville, Mississippi for ginning to determine what problems, if any, might be encountered because of the small seeds and course fiber. No problems were encountered.

A stripper was not located in southeast Arkansas for the 1998 season so the trials were planted at NEREC. The 1998 growing season was exceptionally poor in that area, but a number of conclusions could be drawn: 1) earliness would be a major consideration for consistently successful production of Asiatic cotton in Arkansas; 2) Asiatic cotton can be harvested well with a stripper; 3) commercial gins can gin the cotton with little or no modification; and 4) the line with the highest seedcotton yield was second in lint yield, and vice versa, because of gin outturn. Sufficient seed were obtained from the high lint yielding line for a 20-acre production trial under ultra-narrow- row which will be conducted in 1999.

PRACTICAL APPLICATION

A line of Asiatic cotton has been selected that has the agronomic qualities and yield potential for economical production in the Delta cotton producing region. Assuming forward contracts can be established with domestic users currently importing Asiatic cotton, the production of this type of cotton may provide an alternative and economical production choice for some producers.

ACKNOWLEDGMENTS

This research was supported in part by Acme Pad Company, whose contributions are gratefully acknowledged. The help of Dr. Stanley Anthony of the USDA Ginning Laboratory is also acknowledged.

EFFECTS OF EXOTIC CYTOPLASMS ON PHOTOSYNTHESIS, CHLOROPHYLL CONTENT, AND AGRONOMIC TRAITS IN COTTON

Jinfa F. Zhang, Gwen Coyle, and James McD. Stewart[1]

RESEARCH PROBLEM

Most cotton breeding has focused on nuclear genome improvement, however, cytoplasmic diversity may also be important. Germplasm diversity is important as a buffer against the potential vulnerability of a genetically uniform crop to precisely adapted pathogens or insects. Also, genetic heterogeneity is important for cotton to maintain maximum yield when grown across diverse environments. Like other higher plants, cotton has two genetic systems, i.e. the nuclear genome and the extra chromosomal or cytoplasmic genomes (mitochondrial and chloroplastic DNAs). All upland cottons share a common cytoplasm, but cytoplasmic diversity is available from other *Gossypium* species. Since some of the genes responsible for photosynthesis and respiration are located on the cytoplasmic genomes, the replacement of cotton cytoplasm with that of another species will affect those physiological processes and possibly other growth and developmental parameters (Zhang *et al.*, 1997; Zhang and Stewart, 1999).

BACKGROUND INFORMATION

Meyer (1973) transferred seven *Gossypium* species cytoplasms (A_1, A_2, B_1, D_{2-2}, F_1, AD_2, and AD_3) into upland cotton (AD_1) nuclear background. Various cytoplasmic effects were found, such as male sterility, external ovules, reduced or increased anther numbers, and decreased yield among others (Meyer, 1973; Meredith *et al.*, 1979; Bourland and Mahill 1985). We have transferred six additional cytoplasms from *G. sturtianum* (C_1), *G. davidsonii* (D_{3-d}), *G. trilobum* (D_8), *G. stocksii* (E_1), *G. mustelinum* (AD_4), and *G. darwinii* (AD_5) into semigametic *G. barbadense* nuclear background (Stewart, 1990).

RESEARCH DESCRIPTION

Cytoplasms from 12 different species were transferred into cotton (*G. barbadense*) nuclear background by repeatedly backcrossing with Pima 57-4 and Sev7 (virescent leaves) as the recurrent parents. The resulting alloplasmic lines were grown in a complete randomized block with three replications during 1996 to 1998. Anther number and photosynthetic traits (chlorophyll content, photosynthetic rate, stomatal conduc-

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tance, transpiration, and water use efficiency) from functional leaves (fourth main-stem leaf from the topmost leaf) were measured during boll-filling stage. Boll traits (boll size, seed index, lint percentage), yield, and fiber quality were determined at harvest.

RESULTS

Chlorophyll

Chlorophyll content in alloplasimic lines were not significantly different from their recurrent parent, 57-4, indicating that the exotic cytoplasms had no effect on chlorophyll content in normal green-leaf background. However, in the virescent background (Sev7), alloplasmic lines with A_2, B_1, D_8, and F_1 cytoplasms had significantly higher chlorophyll a, b, and total chlorophyll contents and lower a / b ratio than their recurrent parent, Sev7. This indicates that these cytoplasms increase chlorophyll a and b contents disproportionally in the virescent nuclear background.

Photosynthesis

Under normal green-leaf nuclear background (57-4), exotic cytoplasms from A_2, B_1, C_1, D_{2-2}, D_{3-d}, D_8, E_1, F_1, AD_1, AD_3, AD_4, and AD_5 species consistently increased net photosynthetic rate, which was correlated with increased stomatal conductance and transpiration rate. On average, the exotic cytoplasms increased net photosynthetic rate by 5 to 10%. Also, on the virescent background (Sev7), cytoplasms from A_2, B_1, D_8, and F_1 species increased net photosynthetic rate by 15 to 18%.

Dark Respiration

Preliminary tests showed that most exotic cytoplasms tend to increase dark respiration rate.

Anther Number and Sterility

All alloplasmic lines were female fertile since they could set bolls when open pollinated. But, C_1, D_{2-2}, and D_8 cytoplamic lines were male sterile. D_{2-2} cytoplasm significantly increased anther numbers, while A_2, B_1, and F_1 cytoplasms significantly decreased anther numbers.

Yield and Yield Components

C_1 and D_{2-2} cytoplasms significantly decreased yield due to the effects in reducing boll weight and lint percentage, while the D_8 male sterile cytoplasm had no effect on yield components.

Fiber Quality

C_1 and D_{2-2} cytoplasms significantly increased fiber length, however, no other consistent cytoplasmic effects were detected during the three-year tests.

PRACTICAL APPLICATION

This study demonstrated that the higher photosynthetic rate in wild species was partially, if not all, due to their cytoplasms. Photosynthetic efficiency may be improved through breeding via introduction of exotic cytoplasms. Although only small differences exist among tetraploid species (AD_1 to AD_5) cytoplasms, the use of cytoplasms from other tetraploids will increase the cytoplasmic diversity of the cultivated cottons and reduce vulnerability to biotic and abiotic stress conditions. This study also revealed that some exotic cytoplasms increased chlorophyll content due to the interaction between the cytoplasms and a specific *G. barbadense* nuclear background (virescent leaves, v_7v_7). D_8 cytoplasm does not show significant deleterious effects on fiber yield and quality, therefore, offering a promising male sterile cytoplasm for hybrid cotton production. These results demonstrate that the alloplasmic lines provide an excellent system to study the mechanism of cytoplasmic-nuclear interactions at the biochemical and molecular level.

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TREND LINE ANALYSIS OF COUNTY LEVEL YIELD DATA FOR COTTON IN ARKANSAS

Lucas D. Parsch and Matias Becerra[1]

RESEARCH PROBLEM

Trend line analysis of annual yield data collected by the Arkansas Agricultural Statistics Service (AASS) is being conducted in order to determine whether (a) Arkansas cotton has experienced significant yield increases in the recent past and, (b) to quantify yield risk associated with dryland and irrigated cotton at the county level. This information is important for producers because the 1996 Farm Bill has placed increased attention on the need for risk management information in decision-making.

BACKGROUND INFORMATION

The implementation of the 1996 Farm Bill has placed increased attention on the need for risk management information because the new "freedom to farm" legislation has exposed cotton producers to greater market risk. Measuring the yield trend of cotton is a first step in quantifying yield risk. Frequently, producers, policy makers, researchers, and extension personnel seek to incorporate risk into decision-making without having available to them a quantified measure of the risk associated with crop production. This research provides a quantified assessment of the yield risk associated with dryland and irrigated cotton for the major cotton producing counties in Arkansas.

METHODS

County level yield data for dryland and irrigated cotton were obtained from the AASS for the major cotton producing counties in Arkansas. Major producing counties were defined as those which continuously produced cotton over the 15-year period, 1981 to 1995. Sample statistics consisting of mean, standard deviation (SD), and coefficient of variation (CV) for dryland and irrigated cotton yield were computed for each county. In addition, the relative importance of each county was measured as the average share of Arkansas state level cotton production contributed by each county over the 15-year period.

A linear trend line was fitted through each county yield data series using ordinary least squares regression techniques. A slope coefficient for each trend line was used to determine the annual change in yield (lb / acre / yr) over the 15-year period, and to establish whether the yield change in each county was statistically significant. A trend line

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"expected" yield (TLY) for each county was computed as the county predicted yield at the endpoint (1995) of the regression trend line. Subsequently, an absolute measure of risk associated with each yield data series was measured as the root mean square error (RMSE) around each regression trend line.

RESULTS

Summary Yields for Arkansas Cotton

Table 1 lists the 19 Arkansas counties which continuously produced cotton between 1981 to 1995. Nearly 50% of all dryland cotton was produced in the northeast district (District 3), whereas over 56% of all irrigated cotton originated in District 9 in the southeast part of the state. Mississippi County was the largest dryland cotton producer with 24% of the state dryland production. Desha County was the largest irrigated county in the state with 16% of Arkansas production

Average yield for irrigated cotton over the 15-year period was over 200 lb / acre greater than for dryland cotton. Average yield at the county level ranged between 458 lb / acre (Woodruff) and 720 lb / acre (Desha) for dryland cotton, and between 728 lb / acre (Poinsett) and 904 lb / acre for irrigated cotton. Yield variability, measured with either the SD or CV, was also lower for irrigated cotton (Table 1). Irrigated counties experienced yield variability (SD) ranging between 104 lb / acre (St. Francis) and 156 lb / acre (Mississippi). By contrast, SDs for dryland counties ranged between 113 lb / acre (Phillips) and 184 lb / acre (Monroe). The average CV across all 19 counties was 23.8% for dryland cotton compared to only 16.0% for irrigated cotton.

Trends in Irrigated and Dryland Cotton Yields

Over the 15-year period, only two dryland counties and six irrigated counties experienced increases in annual yield that were significant at the 0.10 level (Table 2). Significant yield increases typically occurred in counties which produced a relatively large share of Arkansas' cotton production. Six dryland counties and two irrigated counties experienced annual yield decreases over the same period, but the decreases were not significant. Across all counties, average yield increases were 8.0 lb / acre / yr for irrigated cotton and 3.5 lb / acre / yr for dryland cotton.

Each trend line yield (TLY) in Table 2 modifies the mean yield reported in Table 1 by adjusting it for the annual yield increase or decrease. Thus, the TLY reflects the "expected" yield for each county by preserving any trend in the data series that a sample mean would not reflect. On average, the TLYs in Table 2 exceed the mean yields in Table 1 by 25 lb / acre and 56 lb / acre for dryland and irrigated cotton, respectively.

Yield Variability and Risk

Trend line RMSEs in Table 2 measure the random variability–risk–associated with cotton production after the systematic effect of trend has been removed. In seven years out of 10 (i.e., 0.68 probability), any county's yield will be in between the TLY plus or minus the RMSE for that county. Three years out of 10, yield will lie outside this range. Thus, risk increases with RMSE. As a measure of yield risk, RMSEs in Table 2 are smaller for irrigated than for dryland cotton. Likewise, the level of yield risk varies greatly from county to county. For dryland counties RMSEs ranged between 111 lb / acre and 182 lb / acre. For irrigated counties, RMSEs ranged between 96 lb / acre and 146 lb / acre. The average RMSE across all counties was 140 lb / acre for dryland cotton compared to only 122 lb / acre for irrigated cotton. This suggests that dryland cotton yields are 15% more risky on average than irrigated production.

PRACTICAL APPLICATION

Because cotton producers face greater risk with the phaseout of government deficiency payments, increased attention has been placed on the need for risk management information in decision-making. Trend line analysis provides decision-makers with a quantified measure of cotton yield risk for each of the major cotton producing counties in Arkansas. This study shows that irrigated cotton results in higher yield and lower risk than dryland cotton, and that yield risk varies dramatically from one county to another. These results are summarized graphically in Fig. 1 which shows that irrigated yields consistently lie above and to the left of dryland yields for major cotton counties in Arkansas.

Table 1. Summary yield statistics for major cotton producing counties in Arkansas, 1981-1995.

County Name	Dryland cotton				Irrigated cotton			
	State share[z]	Mean[y]	SD[y]	CV[y]	State share[z]	Mean[y]	SD[y]	CV[y]
	(%)	--------- (lb/acre) ---------		(%)	(%)	--------- (lb/acre) ---------		(%)
District 3 (northeast)								
Clay	2.2	496	127	25.7	1.3	743	139	18.7
Craighead	11.3	575	115	20.0	5.3	735	109	14.9
Greene	2.8	531	134	25.2	—[x]	---	---	---
Mississippi	23.6	634	151	23.8	9.6	808	156	19.4
Poinsett	8.6	585	164	28.0	3.1	728	138	18.9
District 6 (east central)								
Crittenden	7.6	641	124	19.4	---	---	---	---
Lee	3.9	604	127	21.1	---	---	---	---
Lonoke	1.0	544	143	26.4	5.9	798	130	16.3
Monroe	3.0	587	184	31.3	3.0	786	149	18.9
Phillips	9.2	638	113	17.7	6.0	792	125	15.8
St. Francis	2.7	564	137	24.4	1.5	785	104	13.3
Woodruff	0.3	458	113	24.6	---	---	---	---
District 7 (southwest)								
Lafayette	0.9	566	152	26.8	1.4	770	124	16.2
District 9 (southeast)								
Ashley	3.6	664	135	20.3	13.6	855	119	13.9
Chicot	4.4	602	141	23.4	6.8	776	113	14.5
Desha	3.8	720	133	18.5	16.3	904	120	13.3
Drew	---	---	---	---	4.4	827	111	13.4
Jefferson	6.7	642	164	25.6	9.8	837	120	14.3
Lincoln	2.2	609	166	27.2	5.5	827	148	17.9

[z] Average county share of total cotton production over the 15-year period 1981-95. Average annual lint production for Arkansas was 450,856 bales dryland and 538,878 bales irrigated.

[y] Mean, standard deviation (SD) and coefficient of variation (CV) of lint yield.

[x] Not applicable.

Table 2. Trendline regression statistics for major cotton producing counties in Arkansas, 1981-1995.

County or district	Dryland cotton: Trend line yield	Dryland cotton: Yield slope coef.	Dryland cotton: Slope coef. sig. level	Dryland cotton: Trend line RMSE	Irrigated Cotton: Trend line yield	Irrigated Cotton: Yield slope coef.	Irrigated Cotton: Slope coef. sig. level	Irrigated Cotton: Trend line RMSE
	(lb/acre)	(lb/acre)		(lb/acre)	(lb/acre)	(lb/acre)		(lb/acre)
District 3 (northeast)								
Clay	533	5.3	0.51	130.000	779	5.1	0.56	142
Craighead	640	9.4	0.18	111.000	815	11.5	0.08	100
Greene	606	10.7	0.19	130.000	---	---	---	---
Mississippi	755	17.3	0.05	134.000	949	20.1	0.02	133
Poinsett	704	17.0	0.08	150.000	842	16.4	0.04	121
District 6 (east central)								
Crittenden	606	-4.9	0.53	127.000	---	---	---	---
Lee	565	-5.6	0.48	130	---	---	---	---
Lonoke	538	-0.8	0.93	149.000	835	5.3	0.51	133
Monroe	670	11.8	0.30	182.000	860	10.6	0.25	146
Phillips	659	3.0	0.68	117.000	848	8.0	0.30	125
St.Francis	596	4.5	0.60	141.000	861	10.9	0.08	96
Woodruff	503	6.4	0.36	113	---	---	---	---
District 7 (southwest)								
Lafayette	524	-6.0	0.53	155.000	721	-7.1	0.36	125
District 9 (southeast)								
Ashley	710	6.6	0.44	137.000	947	13.1	0.06	107
Chicot	538	-9.1	0.30	140.000	798	3.0	0.67	116
Desha	735	2.1	0.80	138.000	1002	14.0	0.05	107
Drew	---	---	---	---	866	5.6	0.42	112
Jefferson	560	-11.6	0.25	161.000	788	-7.0	0.35	120
Lincoln	656	6.8	0.51	169.000	906	11.2	0.21	144

[z] Not applicable.
NOTE: All trend line intercepts are different from zero at the 0.10 level of significance.

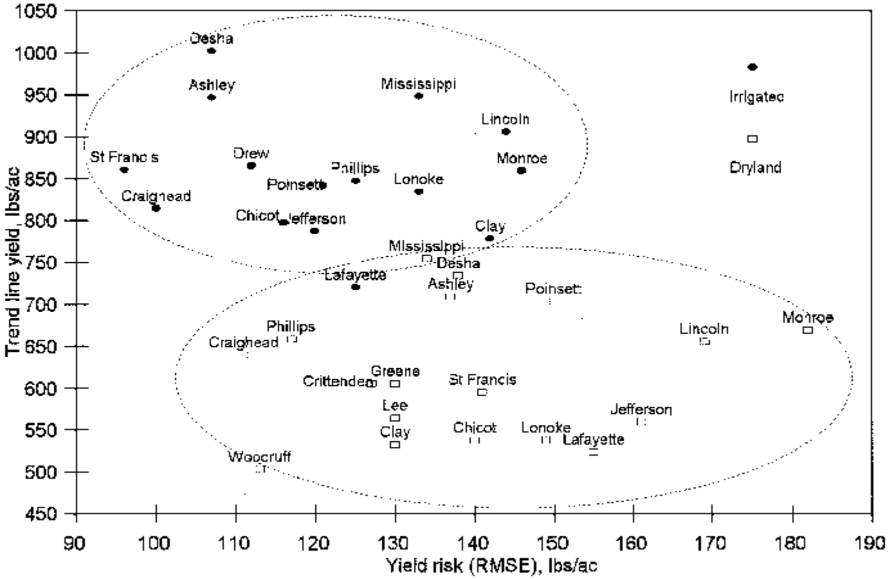

Fig. 1. Trendline yield and yield risk (RMSE) for major cotton producing counties in Arkansas.

FACTORS AFFECTING YIELD IN THE 1998 COTTON RESEARCH VERIFICATION PROGRAM (CRVP) FIELDS

Don E. Plunkett[1]

INTRODUCTION

Yields of the fields enrolled in the 1998 Cotton Research Verification Program (CRVP) were adversely affected by weather and pest factors. Yield variability is easily seen across years even when yields are high, but variability is especially noticeable in years like 1998 when periods of drought and heat were coupled with pest problems. In some situations too frequent rainfall or irrigation followed by rainfall and cloudy, hazy conditions affected yields.

BACKGROUND INFORMATION

There were seven fields enrolled in the CRVP during 1998 (Plunkett, 1998). One of the fields was non-irrigated and six were irrigated. Of the irrigated fields two had center pivot irrigation and four were furrow-irrigated. All of the furrow-irrigated fields were watered down every other middle (EOM) when irrigation water was applied.

Pest pressure was higher than normal in the northeast Arkansas counties (Mississippi and Poinsett). Cotton bollworm and some fall armyworm flights occurred on three occasions. Boll weevil activity was high in all but the Lincoln and Poinsett county fields. Also, tobacco budworm flights were found in the Phillips and St. Francis county fields, with beet armyworm also found in the Phillips County field in a small area of non-Bt cotton in that field.

From planting in May until about mid-June the lack of rainfall coupled with hot, dry winds and high temperatures affected plant growth and development statewide. The most severe stress from drought conditions was noted in the Cross County non-irrigated field. In very late season the highest temperatures were noted in the Chicot County field with over six days of 100°F or above recorded from mid-August to early September.

RESULTS

The field information and yield results of the six irrigated fields and the one non-irrigated field show the yield variability between the two production schemes (Table 1). The non-irrigated field was so severely drought stressed as the flowering period

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began that it reached cutout about four days after onset of first flower. Plant mapping of the field with the COTMAN program indicated the field reached Nodes Above White Flower = 5 (physiological cutout) on 30 June.

Comparison of the irrigated fields information without more information than that shown in the tables reported in this paper would be misleading. For example, the Mississippi and Poinsett county fields were planted the same day with the same variety. However, the Mississippi County field was inundated with frequent and often heavy rainfall from 24 July until early August, and the Poinsett County field was on the fringe of the heavy rainfall. The field in Mississippi County shed small bolls very rapidly throughout that period of time, and set a top crop of bolls which matured due to favorable weather and temperatures in September. The Lincoln County CRVP field received over 5 inches of rain just after the final irrigation for that field which caused small boll shed of the uppermost bolls. That field failed to set a top crop that matured for harvest.

The impact of insects is reported in Table 2. As explained earlier, heavy insect pressure required more treatments than normal in several fields. The St. Francis County field had the highest number of insect control trips, mostly for boll weevil. Two clean up sprays were needed when tobacco budworm larvae escaped the pyrethroid treatments that were recommended initially for cotton bollworm.

SUMMARY

The yields in fields enrolled in the CRVP during 1998 were affected by environmental and physical factors such as drought, too frequent rainfall, or irrigations followed by rainfall, and cloud cover as well as insect pests.

Yield variability will always occur from field-to-field and from year-to-year because of differences in soil type, timing of irrigations or occurrence of timely rainfall, occurrence of pest outbreaks, and uneven fertility. Temperatures at key times of the year will also affect emergence and growth / development of the cotton crops statewide. Since environmental effects are out of the control of the cotton producer, there should be attempts made to research the effect that applications of irrigation can have on cooling soil and crops. Possibly research should be targeted toward use of foliar applications of boron (B) or nitrogen (N) when stress -- either from heat, moisture, insects, or “crazy cotton” -- begins to affect cotton growth and development, or where a transgenic variety is grown. Additionally research needs to be generated about the effect B applications might have on slowing the symptoms of small boll loss due to high levels of purported cavitation.

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Table 1. Irrigated and non-irrigated field information, 1998 CRVP program.

County	Acres	Planting date	Variety	Lint yield (lb/acre)	Soil type
Irrigated					
Chicot	29	May 7	ST BXN 47	976	Bowdre Si Cl Loam
Lincoln	104	May 11	SG 501	742	Hebert SiL, Perry Clay
Mississippi	69	May 14	ST BXN47	868	Convent fine sandy Lm
Phillips	22	May 6	DP NC 33B	838	Dubbs silt loam
Poinsett	75	May 14	ST BXN47	996	Mhoon, Dundee silt loam
St. Francis	38	May 9	ST 453	920	Henry SiL
1998 avg	56			890	
Non-irrigated					
Cross	65	May 4	DP 20	391	Collins silt loam

Table 2. Number of insecticide applications made for CRVP fields, 1998.

	Boll weevil						
County	Spring suppression	In-season	CBW/ TBW[z]	Weevil/worm combinations	Aphids	Thrips	Plant bugs
Chicot	3	0	2	2	0	0	1
Cross	2	0	0	1	0	0	0
Lincoln-ADC	1	0	3	0	0	0	0
Mississippi	0.09	0	1	2	0	0	1
Phillips	2	4	0	1	0	0	2
Poinsett	1	0	3	0	1	0	0
St. Francis	2.2	5	4	3	1	0	0
1998 Avg	1.60	1.3	1.86	1.3	0.30	0.0	0.57
1997 Avg	1.94	1.6	0.88	1.0	0.00	0.2	0.77
1996 Avg	1.00	1.5	1.30	0.9	0.20	0.1	1.30
1995 Avg	1.77	2.0	2.90	0.8	0.36	0.5	0.55
1994 Avg	1.90	2.9	2.00	1.4	0.00	0.0	2.70

[z] CBW = cotton bollworm, TBW = tobacco budworm.

EFFECTS OF SOIL BURIAL ON BIODEGRADATION PROPERTIES OF COTTON, RAYON, AND TENCEL FABRICS

Mary M. Warnock and Samina Khan[1]

RESEARCH PROBLEM

This study was undertaken to determine the use of soil burial as a means of assessing the environmental compatibility of 100% cotton, rayon, and Tencel fabrics. Flex abrasion, tensile and tearing strength, and microscopic analyses were used to evaluate post burial degradation.

BACKGROUND INFORMATION

With a major shift in values represented by environmentalism in recent years, the textile industry has begun to implement ecological strategies to ensure that production and manufacturing processes are benign to the environment (Brookhart, 1991). The growing demand by consumers for more environmentally sound products of all types, including fibers, has led to the development of Tencel--a cellulosic fiber made via a new solvent spinning process which does not pollute. Even though fiber manufacturing processes may not be hazardous to the environment, the repercussions of filling landfills with such fabric and products requires examination.

RESEARCH DESCRIPTION

Physical and morphological characteristics of three plain woven fabrics were assessed following burial for 2, 4, 13, 26, and 52 weeks in Calloway silt loam (pH=7.5) and Red Clay (pH=4.8) soils. Each of the cotton, rayon, and Tencel plain weave fabrics exhibited warp and filling yarn sizes of 18/1, weighed 5.4 oz/yd , possessed a fabric count of 82X50-60, had 16.12 yarn turns/inch, and were navy blue in color. Fabric specimens were buried in compartmentalized trays, representative of each soil type, and placed within a controlled environmental room (70°F, 65% RH). Flex abrasion, tensile strength, and tearing strength tests were performed. Data analyses used natural logarithms of fabric measurements that were regressed on the number of weeks the fabric was buried using a straight line model. Dependence of the slope and intercept on type of fabric was tested using analysis of covariance techniques. Single degree of freedom contrasts were used to determine differences among slopes, where appropriate.

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RESULTS

All fabric types buried in the Calloway silt loam soil were completely degraded by the end of the 26-week period. Whereas in the Red Clay soil, some cotton, rayon, and Tencel fabrics were intact following 26 weeks of burial, but no fabric specimens remained after 52 weeks. On the log scale, tearing strength of cotton decreased at a significantly faster rate than did that of rayon and Tencel, which decreased at the same rate following burial in Red Clay soil. With respect to the entire study, flex abrasion and tensile strength results were higher for the Tencel fabric (Figs. 1 and 2). Microscopic examination revealed cracks, fibrillations, and the growth of fungi within fiber structures.

PRACTICAL APPLICATION

Results of this study indicate that soil burial is an effective method to determine biodegradation properties of plain woven fabrics. The less acidic Calloway silt loam soil contributed to faster fabric biodegradation. Rayon, in general, was more susceptible to biodegradation followed by cotton and Tencel, respectively. Although a recycling program has been established for the manufacturing of Tencel fibers, another such program may be necessary for Tencel fabrics which would otherwise be dumped into existing landfills.

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Soil type - Calloway Silt Loam

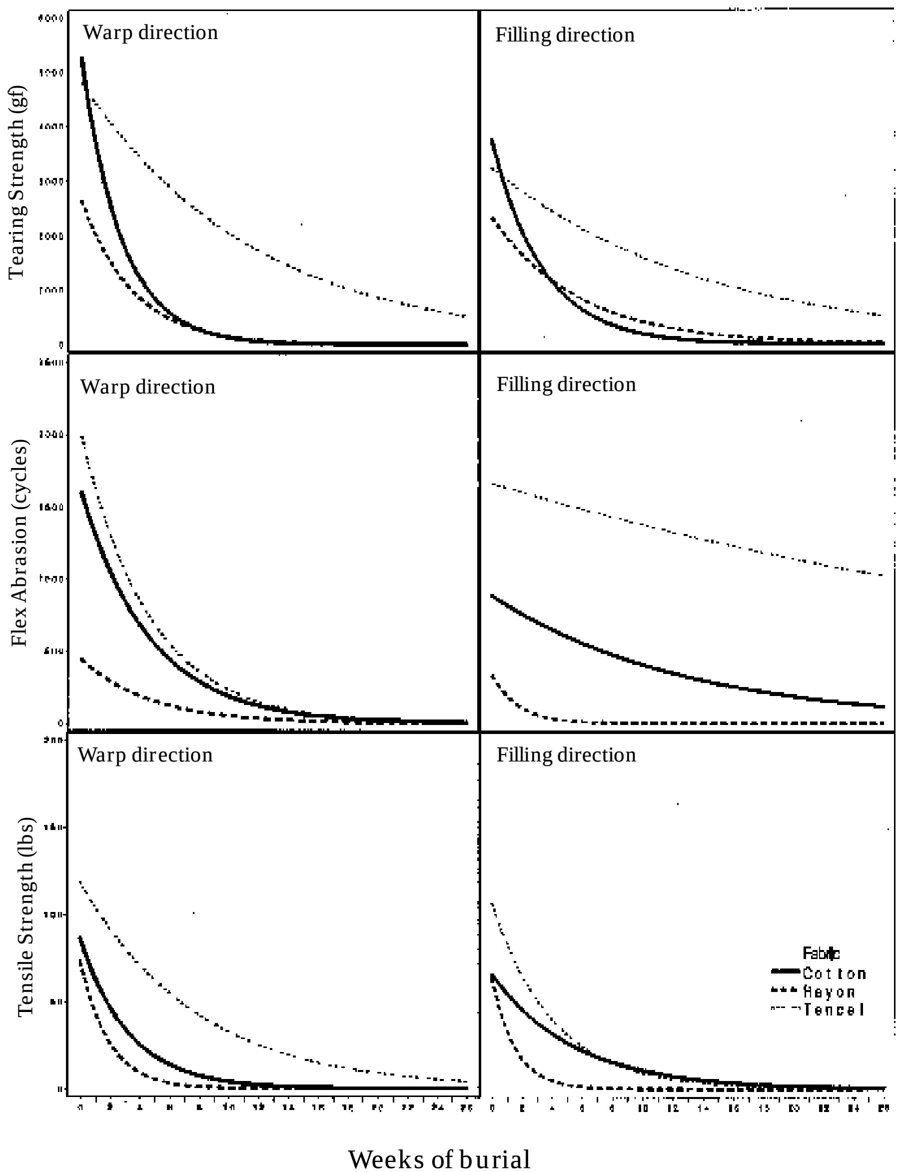

Fig. 1. Strength and abrasion characteristics of experimental fabrics buried in Calloway Silt Loam soil.

Soil type - Red Clay

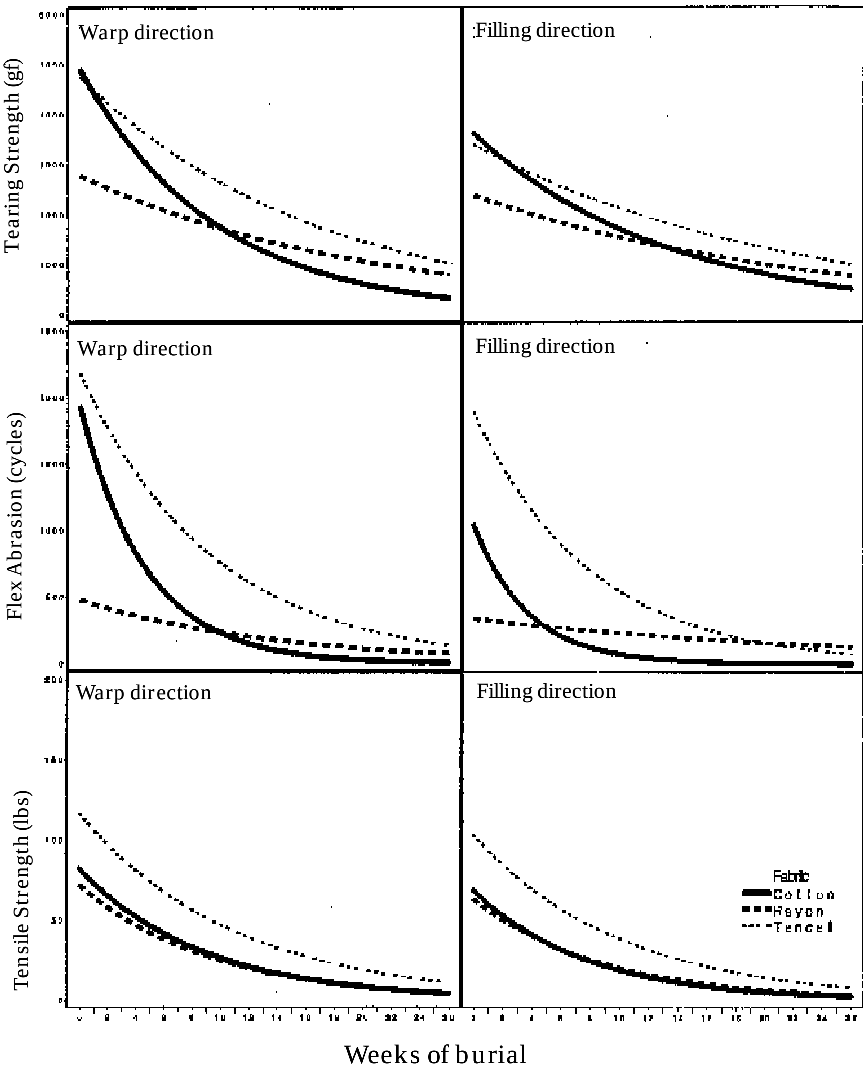

Fig. 2. Strength and abrasion characteristics of experimental fabrics buried in Red Clay soil.

APPENDIX I

STUDENT THESES AND DISSERTATIONS IN PROGRESS IN 1998

Ashfaq, Mohammad. Mortality and sublethal effects in major lepidopterous larval pests on Bt-cotton and *Bacillus thuringiensis* var. *Kurstaki*-treated non-Bt-cotton. (Ph.D., advisor: Dr. Young).

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APPENDIX II
RESEARCH AND EXTENSION
1998 COTTON PUBLICATIONS

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