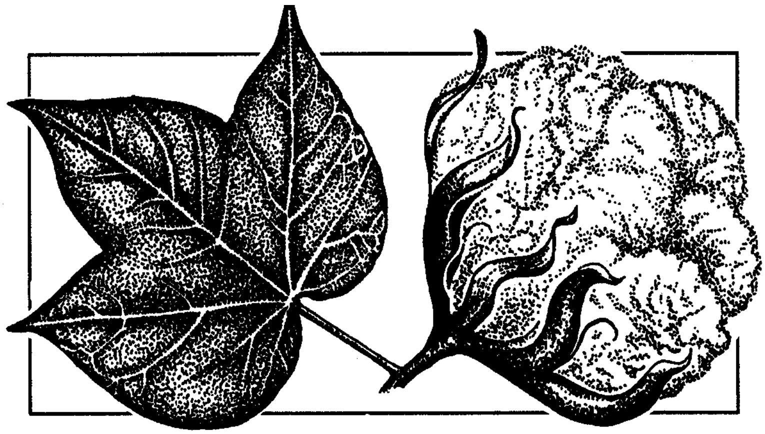
Proceedings of the 1997 Cotton Research Meeting

and

1997 Summaries of Cotton Research in Progress



Edited by Derrick M. Oosterhuis and James McD. Stewart

ARKANSAS AGRICULTURAL EXPERIMENT STATION

Division of Agriculture University of Arkansas

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AND

1997 SUMMARIES OF COTTON RESEARCH IN PROGRESS

Edited by Derrick M. Oosterhuis and James McD. Stewart

Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701

CONTRIBUTORS

Allen, C.T., Extension Entomologist, Arkansas Cooperative Extension Service, Southeast District, Monticello

Altaf, M.K., Graduate Student, Department of Agronomy, Fayetteville

Baker, W.H., Research Assistant Agronomist, Soil Test Laboratory, Marianna

Baldwin, F.L., Extension Weed Scientist, Coop. Extension Service, Little Rock

Beyrouty, C.A, Soil Scientist, Department of Agronomy, Fayetteville

Bourland, F.M., Plant Breeder, Department of Agronomy, Fayetteville

Bryant, Kelly J., Area Extension Specialist, Southeast Research and Extension Center, Monticello

Caldwell, W.D., Professor, Louisiana State University, Red River Research Station, Bossier City, Louisiana

Calhoun, S.D., Associate Agronomist, Delta Research and Extension Center, Stoneville, Mississippi

Cantrell, T.G., Professor, Agronomy and Horticulture Department, New Mexico State University, Las Cruces, New Mexico

Coyle, G., Research Specialist, Department of Agronomy, Fayetteville

Earnest, L., Research Specialist and Superintendent, Southeast Branch Experiment Station, Rohwer

Frizzell, B. S., Research Specialist, Southeast Research and Extension Center, Monticello

Gbur, E.E., Statistician, Department of Agronomy, Fayetteville

Griffin, B., Desha County Extension Agent, Cooperative Extension Service, McGehee

Haynes, J., Student Worker, Southeast Branch Experiment Station, Rohwer

Hoyt, J.M., Research Specialist, Department of Agronomy, Fayetteville

Johnson, D.R., Extension Entomologist, Department of Entomology, Little Rock

Keino, J., Graduate Assistant, Department of Agronomy, Fayetteville

Kim, M.J., Graduate Assistant, Department of Agronomy, Fayetteville

Kirkpatrick, T.L., Associate Professor, Southwest Research and Extension Center, Hope

Leonard, B.R., Research Entomologist, LSU Agricultural Center's Macon Ridge Station, Winnsboro, Louisiana

Lorenz, G., IPM Coordinator, Cooperative Extension Service, University of Arkansas, Little Rock

McConnell, J.S., Agronomist, Southeast Research and Extension Center, Monticello

Meyers, H.B., Extension Entomologist, Cooperative Extension Service, Lonoke

Murphy, J.B., Professor, Department of Horticulture, Fayetteville

Nepomuceno, A., Graduate Assistant, Department of Agronomy, Fayetteville
Oosterhuis, D.M., Crop Physiologist, Department of Agronomy, Fayetteville
Page, L.M., Agricultural Technician - Entomology, Cooperative Extension Service, Lonoke
Plunkett, D., Cotton Research Verification Coordinator, Southeast Research and Extension Center, Monticello
Riddle, A.C., Student Assistant, Southeast Branch Experiment Station, Rohwer
Robertson, W.C., Extension Agronomist - Cotton, Univ. of Arkansas Coop. Extension Service, Little Rock
Scott, K., Student Worker, Southeast Branch Experiment Station, Rohwer
Singer, T.L., Assistant Specialist - Entomology, Cooperative Extension Service, Lonoke
Shumway, C.R., Assistant Professor, Arkansas State University, Jonesboro
Snyder, C.S., Extension Soils Specialist, Univ. of Arkansas Coop. Extension Service, Little Rock
Steger, A., Research Specialist, Department of Agronomy, Fayetteville
Steinkraus, D.C., Professor, Department of Entomology, Fayetteville
Stewart, J.M., Professor, Department of Agronomy, Fayetteville
Teague, T.G., Associate Professor, Arkansas State University, Jonesboro
Tugwell, N.P., Entomologist, Department of Entomology, Fayetteville
Tugwell, P., Student Worker, Southeast Branch Experiment Station, Rohwer
Vivien, D., National Cotton Council, Memphis, Tennessee
Wajahatullah, M.K., Visiting Scholar, Department of Agronomy, Fayetteville
Warnock, M.M., Associate Professor, School of Human Environmental Sciences, Fayetteville
Webster, E.P., Extension Weed Scientist, Southeast Research and Extension Center, Monticello
Willis, S., Student Worker, Southeast Branch Experiment Station, Rohwer
Zhang, J., Graudate Assistant, Department of Agronomy, Fayetteville
Zhao, D., Graduate Assistant, Department of Agronomy, Fayetteville

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PROCEEDINGS OF THE 1997 COTTON RESEARCH MEETING

1997 SUMMARIES OF COTTON RESEARCH IN PROGRESS

PREFACE

The 1996 cotton growing season in Arkansas was a good one with 990,000 acres harvested with an average yield of 776 lb lint/acre. The average state yield was about 50 lb greater than the five-year average (see page 92 in this issue for more details). However, there was concern for the increasing cost of production. The 1996 season got off to a good start. Temperatures early season were a little cooler than normal, but for the remainder of the season they were about average. Most fields experienced some degree of early-season stress associated with cool temperatures at planting, high winds with some herbicide damage and insects. Nevertheless, square and early boll retention was extremely high, and by mid-season expectations were high for a potentially bumper early crop. The previous cold winter appeared to have impacted boll weevil populations. Aphids were generally not a problem, and Tobacco Budworm populations never reached predicted levels. However, by mid-July, bollworm numbers were increasing and causing concern in conventional and Bt cotton. Temperatures cooled somewhat in late July and early August, and rainfall increased, which led to a higher incidence of boll rot. The end of season was wetter than usual with increased insect pressures. Near-record yield projections were forecast at mid season, but projections declined monthly during the latter half of the season to the good, but disappointing, state yield average of 776 lb lint/acre. Fiber quality in Arkansas in 1996 was also good. The main focus of attention in the state during the season, and a point of contention, was the large acreage (>156,000 acres) planted to Bt cotton. This is discussed by Fred Bourland, Charles Allen and Roger Leonard in this issue. There are also two articles about the 1996 cotton production season by Derrick Oosterhuis and Bill Robertson.

ARKANSAS COTTON RESEARCH GROUP

The University of Arkansas Cotton Research, Extension, Production and Marketing Group is composed of three sub-committees representing production, genetics and pest management. The group and the sub-committees contain appropriate representatives in all the major research disciplines as well as representatives from the Cooperative Extension Service, the Farm Bureau and the Agricultural Council of Arkansas. The objectives of the Arkansas Cotton Group are to coordinate efforts to improve cotton production and to keep Arkansas producers abreast of all new developments in research. Excellent progress is being made in this cooperative effort for the benefit of the cotton industry in Arkansas.

Steering Committee: Bob Frans (emeritus), Thad Freeland, Robert McGinnis, Gene Martin, Keith Martin, Derrick Oosterhuis (Chm.), Jake Phillips (Emeritus), Bill Robertson, Kent Rorie, Craig Rothrock, Mac Stewart, Don Wiley, Cecil Williams, Jerry Williams

Pest Management: Charles Allen, Ford Baldwin, Mark Cochran, Gary Felton, Don Johnson, Terry Kirkpatrick, Gus Lorenz, Jake Phillips (emeritus), Craig Rothrock (Chm.), Don Steinkraus, Glen Studebaker, Phil Tugwell, Tina Teague, Eric Webster

Production: Bill Baker, Mark Cochran, Mike Daniels, Terry Keisling, Gus Lorenz, Scott McConnell, Derrick Oosterhuis (Chm.), Don Plunkett, Bill Robertson, Cal Shumway, Phil Tacker, Earl Vories

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

ACKNOWLEDGMENTS

The organizing committee would like to express its appreciation to all those individuals who helped with the arrangements for the 1997 Arkansas Cotton Research Meeting, particularly Don Wiley and Kent Rorie, and the companies who sponsored the Continental Breakfast and coffee breaks: Paymaster, DuPont and Monsanto. We also extend our gratitude to Marci Milus for help in typing this Special Report.

COTTON INCORPORATED AND THE ARKANSAS STATE SUPPORT COMMITTEE

The 1997 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 all funds collected within Arkansas under the auspices of the Cotton Research and Promotion Act are spent for research or promotion activities within Arkansas, as determined by the State Support Committee.

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; 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 1992-1997

Project	Principal Investigator	Amount Funded ($) 1992	1993	1994	1995	1996	1997
Late season harvest aid decisions based on the nodes above white flower concept	Bonner	17,000	17,000	17,000	----	----	----
Characterization of cotton root growth in relation to plant growth, boll load and crop management	Oosterhuis	28,000	28,000	28,000	----	----	----
Row-spacing effects on management options	Vories	27,000	27,000	30,000	----	----	----
Manipulation of the effective fruiting window for optimum yield and quality	Bourland	27,000	27,000	27,000	25,550	24,550	24,550
Conservation tillage for Arkansas cotton	McClelland	28,000	28,000	28,000	18,190	----	----
Boll weevil survey and eradication research	Johnson	----	6,000	36,000	45,000	----	----
Proceedings of the annual Arkansas research meeting and summaries of research in progress	Oosterhuis	----	4,000	4,000	6,000	6,000	6,000
Cottonseed pool — Arkansas	Cotton Inc. Staff	----	8,000	9,000	10,000	11,000	10,000
Conditions for successful use of foliar nitrogen	Baker	----	----	----	21,410	21,400	21,400
Integration of boll weevil control technology into the eradication program	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 the boll weevil eradication program in Arkansas	Alexander	----	----	----	----	15,000	15,000
Boll weevil eradication: overwintering, dispersal and tactics	Yearian	----	----	----	----	123,450	123,450
Research on the cotton aphid fungus	Steinkraus	----	----	----	----	8,000	11,000
Integration of Staple, Buctril and Roundup into weed control programs	Baldwin (1996) Webster (1997)	----	----	----	----	10,000	10,000
Totals:		127,000	145,000	185,000	211,000	276,000	278,000

PROCEEDINGS OF THE 1997 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
University of Arkansas, Monticello
February 13, 1997

WELCOME

Charles Scifres[1]

It is my pleasure to open this conference and welcome you on behalf of the Division of Agriculture, University of Arkansas System. In years past, we have discussed potential changes in government policy that could influence crop production in historic proportions, not only in Arkansas but across the entirety of the United States. In the time since the last meeting, these potential changes have become reality. Now we must prepare not only to deal with them but to respond to the “new” production environment in ways that bring a competitive advantage to producers in Arkansas. To my way of thinking, this will be achieved only by applying the technology at hand in the most effective manner possible and rapidly developing new, even-more-effective technologies. The research scientists and Extension specialists whose research is published in this Special Report are more than capable of doing just that and stand ready to accomplish the task. We in the research and Extension programs look forward to the challenges we face as real opportunities, challenges that can be turned into competitive advantage through research and education.

[1]Dean and Associate Vice President for Agriculture, Dale Bumpers College of Agricultural, Food and Life Sciences, Arkansas Agricultural Experiment Station, Fayetteville, Arkansas.

U.S. AND WORLD COTTON ECONOMIC SITUATION

Deborah Vivien[1]

INTRODUCTION

This paper will review the situation for the world and U.S. crops in the current crop year, along with an early forecast for 1997/98. It will cover the big issues that are affecting what we expect for next year and touch on current issues facing the industry today, exploring some of the steps being taken to address them.

The 1996 cotton crop was planted in the absence of Acreage Reduction Programs (ARP's), Normal Flex Acres or any supply restraints aside from conservation programs and compliance, marking the first time in over 60 years that farmers participating in a government program were free to plant any, or in some cases no, crop and still receive a government payment. Of course, with the new seven-year contract, this payment, because it is fixed at about half the average level of the past and grows smaller over the seven years of the contract, places producers squarely at the mercy of the market and allows the returns from alternative crops to play a larger role in planting decisions than ever before. Within this new environment, current price relationships between cotton and competing commodities have raised concerns regarding the potential cotton acres for 1997.

U.S. SITUATION 1996/97

We began the current season for the U.S. crop with extremely tight stocks of only 2.6 million bales but, unlike many other areas of the world, posted record yields of 709 lb/acre. The crop is now pegged at 19.0 million bales, the second largest on record (Fig 1). This is testimony to the disastrous crop of 1995/96, as this crop is almost 1.5 million bales larger but was produced on nearly 20% fewer acres.

The dashed white line in Fig. 2 shows the five-year average yield for each state indexed to 100. All states except Oklahoma and Florida were at or above the five-year average. The U.S. (the bar on the right of Fig. 2), at 709 lb, was nearly 12% above its five-year average.

Regional production in the U.S. shows the Southeast now as the second largest region with 25% of production (Fig. 3), prompted by improved production costs brought about by boll weevil eradication and increased investment in spinning in the region. The largest region is still the Mid-South, with 31% of cotton production, followed by the Southwest at 24% and the West at 20%.

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

Total supply of cotton in 1996 was significantly higher than in 1995 but did not quite reach the record year of 1994 (Fig. 4). The dark shaded-in portion of total supply shows the imports that came into the U.S. in the 1995 and 1996 crop years. Given the havoc that this small number created, this shows just how little cotton it takes to influence the price.

As stated, the effects of the small crop in 1995/96, coupled with a tight stocks situation through the late summer and early fall, prompted continued interest in imported raw cotton by U.S. textile manufacturers, and the USDA now tallies landed imports at 400,000 bales during this season. This may be a little misleading, though, as the crop year begins 1 August 1996, so timing of imports is not necessarily related to the availability of new crop cotton due to reporting procedures.

U.S. IMPORTS OF RAW COTTON

In monthly imports of raw cotton, landings by mid-December had reached 760,000 bales and remained under 770,000 bales by year's end (Fig. 5). No imports have been reported for the calendar year 1997. Imports have been arriving in the U.S. under Step 3 of the competitiveness provisions in the U.S. upland cotton marketing loan and slowed considerably due to increased availability of U.S. cotton at harvest. Considering that other cotton-producing countries were having production problems in 1996, the availability of exportable surpluses seems to be defaulting to the U.S. This issue will be addressed later in this review.

In 1996/97, the U.S. had the largest cotton crop, followed closely by China, with India, Pakistan, Uzbekistan and Turkey rounding out the remaining countries. All except the U.S. and, possibly, India have experienced poor-yielding crops this year. Incidentally, China, Turkey and, potentially, Pakistan are all net importers of cotton this year.

U.S. OFFTAKE FOR 1996/97

The USDA currently estimates mill use at 11 million bales, but it could be 11.1 million bales by the end of the crop year if Commerce reports on cotton consumption remain strong (Fig. 6).

The biggest wildcard in the U.S. 1996 outlook is raw cotton exports. In February, the USDA increased its export estimate to 6.5 million bales, citing production problems in major cotton producing regions outside the U.S. opening up opportunities for U.S. cotton. Mr. Dunavant has stated he expects the final export number to be closer to 7.2 million bales, while the National Cotton Council sees a minimum of 6.8 million bales. If increased exports come about, they will come at the expense of the ending stocks number, which now stands at 4.5 million bales. This is a stocks:use ratio of 26%, up strongly from last year's 14%. Thus, we should begin 1997 in a much more comfortable stocks situation than in the past few years.

One driver of increased cotton mill use stems from exports of textile products from the U.S. Continually, textile exports make up a larger amount of domestic mill use, and 1996 is no exception. Currently, about 32% of domestic mill use is exported as final product, and that trend is expected to grow.

U.S. COTTONSEED 1996/97

Record yields in 1996 added 7.3 million tons of cottonseed production to 460,000 tons of carryover, leading to a total 1996 supply of 7.8 million tons.

With higher cottonseed prices, crush demand is expected to slow through 1996 to 3.9 million tons, down 11,000 tons from last year, even though meal and oil prices have remained respectable this season. Wholeseed feeding is expected to increase to 3.2 million tons as the large crop coupled with lower margins provides opportunity. With exports up slightly at 140,000 tons, total use of cottonseed is forecast at 7.2 million tons. This leaves carryover for 1997 at 600,000 tons.

WORLD SITUATION FOR 1996/97

As the production year of the large producers in the Northern Hemisphere begins to come into focus, the world cotton crop is projected to be approximately 86.2 million bales, better than initial estimates but still a decline of about 5.5 million bales from 1995 (Fig. 7). This production decline reflects the pressure competing crops have placed on cotton acreage as well as huge yield shortfalls coming to light in many regions.

China sustained flooding and other weather-related problems earlier in the year and battled disease and an unexpected early frost. For the “Big 7” producers in aggregate, less the U.S. production, estimates have fallen 1 million bales since August. Pakistan is again under threat of a leaf curl epidemic. The CIS production estimates continue to plummet amidst reports of boll worms and poor weather. From November to December alone, this region was estimated to lose more than 10% of its crop. Southern Hemisphere crops are also forecast to decrease in production as alternative crops continue to absorb cotton acreage allocations.

Based on improving worldwide demand for cotton products, the USDA expects 1996 mill use to move up to 85.8 million bales, 1 million bales higher than in 1995/96, moving world mill use of cotton back toward the long-term trend (Fig. 8). However, the USDA-projected increase in mill use may be difficult to obtain if the “A” Index continues to trade above 75 cents and Chinese mill use of cotton continues to decline. These estimates result in ending stocks of 36.8 million bales on 31 July 1996, adding 500,000 bales to world carryover. Keep in mind that 36.8 million bales equates to 43% of world mill use, as calculated in the stocks:use ratio. While the bulk of the stock increase will be held in China, which typically holds one-third to one-half of world stocks, stock building of this proportion has obvious price implications. The ending stocks:use ratio is 43%. When the world stocks:use ratio nears 40%, world cotton prices tend to soften on average.

The big question now is the disposition of Chinese stocks. China’s crop for 1996 may end up at 17 million bales or even slightly smaller. However, given its beginning stock position, a small crop in China does not necessarily translate into high Chinese imports because stocks could be released to make up the shortfall.

Due to its substantial impact on the world market, China will continue to be one of the major focal points. A tool to better see China's impact on the world price is the International Cotton Advisory Committee's (ICAC) "A" Index price model.

ICAC PRICE MODEL

ICAC's price model tracks the annual average "A" Index quite well and explains 95% of the year-to-year variation in the "A" Index. The model is based on market fundamentals such as the world's stocks:use ratio net of China, China's net trade position and the barter activity of the Central Asian Republics.

How do these supply and demand estimates fit with price expectations for 1996/97? ICAC's price model indicates an average "A" Index of 78 cents (Fig. 9). The model is a good tool to demonstrate the potential impact China may have this year. China has built stocks and will face serious policy decisions about cotton in 1996/97 regarding pricing, imports and use of stocks. Price forecasting is a perilous business. But using ICAC's model, essentially it boils down to a million-bale change in China's net trade position and moves the annual average "A" Index 4.5 cents/lb. That is, if China's net imports increase 1 million bales, the expected annual average "A" Index goes up 4.5 cents. The USDA currently projects China's net imports at 1.8 million bales, down from 3 million last year. If Chinese imports prove to be higher, world price prospects could be different.

U.S. COTTON SITUATION FOR 1997/98

Planting decisions for the 1997/98 crop are in the beginning stages with many factors under consideration. Due to the flexibility brought about through current farm bill provisions, prices of competing crops remain one of the most influential indicators of acreage changes.

The thin line on Fig. 10 shows last year's harvest time corn contract showing the run up in the spring, which brought large amounts of corn acreage to the mid-South, as well as other parts of the country. The thick line traces the current harvest time corn contract at the same point in growers' planting decisions. Although corn traded higher than last year during the summer months, it has failed to follow the spike of last spring, instead remaining well below last year's level for the last few months. But keep in mind that growers, especially in the lower reaches of the Cotton Belt, harvest corn earlier than the Midwest and are able to sell on Chicago at that time.

Soybeans, on the other hand, traded higher than last year through the summer months and have continued to follow the upsurge found last spring (Fig. 11). At this time, beans are at nearly identical levels to those found last year when planting decisions were made. This is also true for cotton, which, as shown in Fig. 12, traded right on top of where it was last year at this time until recently where it failed to show upward potential. Therefore, cotton acreage is expected to shift to beans due to price incentives. Corn is also expected to capture more cotton acreage away this year, but it is mainly due to less risky crop, less extensive management requirements and willingness of banks to lend more readily for corn instead of cotton crops.

In fact, the National Cotton Council planting intensions survey showed a decline of 7% in cotton acreage this year to 13.4 million acres of upland (Fig. 13). Most of the decline comes in the Mid-South as producers respond to favorable bean prices and continue switching to corn with continued eroding of cotton acreage in the Southwest as well.

ELS acreage is also expected to drop almost 7.5 %, leaving total cotton acreage down 7% at 13.6 million acres.

With average abandonment, harvested area is expected to be slightly higher than the levels of last year, but the million acres lost in Texas due to delayed plantings and inclement weather early in the season virtually has been lost to other crops or pasture or idled when combined with other areas of the country this year.

Using average yields, production for 1997/98 is expected to 17.8 million bales, and, due to the large carryover, no imports are expected during the crop year (Fig. 14). This leaves us with a total supply of 22.3 million bales, 300,000 bales higher than last year.

Moving to the demand side, mill use is expected to continue to increase into 1997, estimated at the time at 11.2 million bales. Given the strong reports issued recently by the Commerce Department, though, mill use next year may be poised to take a larger jump, possibly as high as 11.4. Exports are also strong at 6.8 million bales as continued production problems are combined with increasing loss of acreage to feed and food grains around the world. Income increases driven by world trade agreements will allow consumers greater disposable income, which will initially be spent on improved diets centered around meat products. This will drive up the demand for feed grains, and higher resulting prices will whittle away cotton acreage. And, given the U.S. position as the world’s residual supplier of cotton, we may again find opportunity to increase exports into next season.

With offtake exceeding production, ending stocks are expected to decline to 4.3 million bales, only 200,000 bales lower, keeping the stocks:use ratio around 24%.

U.S. COTTONSEED SITUATION FOR 1997/98

From our 1997 lint production estimates, corresponding cottonseed production is expected to be 7.1 million tons for 1997, which will result in a total supply of 7.7 million tons, almost 75,000 tons below last year.

Crush is expected to decline somewhat to 3.8 million tons as prices of the competing oilseed products, especially soybeans, remain attractive. Exports are expected to be 150,000 tons, while wholeseed feed use (or the other category) climbs slightly to 3.2 million tons. With use totaling 7.2 million tons, stocks are forecast at 536,000 tons.

WORLD COTTON SITUATION FOR 1997/98

The world should begin the 1997 crop year with the exorbitant stock number of 36.8 million bales, most of which again will be carried in China (Fig. 15). Production is expected to increase only slightly to 87 million bales, but the U.S. is giving up 1.2 million bales in 1997, so this is a relatively large increase in production outside the U.S.

World offtake is predicted to climb to 86.2 million bales, even under continued threat of inexpensive polyester, mill shutdowns in China, and budgetary competition in the Third World arena. This leaves ending stocks of 37.6 million bales and a stocks:use ratio of 44%, still above the 40% threshold expected to weaken prices.

Increasingly the trend in world cotton trade is the holding of cotton inside the cotton-producing countries where it can be turned into a finished product, thereby allowing the country to extract the value-added themselves instead of relinquishing only its raw resources. This trend is expected to continue, as shown by flat trade of raw cotton amidst increased use.

CONCLUSION

A new era dawns on U.S. cotton and the cotton industry with competitiveness as the watch word. As U.S. corporations continue to seek cost-reducing alternatives, U.S. agriculture is being rapidly forced down the same path. With increased availability of information, knowledge of marketing strategies and cost efficiency at all levels, the U.S. cotton industry will have the mechanisms in place to make a successful transition to the new age of technology from production to processing.

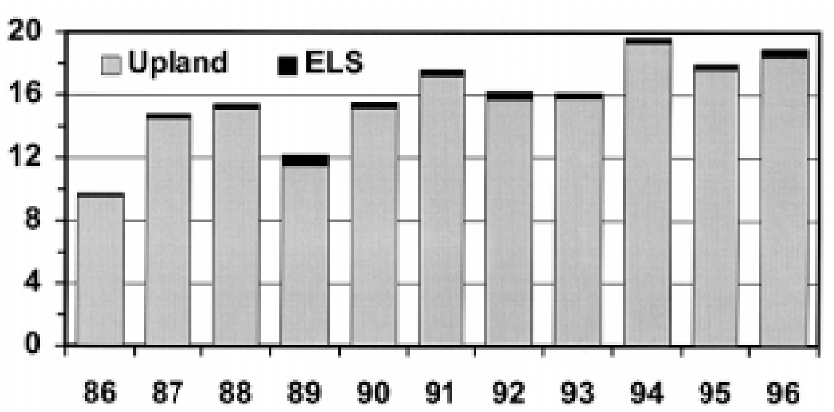

Fig. 1. U.S. cotton production (million bales).

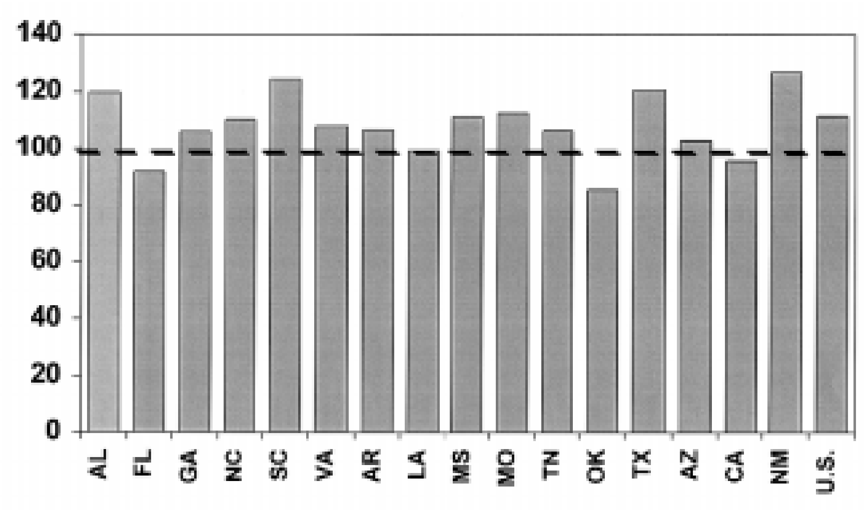

Fig. 2. Index of 1996 upland yields. Five-year average = 100.

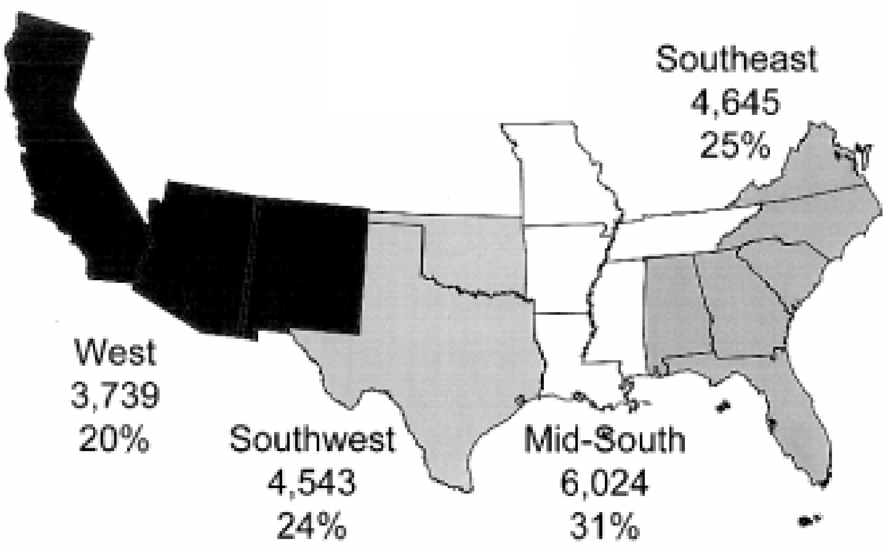

Fig. 3. U.S. regional production 1996-97 (thousand bales).

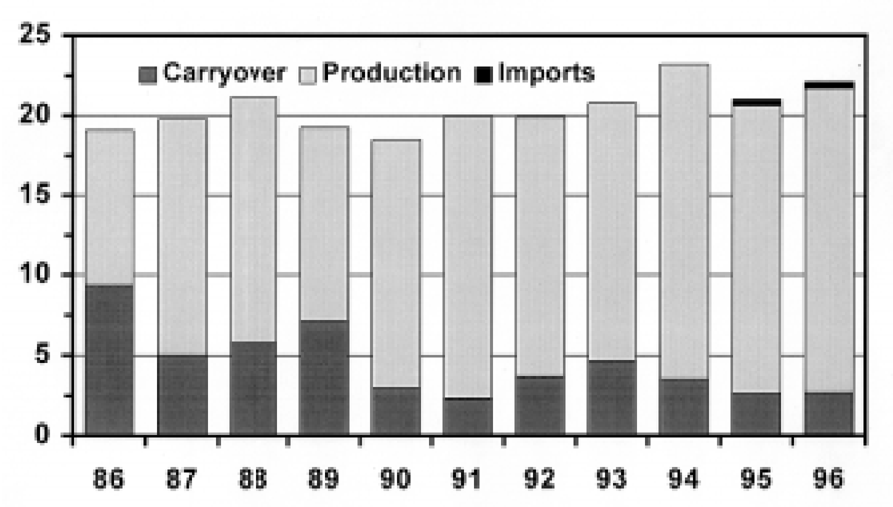

Fig. 3. U.S. cotton supply (million bales)

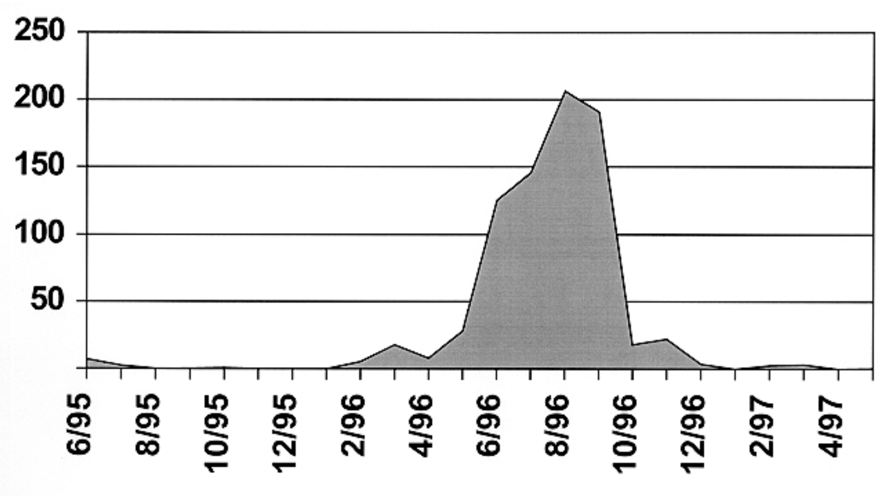

Fig. 5. U.S. raw cotton imports (thousand bales).

	1996-97	1997-98
Beginning Stocks	2.6	4.1
Production	19.0	
Imports	0.4	
Supply	22.0	
Domestic Use	11.0	
Exports	6.5	
Offtake	17.5	
Ending Stocks	4.5	
S-U-R	25.7%	

Fig. 6. U.S. supply and offtake (million bales).

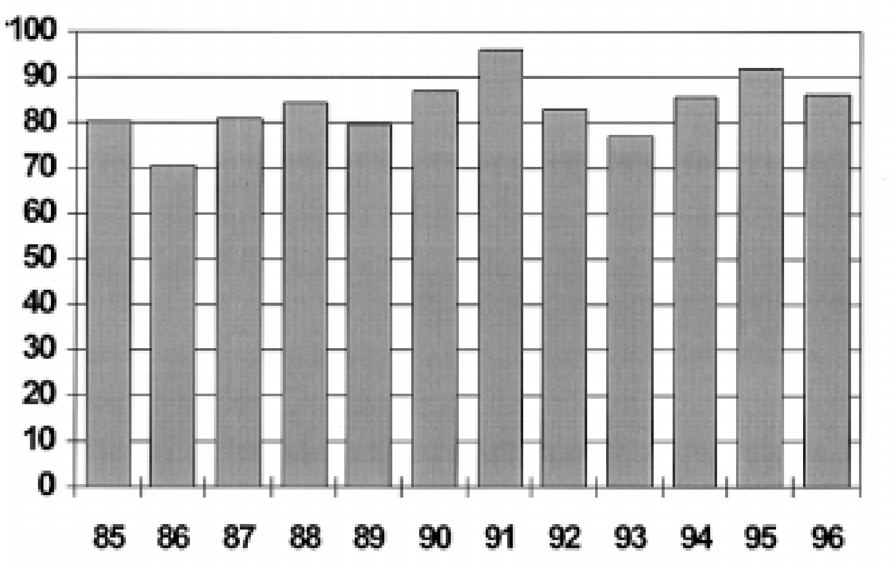

Fig. 7. World cotton production (million bales).

	1996-97	1997-98
Beginning Stocks	35.4	36.8
Production	86.2	
Supply	121.6	
Offtake	85.8	
Ending stocks	36.8	
S-U-R	42.9%	

Fig. 8. World supply and offtake (million bales).

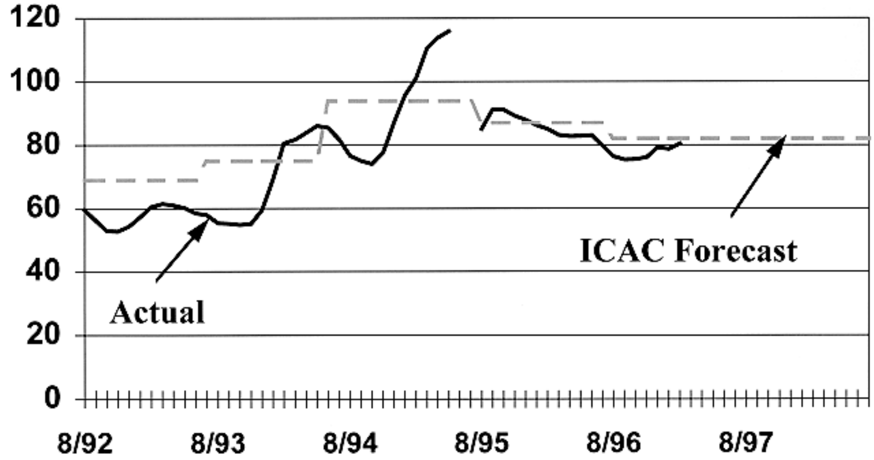

Fig. 9. "A" index (cents/lb).

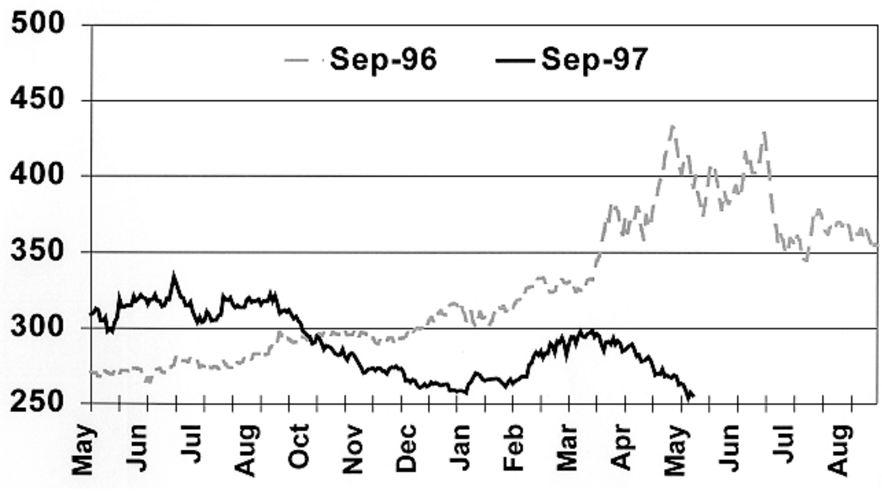

Fig. 10. September corn futures (cents/bu).

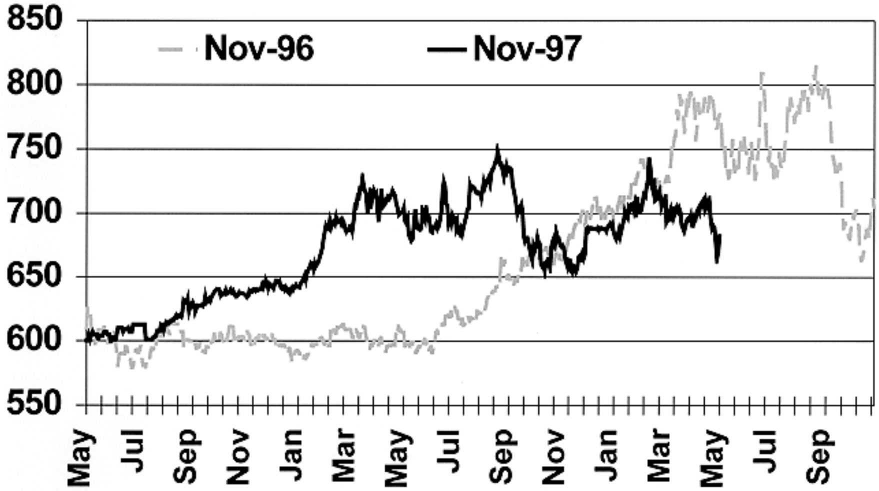

Fig. 11. November soybean futures (cents/bu).

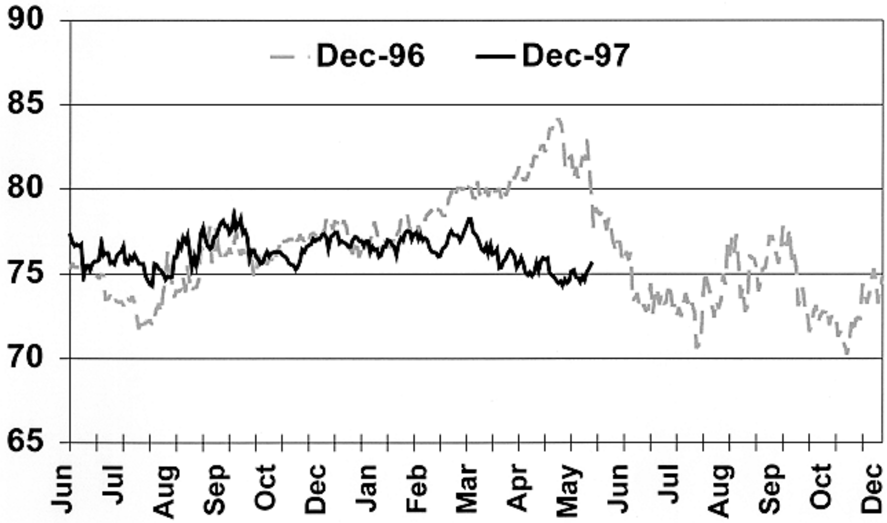

Fig. 12. December cotton futures (cents/lb).

	1996 Actual	1997 Projected
Southeast	3,098	3,077
Mid-South	3,940	3,525
Southwest	5,995	5,415
West	1,375	1,376
UPLAND	14,408	13,393
ELS	258	239
ALL COTTON	14,666	13,632

Fig. 13. Prospective 1997 cotton plantings (thousand acres).

	1996-97	1997-98
Beginning Stocks	2.6	4.5
Production	19.0	17.8
Imports	0.4	0
Supply	22.0	22.3
Domestic Use	11.0	11.2
Exports	6.5	6.8
Offtake	17.5	18.0
Ending Stocks	4.5	4.3
S-U-R	25.7%	23.9%

Fig. 14. U.S. supply and offtake (million bales).

	1996-97	1997-98
Beginning Stocks	35.4	36.8
Production	86.2	87.0
Supply	121.6	123.8
Offtake	85.8	86.2
Ending Stocks	36.8	37.6
S-U-R	42.9%	43.6%

Fig. 15. World supply and offtake (million bales).

TRANSGENIC Bt COTTON: 1996 UPDATE

B.R. Leonard[1]

INTRODUCTION

The most recent estimates show that producers in the U.S. harvested over 12.8 million acres of cotton in 1996. This figure includes approximately 98% upland and 2% Pima cotton. Transgenic (Bt) cotton cultivars were planted on approximately 1.5 million acres in 1996. The majority of this acreage was located within the cotton production regions of Alabama (430,000), Arkansas (156,000), Georgia (358,000), Louisiana (138,000) and Mississippi (440,000). The concentration of Bt acreage in these areas was generally proportional to the severity of damage by populations of tobacco budworm, *Heliothis virescens* (F.), in previous years.

The objective of this paper is to summarize the performance of Bt cotton technology in 1996. In order to accomplish this objective, several issues will be discussed, including 1) a review of the problem justifying producers' need of the technology, 2) efficacy and insect pest spectrum controlled and 3) agronomic performance of available cultivars.

COTTON INSECT PEST MANAGEMENT AND INSECTICIDE RESISTANCE

Average estimates of yield losses by cotton arthropod (insect and mite) pests in 1995 across the U.S. Cotton Belt were 11.1% with control measures costing $58/acre (Williams, 1995). In 1996, these pests accounted for less than an 8% yield reduction, but producers spent over $70/acre for their pest control (Williams, 1996). Important insect pests in 1995 and 1996 included the bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm complex, *Spodoptera* spp.; boll weevil, *Anthonomus grandis grandis* (Boheman); cotton aphid, *Aphis gossyppii* Glover; and *Lygus* spp. Table 1 shows estimates of infestation levels, yield losses and insecticide applications for these pests and illustrates the importance of several insect pests attacking cotton. Of those listed, the bollworm/tobacco budworm complex is considered the most serious because economic losses by this complex have been increasing dramatically during the past several years. Since 1990, significant acreage in some cotton production regions have experienced greater than 40% yield losses in spite of excessive control costs for tobacco budworm infesta-

[1]Research Entomologist, LSU Agricultural Center's Macon Ridge Station, Winnsboro, Louisiana.

tions. In addition to widespread and intense infestations across several production regions, the presence of tobacco budworm populations that express genetic resistance to nearly every class of synthetic chemistry recommended for their control has produced a crisis for the cotton industry. The question of severe economic losses by tobacco budworm in a given production area does not appear to be *if* it will occur but rather *where* it will happen next. Without new technology to manage tobacco budworm populations, many producers will be forced to consider alternative crops and/or reduce cotton acreage.

Although the bollworm/tobacco budworm complex is recognized as the primary pest complex in many production regions, it is important to note that pests such as boll weevil, *Spodoptera* spp., cotton aphid and *Lygus* spp. are capable of drastic economic losses if not controlled.

EFFICACY AND INSECT PEST SPECTRUM CONTROLLED

Field studies characterizing the efficacy of the Bollgard™ technology against cotton insect pests have been conducted for several years. A general summary of those results are depicted in Fig. 1.

Bollgard was used primarily to target insecticide-resistant tobacco budworm and bollworm in the Mid-South in 1996. Considerable data have confirmed Bollgard's effectiveness against these pests and allowed University entomologists to recommend this technology as one of several insect pest management options. Most of the initial reports following the 1996 season indicate satisfactory performance against tobacco budworm. However, tobacco budworm population densities in most states were relatively low compared to that for the past few years and appeared to be a significant problem only at the very end of the season. Very few insecticide treatments were needed in most areas for control of tobacco budworm in conventional cotton in 1996.

An early indication of high bollworm infestation densities in 1996 occurred as cotton seedlings began to emerge during the late spring. Many producers had relatively heavy infestations of weedy plants in fields at the time of planting cotton. Bollworms feeding on these alternate hosts moved to cotton seedlings as the weedy vegetation was terminated with herbicides. Significant plant loss in both Bollgard and conventional cultivars by bollworm was observed. As a result, significant cotton acreage in the Mid-South was treated with pyrethroids to manage bollworms within three weeks of seedling emergence.

In 1996, increased acreage of field corn contributed to high regional bollworm populations in June. Mid-season bollworm populations in cotton were relatively high for an extended period of time. In some instances, particularly in fields previously treated with foliar insecticides, bollworms were not satisfactorily controlled with Bollgard. General recommendations by Monsanto's field personnel emphasized that Bollgard should provide at least 95% bollworm control. However, in Alabama, Arkansas, Louisiana, Mississippi and Texas, significant Bollgard acreage was treated with pyrethroids for control of bollworm.

Previous data reported for Bollgard efficacy against other pests has been somewhat variable and raised concerns about consistently satisfactory performance. Under low to moderate population densities, most of the more-susceptible lepidopterous pests may be adequately controlled or suppressed to a level not requiring supplemental foliar insecticide treatments. In some situations, supplemental treatments to provide satisfactory control may be warranted.

In the Mid-South region of the U.S., selective insect control strategies are often ineffective because of multiple pest problems. Many of the pests listed in Fig. 1 co-exist at similar periods during the season, and control measures must target the complex rather than an individual problem. The Bollgard technology represents an IPM tool for managing a narrow range of lepidopterous pests. It is unfortunate that in some instances, the reluctance to use foliar insecticides in Bollgard fields for tobacco budworm has resulted in difficulties controlling other concurrent pests, such as boll weevil or tarnished plant bug, that would normally be controlled by those same foliar treatments. The restricted insect pest spectrum controlled in Bollgard and the realization that supplemental foliar insecticide use is generally needed to manage insect pest complexes may limit the value of this technology.

AGRONOMIC PERFORMANCE

'NuCOTN 33' and 'NuCOTN 35' were the only two cultivars available to producers in 1996. Prior to their sale this past season, only limited agronomic data from university tests were available to compare performance to normal commercial cultivars. Without comparative data from standard commercial variety trials, university agronomists in most states generally did not include the Bollgard cottons in the list of recommended cultivars.

NuCOTN 33 and NuCOTN 35 are classified as full-season cotton varieties, meaning that their crop maturity period is similar to normal non-Bollgard cottons that require the longest period to attain their maximum harvestable yield. Late maturity is undesirable to producers because it increases the period that the crop is susceptible to insect pest injury as well as yield and quality losses due to adverse weather.

In 1996, limited data from commercial variety trials in Louisiana show comparable yields between the NuCOTN cultivars and other recommended varieties. In general, seedcotton yields of the NuCOTN cultivars were higher than those of non-Bt cultivars if economic infestations of bollworm and tobacco budworm persisted across the test site and optimum late-season environmental conditions occurred for crop development. Cotton lint quality tests indicated similar performance among the Bollgard and non-Bt cultivars.

SUMMARY

Based on the 1996 results, the Bollgard technology in the Southeast and Mid-South United States appears to serve primarily as an insurance policy to reduce the probability of severe economic losses by tobacco budworm. Reductions in foliar insecticide use against this target pest appeared to cause an increase in the treatment application frequency for other concurrent pests. Therefore, the total cost of insect pest control in Bollgard and conventional cultivars was similar in many instances in 1996. This is likely to be common in the future because of the pest complexes in the Mid-South region. Yields and fiber quality do not appear to be limiting factors for the Bollgard cultivars, although lateness in crop maturity is an undesirable quality. Additional cultivars possessing the Bollgard technology, herbicide resistance and a combination of both traits will be available from DPL and Paymaster Seed Companies in 1997.

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Table 1. A brief listing of the primary insect pests in the U.S. during 1995-96.

Arthropod Pest	1995 Acres Infested	1995 Yield Loss	1995 Insecticide Applications	1996 Acres Infested	1996 Yield Loss	1996 Insecticide Applications
BW/TBW*	82%	3.97%	2.4	78%	2.31%	1.20
Spodoptera spp.	65%	1.68%	0.4	44%	0.14%	0.11
Boll weevil	62%	1.77%	2.0	54%	1.72%	1.72
Cotton aphid	90%	1.09%	0.6	67%	0.43%	0.43
Lygus spp.	54%	1.02%	0.5	46%	0.73%	0.50

*Bollworm/tobacco budworm complex.

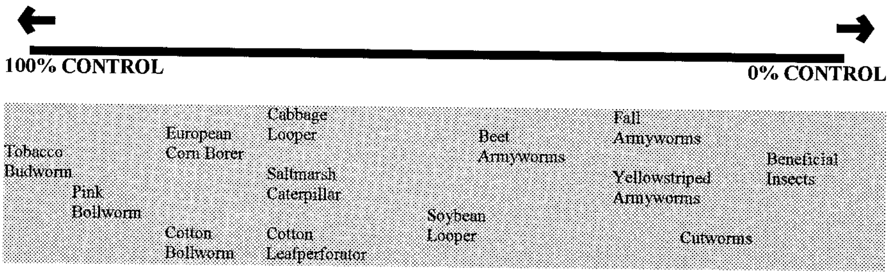

Figure 1. Susceptibility of selected insects to Bollgard (Bt) cotton.

CULTIVAR EVALUATION OF Bt COTTONS IN THE MID-SOUTH

F.M. Bourland, D.S. Calhoun and W.D. Caldwell[1]

INTRODUCTION

"This year we conducted a 300,000 acre test of Bt cotton in Mississippi." This quote from Will McCarty (*Delta Farm Press*, September 20, 1996) indicates the situation that many cotton growers experienced in 1996. The 300,000-acre test in Mississippi was part of a nearly 2-million-acre Beltwide test. Unfortunately, for the most part *the 1996 test* had no experimental design and was predominated by one cultivar.

Producers were wise to be apprehensive about the 1996 test. New cultivars are usually evaluated for three to four years in state cultivar tests before they are widely planted. In the first two years after being entered in the Arkansas Cotton Variety Test, 'Deltapine 5415', 'Stoneville 474' and 'Sure-Grow 125' were not even listed among cultivars planted in Arkansas by the USDA-AMS Cotton Division. This normal delay between entry into cultivar tests and becoming widely available to producers provides time for evaluation in numerous environments. From this testing, the specific adaptation of new cultivars becomes well-established, and many genetically related production disasters are avoided.

This normal delay did not occur with Bt cottons. In its first year in the Arkansas Variety Test, 'Deltapine NuCOTN 33B' occupied 35.5% of the cotton acreage in southeastern Arkansas. Such a rapid acceptance of a new cultivar is unprecedented. Previous work with Bt cottons has mostly had an entomological focus, with relatively few reports on the agronomic performance of Bt cotton. Therefore, we entered 1996 with the assumption that adaptation and agronomic management of Bt cotton would not differ from its recurrent parent, i.e., Deltapine 5415 for NuCOTN 33B.

This paper will review yield and fiber data for Bt cotton cultivars collected prior to 1996 and data from 1996 state variety tests in Arkansas, Mississippi and Louisiana. Data for two herbicide-tolerant, transgenic cultivars will also be presented.

[1]Professor, Department of Agronomy, University of Arkansas, Fayetteville; Associate Agronomist, Mississippi Agricultural and Forestry Experiment Station, Stoneville, Mississippi; and Professor, Louisiana Agriculture Experiment Station, Bossier City, Louisiana, respectively.

Bt PERFORMANCE PRIOR TO 1996

Most reports on Bt cotton prior to 1996 dealt with general considerations of transgenic cotton, the mechanics of gene transfer or the entomological aspects of the Bt toxin. Relatively few reports appeared to even remotely address the adaptation of Bt cultivars. The earliest field tests used ‘Coker 312’ as the base, recurrent cultivar. Deaton (1991) presided over a series of seven papers (abstracts on pages 576-579, Beltwide Proceedings) in which insect and yield data for Coker 312 and its Bt isolines, which were collected from different regions of the Cotton Belt in 1990, were presented. Generally, the Bt isolines yielded as well as or better than their recurrent parent, Coker 312. No specific agronomic problems associated with the Bt lines were reported. Benedict (1996) reported yields from 1990 through 1994 of Bt isolines of Coker 312 at College Station, Texas. Yields of the Bt lines (without worms controlled) ranged from -9 to +64% of the recurrent parent line (with worms controlled). Relative yields of Bt cotton were poor in 1990 and 1991 but very good the other three years. From the same tests, Benedict et al. (1996) reported that in 1990 and 1991, the Bt lines had increased lint percentage and fiber strength and decreased boll weight and fiber length and produced micronaire similar to that of the recurrent parent.

Jenkins et al. (1995) reported that lint yields of Bt isolines of Deltapine 5415, ‘Deltapine 5690’, ‘Deltapine 90’ and Coker 312 exceeded their recurrent parent by 20, 6, 1 and 13%, respectively, in a worm-controlled test conducted in 1994 at Mississippi State, Mississippi. Overall, the Bt lines yielded 8.3% more lint than the recurrent parents.

Lint yields from nine large-plot, on-farm tests conducted in Texas in 1995 were reported by Benedict (1996). Seven of the tests compared NuCOTN 33B with its recurrent parent, Deltapine 5415. The other two tests compared ‘NuCOTN 35B’ with its recurrent parent, Deltapine 5690. In each test, worms were controlled for the recurrent parent but not for the Bt cotton. Lint yields of the Bt cottons ranged from +11 to +30% (overall +23%) more than those of the recurrent parents.

Jones et al. (1996) summarized data from tests comparing NuCOTN 33B and NuCOTN 35B (without sprays for budworm, bollworm or pink bollworm) with their recurrent parents, Deltapine 5415 and Deltapine 5690 (sprayed). The tests were conducted in the Texas-picker (two in 1994 and seven in 1995), Mid-South (12 in 1994 and five in 1995) and Southeast (11 in 1994 and 15 in 1995) regions. Mean lint yields within regions and years for the two Bt cottons ranged from 2 to 40% more than those for their respective recurrent parents. There was no significant difference between the Bt cottons and recurrent parents for seed vigor, plant height, number of main-stem nodes, height-to-node ratio, node of first fruiting branch, percentage retention of bolls in the first position of the lowest five fruiting branches, cutout node number, number of nodes on 15 July, fiber length or fiber strength. Micronaire of the Bt cottons was significantly lower, and “percentage retention in the 95% fruiting zone” was significantly higher. Seed size was significantly increased in NuCOTN 33B but not in NuCOTN 35B. Detailed test conditions, e.g., specific location of test, soil type, management practices, which are needed to determined adaptation, were not included in the report. Similar results were reported by Kerby et al. (1995) for 28 tests in 1994. From the papers, it is unclear whether the 1994 results reported by Kerby et al. (1995) were included in the 1994 results reported by Jones et al. (1996).

Williams et al. (1996) evaluated six Bt cotton lines (Hartz, now Paymaster, cultivars), their recurrent parents and two other conventional cultivars. The tests were conducted at eight locations from Texas to North Carolina with all plots managed equally and worms controlled, but test conditions were not included in the published abstract. In 46 of the 48 comparisons (six Bt lines vs. their recurrent parents at eight locations), the lint yield and lint percentage of the Bt lines were equal to or greater than those for the recurrent parent. Boll size of the Bt lines was equal to or greater than that for the recurrent parent in 45 of the 48 comparisons. Fiber properties for the Bt lines were similar to those for the recurrent parents.

Therefore, in tests conducted prior to 1996, all reported lint yields for Bt lines were equal to or greater than those for their recurrent parents, except two early reports of a Coker 312 Bt line and two out of 48 comparisons of Hartz Bt lines. Two reports indicated increased lint percentage in Bt lines. Due to the limited number of reports, no consistent effects of the Bt gene on plant conformation could be confirmed. Due to the limited testing (and test information), we were forced to assume that Bt lines have the same adaptation as their recurrent parents.

PERFORMANCES IN 1996 STATE CULTIVAR TESTS

Transgenic cotton cultivars were entered in state cultivar trials for the first time in 1996. Performance of transgenic cultivars in Arkansas, Mississippi and Louisiana will be summarized. The transgenic cultivars, their recurrent parents (when entered in the test), and one other conventional cultivar, Sure-Grow 125, were extracted from the state cultivar test reports.

The 1996 Arkansas Cotton Variety Test included four Bt, one Round-up Ready, and one BXN cultivar (Table 1). Over locations, four of the six transgenic cultivars yielded statistically equal to or more than Sure-Grow 125. Where comparisons to recurrent parents were available, yields of the transgenic cultivars were comparable to those of their recurrent parent. The yield of Deltapine NuCOTN 33B ranked 28th out of 30 entries over all locations. This disappointing yield was alarming because about one-third of the 1996 cotton acreage in southeastern Arkansas was planted to this cultivar. Evaluation of Bt cultivars in Arkansas should focus on the Rohwer location in southeastern Arkansas, which represents the area where insect pressure is highest and, thus, Bt cotton is most beneficial. At Rohwer, yield of NuCOTN 33B was 22nd and not significantly lower than that of Sure-Grow 125. This performance of NuCOTN 33B was similar to that previously experienced with its recurrent parent, Deltapine 5415. The three-year (1993-1995) mean of Deltapine 5415 ranked 20th out of 27 cultivars at Rohwer (Bourland et al., 1996). The relatively low yield of NuCOTN 33B may be due to its relatively late maturation (Table 2).

The transgenic cultivars tended to have similar maturity, leaf pubescence, lint fraction and fiber properties as their recurrent parents (Table 2). However, some distinct and significant differences occurred. For example, ‘Stoneville 47BXN’ had smoother leaves and lower fiber strength than Stoneville 474. ‘PM 1220 BG’ was more hairy than ‘PM H1220’. ‘PM H1560 BG’ was earlier and had a lower leaf hair rating and shorter fiber length than ‘PM H1560’. ‘PM 1330 BG’ was earlier and had a higher lint fraction and lower fiber strength than ‘PM H1330’. These differences illustrate that the transgenic cultivars are not identical to their recurrent parents and, therefore, must be evaluated for their own merits. Generally, the transgenic cultivars were comparable to the conventional cultivars. However, NuCOTN 33B had the lowest lint fraction of the 12 cultivars in Table 2.

In the 1996 Mississippi Delta tests, three Paymaster Bt cultivars and their recurrent parents were included in the early-maturity cotton cultivar trial, which was conducted at five locations (Table 3). NuCOTN 33B and Deltapine 5415 were included in the mid-maturity cultivar trial conducted at four locations. Over locations, yields of ‘PM 1244 BG’, ‘PM 1215 BG’ and NuCOTN 33B were significantly higher than those of their respective recurrent parents. Overall, the Paymaster Bt lines yielded 62 lb lint/acre more than their recurrent parents, while NuCOTN 33B exceeded Deltapine 5415 by 113 lb lint/acre. Yields of Stoneville 47BXN were similar to yields of its recurrent parent, Stoneville 474.

Overall, the Bt cultivars performed relatively better in Louisiana than in Arkansas or Mississippi (Table 4). NuCOTN 33B had significantly higher yield than Deltapine 5415 in seven of 12 comparisons (early- and medium-maturing tests) and out yielded Deltapine 5415 by an average of 132 lb lint/acre. Except for the higher yields of NuCOTN 33B and PM 1560 BG (at one location), yields of transgenics and their recurrent parents were always equal in the Louisiana tests. As in the Arkansas test, the two herbicide-tolerant cultivars, PM 1220 RR and Stoneville 47BXN, demonstrated strong agronomic performance.

These data from 17 locations of cultivar tests in Arkansas, Mississippi and Louisiana suggest that these transgenic cultivars generally yield as much as or more than their recurrent parents and are competitive with other conventional cultivars. Out of 94 comparisons of transgenic cultivars and their recurrent parents, significantly less yield by a transgenic cultivar was found for only one comparison (one cultivar at one location) while a transgenic cultivar had significantly higher yield in 19 of the 94 comparisons.

CONCLUSIONS

For the most part, Bt cottons, and transgenics in general, have survived and performed well in the 1996 test. However, only one year of extensive data are available on transgenic cotton. An incredible amount of Bt cotton was planted in 1996 with the assumption that the Bt lines would have the same adaptation as their recurrent parents. Most transgenic cultivars appear to be extremely similar to their recurrent parent, while others differ significantly. Data from several tests indicate that NuCOTN 33B has larger seed, early maturity, lower lint percentage and higher yield than Deltapine 5415. Some, but not all, of these differences may be related to insect control. Whenever differences that cannot be attributed to insect control are detected, the specific adaptation of the Bt line should be carefully examined. In the future, transgenic cultivars should be tested and receive the same scrutiny as conventional cultivars have in the past. In this way, vulnerability of producers to unexpected genetically related disasters can be minimized.

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Table 1. Lint yields (and rank out of 30 entries within each test) of transgenic cotton cultivars and some recurrent parents in the 1996 Arkansas Cotton Variety Test (extracted from Bourland et al., 1997).

	Lint yield by location													
	Keiser		Clarkedale				Marianna				Rohwer		Overall	
Cultivar	irrigated		irrigated		not irrigated		irrigated		not irrigated		irrigated		mean	
	lb/acre (rank)													
PM H1244	755	(14)	1218	(19)	788	(6)	1284	(1)	1043	(2)	1803	(1)	1148	(1)
PM 1220 RR	773	(11)	1277	(8)	790	(4)	1216	(5)	1002	(5)	1795	(2)	1142	(3)
Stoneville 474	755	(15)	1449	(3)	756	(15)	1207	(6)	944	(8)	1696	(6)	1135	(4)
PM 1220 BG	801	(5)	1214	(21)	742	(19)	1141	(12)	1105	(1)	1793	(3)	1133	(5)
ST 47BXN	723	(18)	1388	(5)	811	(3)	1154	(10)	850	(19)	1768	(4)	1116	(6)
Sure-Grow 125	793	(8)	1393	(4)	782	(7)	1197	(7)	920	(10)	1599	(14)	1114	(7)
PM H1220	706	(22)	1218	(18)	730	(23)	1228	(4)	1034	(4)	1722	(5)	1106	(8)
PM 1560 BG	904	(1)	1087	(29)	732	(22)	1281	(2)	855	(17)	1625	(12)	1081	(10)
PM 1330 BG	821	(4)	1227	(15)	738	(21)	1068	(19)	823	(23)	1646	(9)	1054	(15)
PM H1560	666	(27)	1247	(13)	767	(12)	962	(28)	879	(12)	1642	(10)	1027	(19)
PM H1330	757	(13)	1106	(28)	742	(18)	982	(27)	818	(24)	1440	(24)	974	(25)
NuCOTN33[B]	830	(2)	1119	(26)	767	(13)	873	(29)	680	(30)	1486	(22)	959	(28)
Test means	744		1242		754		1099		878		1573		1049	
$LSD_{0.05}$	96		187		NS*		174		138		119		53	
R-square x 100	66		70		53		70		58		78		94	

* NS = nonsignificant (*P*=0.05).

Table 2. Maturity, leaf pubescence, lint fraction and fiber properties for transgenic cotton cultivars and some recurrent parents over all locations of the 1996 Arkansas Cotton Variety Test (extracted from Bourland et al., 1997)*.

Cultivar	Lint yield	Open bolls	Leaf pubescence	Lint fraction	Fiber properties Mic.	Len.	Univ.	Str.	Elo.
	rank	%	rating	%		in.	%	g/tex	%
PM H1244	1	61	3.3	40.2	4.91	1.13	84.5	29.2	7.8
PM 1220 RR	3	49	3.7	39.8	5.15	1.14	85.6	30.6	8.1
Stoneville 474	4	54	6.8	42.2	5.07	1.10	84.2	29.8	7.2
PM 1220 BG	5	52	4.3	39.8	4.96	1.15	84.6	30.9	7.8
Stoneville BXN47	6	54	5.3	41.9	5.10	1.12	83.8	28.7	7.2
Sure-Grow 125	7	60	1.9	40.1	4.92	1.16	84.5	28.5	7.7
PM H1220	8	56	3.2	39.1	5.04	1.14	85.1	30.0	8.0
PM 1560 BG	10	48	3.5	39.5	5.00	1.12	85.0	30.9	7.4
PM 1330 BG	15	62	4.2	40.2	4.53	1.13	83.8	28.3	7.0
PM H1560	19	37	4.5	39.5	4.63	1.16	84.9	30.4	7.4
PM H1330	25	56	4.6	37.8	4.70	1.15	84.4	29.9	7.1
DP NuCOTN 33B	28	40	1.5	38.5	4.72	1.15	84.0	29.9	7.3
Test mean	–	52	3.4	39.1	4.82	1.14	84.4	29.6	7.3
LSD $_{0.05}$	–	8	0.4	1.1	0.21	0.02	0.9	1.0	0.3
R-square X 100	–	75	96	81	78	85	68	86	86
Variety X Loc.	--	**[†]	**	NS	NS	NS	NS	NS	**

[*] Percentage of open bolls was visually rated near time of defoliation. Leaf pubescence was rated using a scale of 1 (smooth leaf) to 7 (very hairy). Lint fraction and fiber samples were derived from hand-harvested boll samples. Fiber micronaire (Mic.), length (Len.), length uniformity (Unif.), strength (Str.) and elongation (Elo.) determined using HVI classing.

[†] ** = Significant at the 0.01 probability level.

Table 3. Lint yields (and rank) of transgenic cotton cultivars in the 1996 Mississippi Early-Season (28 entries) and Mid-Season (12 entries) Cotton Variety Trials (extracted from Calhoun et al., 1997).

Cultivar	Lint yield by location										Overall mean	
	Stoneville		Tunica		Choctaw		Rolling Fork		Tribbett			
	lb/acre (rank)											
Early-season:												
PM 1244 BG	1433	(2)	1089	(1)	1352	(1)	981	(1)	1169	(5)	1205	(1)
PM 1215 BG	1441	(1)	978	(4)	1320	(2)	793	(16)	1225	(1)	1151	(2)
PM H1220	1324	(3)	907	(9)	1192	(5)	856	(6)	1195	(2)	1094	(4)
PM H1215	1297	(5)	950	(6)	1224	(4)	809	(13)	1134	(8)	1083	(5)
PM 1220 BG	1290	(6)	983	(2)	1046	(13)	843	(8)	1189	(3)	1070	(6)
PM H1244	1289	(7)	920	(7)	1144	(6)	785	(17)	1172	(4)	1062	(7)
ST 47BXN	1201	(11)	908	(8)	1079	(9)	830	(12)	1149	(6)	1033	(8)
Stoneville 474	1261	(9)	880	(11)	1111	(7)	839	(10)	977	(20)	1014	(9)
Sure-Grow 125	1148	(14)	833	(17)	994	(18)	946	(2)	1139	(7)	1012	(10)
Test mean	1156		855		1029		807		1040		977	
$LSD_{0.10}$	54		78		84		82		83		55	
R-square x 100	86		51		77		48		51		80	
Mid-season:												
Sure-Grow 125	1218	(4)	--		1273	(2)	916	(1)	1028	(1)	1109	(1)
Stoneville 474	1226	(3)	--		1371	(1)	756	(3)	916	(5)	1067	(2)
DP NuCOTN33B	1261	(1)	--		1208	(4)	748	(4)	1018	(2)	1059	(3)
Deltapine 5415	1049	(11)	--		1075	(9)	759	(2)	901	(8)	946	(8)
Test mean	1146		--		1162		705		908		980	
$LSD_{0.10}$	62		--		77		39		69		53	
R-square x 100	57		--		58		80		58		89	

Table 4. Lint yields (and rank) of transgenic cotton cultivars in the 1996 Louisiana Early-Maturing (22 entries) and Medium-Maturing (15 entries) Cotton Variety Trials (extracted from Caldwell et al., 1996).

	Lint yield by location										Overall	
							Winnsboro					
Cultivar	Alexandria		Bossier City		St. Joseph		irrigated		not irrigated		mean	
	lb/acre (rank)											
Early-Maturing												
DP NuCOTN33B	1160	(3)	1605	(1)	1630	(1)	1187	(4)	1046	(2)	1326	(1)
PM 1220 RR	1137	(4)	1503	(2)	1398	(8)	1180	(6)	1067	(1)	1257	(2)
PM 1244 BG	1173	(1)	1489	(3)	1345	(13)	1230	(2)	1045	(3)	1256	(3)
Stoneville 474	968	(17)	1318	(10)	1474	(2)	1227	(3)	1042	(4)	1206	(4)
PM 1220 BG	1070	(9)	1440	(4)	1323	(16)	1168	(8)	978	(11)	1196	(7)
ST 47BXN	1066	(10)	1344	(9)	1457	(3)	1155	(9)	956	(13)	1196	(7)
PM H1220	1064	(11)	1372	(6)	1317	(17)	1173	(7)	1022	(5)	1189	(9)
PM H1244	1092	(8)	1392	(5)	1284	(20)	1183	(5)	991	(8)	1188	(10)
Deltapine 5415	1031	(14)	1351	(8)	1442	(5)	1029	(16)	967	(12)	1164	(12)
Sure-Grow 125	1130	(5)	1266	(14)	1397	(9)	1023	(12)	954	(14)	1154	(13)
Test mean	1044		1267		1336		1104		971		1144	
LSD $_{0.05}$	122		140		144		107		92		--	
C.V., %	8.3		7.8		7.7		6.9		6.7		–	
Medium-maturing:												
DP NuCOTN33B	1130	(5)	1429	(2)	1558	(1)	1025	(2)	1013	(4)	1231	(1)
Sure-Grow 125	1194	(1)	1267	(3)	1336	(9)	1021	(3)	1001	(5)	1164	(3)
DP NuCOTN35B	1160	(3)	1442	(1)	1386	(6)	831	(12)	984	(6)	1161	(4)
Deltapine 5415	1023	(11)	1118	(7)	1488	(2)	971	(5)	1045	(2)	1129	(5)
Deltapine 5690	1121	(6)	1111	(8)	1429	(4)	795	(14)	1033	(3)	1098	(6)
PM H1560	1192	(2)	1157	(5)	1279	(12)	910	(6)	951	(10)	1098	(6)
PM 1560 BG	1012	(12)	1245	(4)	1239	(13)	999	(4)	905	(15)	1080	(9)
Test mean	1073		1150		1353		898		907		1089	
LSD $_{0.05}$	114		157		128		126		106		--	
C.V., %	7.4		9.6		6.6		9.9		7.7		–	

EVALUATION OF STAPLE WEED CONTROL PROGRAMS

Eric P. Webster and Ford L. Baldwin[1]

INTRODUCTION

Staple® is a recently developed, low-use-rate herbicide for postemergence (POST) cotton weed control programs (Anonymous, 1993). To date, cotton producers have had no POST over-the-top herbicides for broadleaf weed control that do not cause substantial crop injury (Jordan et al., 1994). Thus, producers have relied heavily on POST directed sprays. However, this is a difficult, slow process and requires a height differential between crop and weed for effective control. Therefore, Staple is expected to be used on a widespread basis, particularly in the southeastern United States, based on its efficacy on morningglory (*Ipomoea* spp.), common cocklebur (*Xanthium strumarium* L.) and pigweed (*Amaranthus* spp.). Staple inhibits the enzyme acetolactate synthase in sensitive plants, although it is not in the imidazolinone or sulfonylurea families (Mitchell, 1991). Staple use rates range from 0.5 to 2.0 oz ai/acre, and these rates control a broad spectrum of weeds when applied preplant incorporated (PPI), preemergence (PRE) or POST (Sims et al., 1991).

In 1996, Staple was applied to several thousand acres in the Cotton Belt. With the advent of new, genetically engineered, herbicide-resistant crops, the use of Staple could potentially decrease in 1997. However, Buctril® is weak on pigweed, and Staple may be needed to help control pigweed when BXN cotton is planted (Hair et al., 1995). Roundup® has problems controlling all of the morningglory species (Wehtje and Walker, 1996), and Staple may be needed to help control these weeds in Roundup Ready cotton. This research was designed to evaluate several weed control programs in conventional, Roundup Ready and BXN cotton production systems.

MATERIALS AND METHODS

Research was conducted at The University of Arkansas Southeast Research and Extension Center at Rohwer, Arkansas, and at Little Rock, Arkansas. Studies were established evaluating Staple applied PRE and Staple applications in BXN and Roundup Ready cotton production systems.

[1]Extension Weed Scientist, Southeast Research and Extension Center, Monticello, Arkansas; and Extension Weed Specialist, Cooperative Extension Service, Little Rock, Arkansas.

Staple Preemergence

A study was established at Rohwer to determine the potential of Staple applied PRE. The experimental design was a randomized complete block with four replications. The planting date was 22 May 1996, and the study was not harvested due to heavy late-season weed pressure.

Staple at 0.6, 0.82 or 0.96 oz/acre plus Cotoran® at 0.94, 1.25 or 1.5 qt/acre were applied PRE. Staple applied POST and Bladex® plus MSMA and Bladex alone post-directed (PDS) were also evaluated. All herbicide PRE and POST applications were made with a CO_2 backpack sprayer at 15 gallons per acre (GPA). The PDS applications were applied with a tractor-mounted sprayer pressurized with CO_2 at 15 GPA. All applications were applied at 3 MPH. Pitted morningglory (*Ipomoea lacunosa*) and ivyleaf morningglory (*Ipomoea hederacea*) were evaluated for control two and four weeks after the POST treatment (Table 1).

Staple Applications in a Roundup Ready Cotton Production System

A study was established near Little Rock to evaluate Roundup Ready cotton with different weed control systems. The experimental design was a randomized complete block with four replications. The planting date was 9 May 1996, and the study was not harvested, due to heavy late-season weed pressure.

Herbicide programs consisted of two applications of Roundup Ultra® at 1.0 pt/acre with no soil-applied herbicides, Zorial® and Cotoran® soil-applied programs followed by Roundup Ultra at 1.5 pt/acre, and two applications of Roundup Ultra at 1.0 pt/acre plus Staple at 0.6 oz/acre with no soil-applied program. All herbicide PRE and POST applications were made with a CO_2 backpack sprayer at 15 GPA at 3 MPH. Palmer amaranth and common cocklebur were evaluated for control three and nine weeks after the four-leaf POST treatments (WAT) (Table 2).

Staple Applications in a BXN Cotton Production System

A study was established at Rohwer to determine the potential of Staple and Buctril applied POST. The experimental design was a randomized complete block with four replications. The planting date was 22 May 1996, and the study was harvested 9 October 1996.

Staple POST at 1.2 oz/acre was applied alone to 3-in. cotton or tank-mixed with Buctril at 1.0 pt/acre applied to 3- and 6-in. cotton. Buctril was also applied alone to 6-in. cotton following Staple 3-in. applications. Prowl was applied PPI followed by Cotoran or Zorial applied PRE. A standard weed control system consisting of Prowl PPI, Cotoran PRE, followed by Cotoran plus MSMA PDS, followed by two applications of Cy-Pro® plus MSMA PDS was included for comparison purposes. All herbicide PRE and POST applications were made with a CO_2 backpack sprayer at 15 GPA. The PDS were applied with a tractor-mounted CO_2 post-directed applicator at 15 GPA. All applications were applied at 3 MPH. Pitted morningglory (*Ipomoea lacunosa*) and ivyleaf morningglory (*Ipomoea hederacea*) were evaluated for control two and four weeks after the POST treatment (Table 1).

RESULTS AND DISCUSSION

Staple Preemergence

Staple applied PRE has a limited spectrum of activity. Staple has excellent activity on sicklepod, spurges, prickly sida and pigweeds. However, at Rohwer, the predominant weeds present in this study were pitted and ivyleaf morninglory. Staple has much more activity on these weeds when applied POST. Staple and Cotoran applied PRE with no POST application controlled pitted and ivyleaf morningglory 30 to 45% at 2 WAT (Table 1). However, when followed by an application of Staple at 1.2 oz/acre POST, control ranged from 80 to 91%.

At 4 WAT, weed control decreased for most treatments. Staple POST or a conventional herbicide program is needed to maintain adequate morningglory control. This research indicates that with timely POST or PDS applications, morningglories can be controlled.

Staple Applications in a Roundup Ready Cotton Production System

At 3 and 9 WAT, a Roundup Ultra-only program provided excellent weed control with no soil-applied herbicides (Table 2). However, two applications will be necessary to obtain adequate control. These data indicate that with the addition of Staple in a tank-mix with Roundup, Palmer amaranth and common cocklebur control can increase compared to a Roundup Ultra-only weed control program.

Staple Applications in a BXN Cotton Production System

At two and four weeks after the 6-in. POST treatment (WAT), ivyleaf morningglory control ranged from 90 to 97% control for all treatments except the nontreated (Table 3). This indicates that two applications of Staple, Buctril or a combination of the two herbicides can control ivyleaf morningglory equal to a standard herbicide program. Barnyardgrass control was 68 to 98% for all treatments. This study had an application of Select to control grass escapes. This study indicates that when Staple is in the herbicide program, grass control increases over a Buctril-only program. In a BXN system, a soil- and POST-applied grass herbicide will probably be necessary to insure grass control.

Cotton yields were 2825 to 3125 lb/acre of seed cotton for all herbicide treatments compared to 1430 lb/acre from the nontreated. This Buctril-resistant cotton variety has good yield potential compared to earlier developed varieties.

CONCLUSIONS

These studies indicate that the new technologies in cotton weed control will provide producers with options that can potentially control any weed infestation. Over the next five years, cotton weed control will probably change more than it has over the past 50 years.

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Table 1. Pitted and ivyleaf morningglory control with Staple applied preemergence and postemergence.

Input	Application timing	Rate	Pitted morningglory 2 WAT*	Pitted morningglory 4 WAT	Ivyleaf morningglory 2 WAT	Ivyleaf morningglory 4 WAT
		product/acre	------------------------	------------------------%	------------------------	------------------------
Nontreated			0	0	0	0
Staple	PRE	0.6 oz.	30	24	33	24
Cotoran	PRE	0.94 qt				
Staple	PRE	0.82 oz	39	39	41	24
Cotoran	PRE	1.25 qt				
Staple	PRE	0.96 oz	43	28	45	28
Cotoran	PRE	1.5 qt				
Staple	PRE	0.6 oz	81	78	85	80
Cotoran	PRE	0.94 qt				
Staple	POST	1.2 oz.				
NIS	POST	0.3 pt				
Staple	PRE	0.82 oz	83	78	89	78
Cotoran	PRE	1.25 qt				
Staple	POST	1.2 oz				
NIS	POST	0.3 pt				
Staple	PRE	0.96 oz	83	63	80	65
Cotoran	PRE	1.5 qt				
Staple	POST	1.2 oz				
NIS	POST	0.3 pt				
Staple	PRE	0.6 oz	86	81	91	84
Cotoran	PRE	0,94 qt				
Staple	POST	1.2 oz				
NIS	POST	0.3 pt				
Bladex	PDS	1.0 qt				
COC	PDS	0.3 pt				
Staple	PRE	0.82 oz	80	78	81	79
Cotoran	PRE	1.25 qt				
Staple	POST	1.2 oz				

continued

Table 1. continued.

NIS	POST	0.3 pt				
Bladex	PDS	1.0 qt				
COC	PDS	0.3 pt				
Staple	PRE	0.96 oz	85	80	91	83
Cotoran	PRE	1.5 qt				
Staple	POST	1.2 oz				
NIS	POST	0.3 pt				
Bladex	Layby	1.0 qt				
COC	Layby	1.2 pt				
Cotoran	PRE	1.5 qt	93	89	95	90
Zorial	PRE	1.25 lb				
Cotoran	3-in. PDS	1.0 qt				
MSMA	3-in. PDS	1.1 qt				
Bladex	6-in. PDS	0.8 qt				
MSMA	6-in. PDS	1.1 qt				
$LSD_{(0.05)}$			9	18	10	13

* WAT = Weeks after POST application.

Table 2. Palmer amaranth and common cocklebur control with Roundup and Staple in Roundup Ready cotton.

	Application		Palmer amaranth		Common cocklebur	
Input	timing	Rate	3 WAT*	9 WAT	3 WAT	9 WAT
		product/acre	----------	----------	% ----------	----------
Nontreated			0	0	0	0
Zorial	PPI	0.75 lb	95	86	95	70
Zorial	PRE	0.75 lb				
Cotoran	PRE	1.2 qt				
Zorial	PPI	0.75 lb	100	90	95	73
Zorial	PRE	0.75 lb				
Cotoran	PRE	1.2 qt				
Roundup Ultra	1 lf POST	1.5 pt				
Zorial	PPI	0.75 lb	100	78	90	53
Cotoran	PRE	1.2 qt				
Roundup Ultra	1 lf POST	1.5 pt				
Roundup Ultra	1 lf POST	1.0 pt	100	88	100	93
Roundup Ultra	4 lf POST	1.0 pt				
Roundup Ultra	1 lf POST	1.0 pt	100	100	100	100
Staple	1 lf POST	0.6 oz				
Roundup Ultra	4 lf POST	1.0 pt				
Staple	4 lf POST	0.6 oz				
$LSD_{0.05}$			5	11	9	11

*WAT = Weeks after POST application.

Table 3. Ivyleaf morningglory and barnyardgrass control with Buctril and Staple in BXN cotton.

Treatment	Application Timing	Rate	Ivyleaf morningglory 2 WAT*	Ivyleaf morningglory 4 WAT	Barnyardgrass 2 WAT	Barnyardgrass 4 WAT	Seed Cotton Yield
		product/acre	%				lb/acre
Nontreated			0	0	0	0	1430
Prowl	PPI	1.8 pt	97	97	97	94	2920
Cotoran	PRE	1.2 qt					
Cotoran	3-in. PDS	1.0 qt					
MSMA	3-in. PDS	1.5 qt					
Cy-Pro	6.in. PDS	1.5 pt					
MSMA	6-in. PDS	1.5 qt					
Cy-Pro	8-in. PDS	1.5 pt					
MSMA	8-in. PDS	1.5 qt					
Prowl	PPI	1.8 pt	95	97	90	91	2860
Cotoran	PRE	1.2 qt					
Staple	3-in. POST	1.2 oz					
NIS	3-in. POST	0.3 pt					
Buctril	6-in. POST	1.0 pt					
Prowl	PPI	1.8 pt	97	96	91	90	3125
Cotoran	PRE	1.2 qt					
Staple	3-in. POST	1.2 oz					
Buctril	3-in. POST	1.0 pt					
Prowl	PPI	1.8 pt	96	97	90	93	2880
Cotoran	PRE	1.2 pt					
Staple	3-in. POST	1.2 oz					
Buctril	3-in. POST	1.0 pt					
Staple	6-in. POST	1.2 oz					
Buctril	6-in. POST	1.0 pt					
Prowl	PPI	1.8 pt	97	90	87	84	2825
Zorial	PRE	1.5 lb					
Staple	3-in. POST	1.2 oz					
NIS	3-in. POST	0.3 pt					
Buctril	6-in. POST	1.0 pt					
Prowl	PPI	1.8 pt	95	93	88	86	2900
Zorial	PRE	1.5 lb					
Staple	3-in. POST	1.2 oz					
Buctril	6-in. POST	1.0 pt					
Prowl	PPI	1.8 pt	96	93	79	73	3015
Cotoran	PRE	1.0 qt					
Staple	PRE	0.48 oz					
Staple	3-in. POST	1.2 oz					
NIS	3-in. POST	0.3 pt					
Staple	6-in. POST	1.2 oz					
NIS	6-in. POST	0.3 pt					

continued

Table 3 continued

Prowl	PPI	1.8 pt	97	94	68	68	2855
Cotoran	PRE	1.0 qt					
Staple	PRE	0.48 oz					
Buctril	3-in. POST	1.0 pt					
Buctril	6-in. POST	1.0 pt					
$LSD_{(0.05)}$			3	5	8	11	315

[*] WAT = Weeks after POST application.

THE RENIFORM NEMATODE, AN EMERGING PROBLEM IN ARKANSAS COTTON

T.L. Kirkpatrick and Gus Lorenz[1]

INTRODUCTION

The reniform nematode, *Rotylenchulus reniformis*, was first described in Hawaii in 1931 and has long been considered primarily a pest in tropical countries. Reniform was first reported in the U.S. on cotton during the 1940s; until 1960 it was confined to cotton fields primarily along the Gulf Coast of Florida, Alabama, Georgia and Texas. Since 1960, however, the reniform nematode has spread northward throughout much of the eastern half of the U.S. Cotton Belt (Heald and Robinson, 1990). In 1996, this nematode was found widely distributed in cotton fields in the Carolinas and in all the Gulf Coast states, and incidence is no longer confined to the southern portions of these states. Spread northward has been relatively steady in some areas. For example, in 1961, this nematode was known to occur in approximately 2,000 acres of cotton in central Louisiana. By 1996, however, reniform nematodes were considered to be the most economically important nematode pest of Louisiana cotton, infesting approximately 510,000 acres of cotton within the state (Overstreet and McGawley, 1997).

In Arkansas, a similar trend in the spread of the reniform nematode appears to be taking place. Extensive surveys of Arkansas cotton conducted in 1986-88 indicated that only 1% of cotton fields had detectible populations of reniform, and incidence was confined to Monroe and southern Jefferson Counties (Robbins et al., 1989) (Fig. 1). Limited surveys were conducted in 1991 in Jefferson County in fields near a cotton field known to be infested by reniform. Of 30 fields sampled in this area, 14 contained moderate to high levels of the nematode (T.L. Kirkpatrick, unpublished). The reniform nematode was also identified for the first time in Lonoke County in 1991 near the town of England (R.T. Robbins, personal communication) (Fig. 2). Since 1992, reniform nematode incidence in cotton has dramatically increased in southeastern Arkansas (Fig. 3). Significant acreage is now known to be infested in Ashley, Chicot, Jefferson, Lonoke and Monroe Counties (Bateman and Kirkpatrick, 1997), with approximately 30% of fields in some areas infested (Lorenz et al., 1996).

[1]Professor, University of Arkansas Southwest Research and Extension Center, Hope, Arkansas; and IPM Coordinator, Cooperative Extension Service, University of Arkansas, Little Rock, Arkansas.

BIOLOGY AND POTENTIAL FOR ECONOMIC EFFECTS ON ARKANSAS COTTON

Although primarily found in tropical environments, the reniform nematode has been found in the U.S. as far north as the panhandle of Texas (Heald and Thames, 1982) and the Missouri bootheel (Wrather et al., 1992). This nematode pest has a broad host range (Birchfield and Brister, 1962; Singh, 1974) that includes many vegetable crops, cotton and soybean. In contrast to the root-knot nematode that is favored by sandy soils, reniform is well suited to a broad range of soil types. Soils containing 28% silt or clay appear to be optimum for survival of the reniform nematode (Koenning et al., 1996). The reniform nematode can also survive well overwinter and in fallow soil and has an extremely high reproductive potential (Koenning et al., 1996; Noe, 1994). Under southeastern Arkansas conditions, it is not unusual to find 50,000 reniform nematodes/pint of soil in infested cotton fields by mid to late summer. There have been no studies conducted in Arkansas, however, to help us understand the population dynamics of this nematode or factors that affect survival or reproduction in the field.

The reniform nematode can cause significant cotton yield suppression under field conditions (Gazaway et al., 1994; Jones et al., 1959; Lawrence et al., 1990). In recent studies in North Carolina, cotton was a more suitable host, and lint suppression was greater for plants infected by the reniform than by the root-knot nematode (Koenning et al., 1996). There are differences in the pathogenicity of the reniform nematode on certain crops (Birchfield and Brister, 1962; Dasgupta and Seshadri, 1971; Heald, 1978), and limited evidence exists indicating that some reniform populations may be more damaging to cotton than others (McGawley and Overstreet, 1995). In addition, the reniform nematode has been shown to interact with fungal pathogens, including the seedling disease pathogen *Rhizoctonia solani* (Sankaralingam and McGawley, 1994) and *Verticillium dahliae*, causal agent of Verticillium wilt (Tachatchoua and Sikora, 1979), to make these diseases more severe.

CONTROL OPTIONS

There are no cotton cultivars that are resistant to the reniform nematode. There may be some cultivars that are more tolerant of reniform nematode infection than others, but yield suppression still may occur, and tolerant cultivars generally increase nematode populations to essentially the same degree as susceptible cultivars, creating an even more severe nematode problem for future crops. Crop rotation may hold some promise for lowering reniform populations. Crops such as corn, grain sorghum and rice are poor or non-hosts for this nematode, and rotation of cotton with these crops may lower reniform numbers for subsequent crops. Unfortunately, in Arkansas there have been no studies to determine the degree of population reduction that can be achieved by rotation to these crops, and no data are available as to how many years or how often rotation out of cotton will be necessary to provide economic nematode control. The economic feasibility of utilizing these crops in rotation with cotton for reniform nematode control must also be thoroughly examined. Prolonged soil flooding, such as would be the case with rice as the rotation crop, appears to be very effective in lowering reniform population levels (T.L. Kirkpatrick, unpublished). Unfortunately, soil type and location of most cotton fields make them relatively poor sites for rice production. Soybean is also a good host for the reniform nematode, and although some reniform nematode-resistant soybean cultivars exist, reproduction still occurs on these cultivars. Consequently, the utility of soybean in lowering reniform population densities for subsequent cotton crops is limited.

The most popular approach to reniform control in cotton has been use of nematicides. Historically, fumigants were used with considerable success (Birchfield, 1968; Thames and Heald, 1974), but environmental concerns severely limit their usage today. Varying degrees of success have been obtained with non-fumigant nematicides. In some areas within fields, yield improvement with nematicides may be as high as 50-70% (Gazaway et al., 1994; Noe, 1994). However, lint yield improvement of 25-30% is probably more likely (Lawrence et al., 1990). In limited studies in Arkansas, lint yield was improved by approximately 60 lb/acre across several cultivars when the nematicide aldicarb (Temik 15 G) was applied (Lorenz et al., 1997). The nematicide oxamyl (Vydate) has been reported to suppress nematode infection when used as a foliar application (Hammes and Mitchell, 1996). Studies in Arkansas, however, have not demonstrated significant yield improvement from applications of Vydate C-LV for reniform nematode suppression (Kirkpatrick et al., 1997). Currently, soil-applied nematicides appear to be the most readily available and economically feasible method for avoiding cotton yield losses in reniform infested fields.

OUTLOOK FOR THE FUTURE

The reniform nematode has moved steadily northward throughout the eastern half of the U.S. Cotton Belt during the past 30 years. In states adjacent to Arkansas, this nematode has become a major economic pest of cotton. Yield losses ranging from 10% to as great as 50-70% have been reported in fields infested by reniform nematodes. There are no cotton cultivars that are resistant to reniform nematodes, and although some cultivars appear to be more tolerant to the nematode than others, yield losses are still unacceptable. This nematode is capable of extremely high reproductive rates during a single season and can live successfully in a relatively broad range of soil types and situations. Its presence in a field can be detected only by soil assay conducted by a nematology laboratory.

There appears to be a high potential for the spread of this nematode to new fields and areas, although the reason for the dramatic increase in incidence during the past five years in Arkansas is unclear. Movement of soil or water may transport reniform nematodes to previously uninfested fields. In addition, very little of the total cotton acreage within the state has been sampled to determine whether or not the nematode is already present. Regardless of the reason for the greater incidence within the state, it appears that this pest of cotton is on the increase and may pose a significantly greater threat to profitable cotton production in the future.

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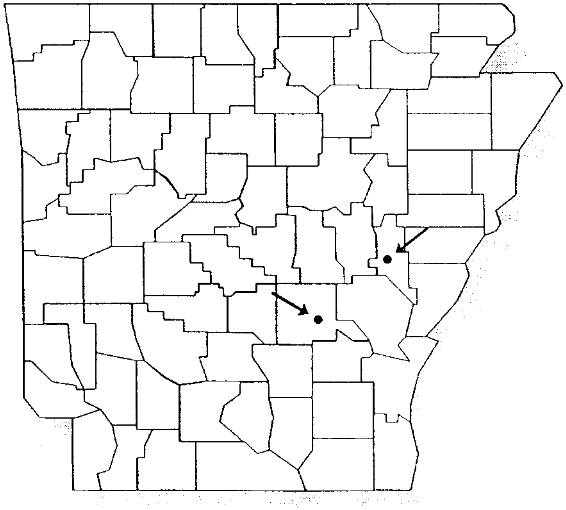

Fig. 1. Distribution of the reniform nematode in cotton, 1989. Dots represent individual fields in which the nematode was detected.

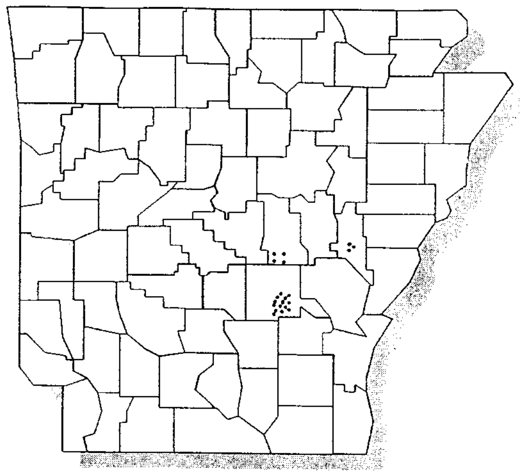

Fig. 2. Distribution of the reniform nematode in cotton, 1991. Dots represent individual fields in which the nematode was detected.

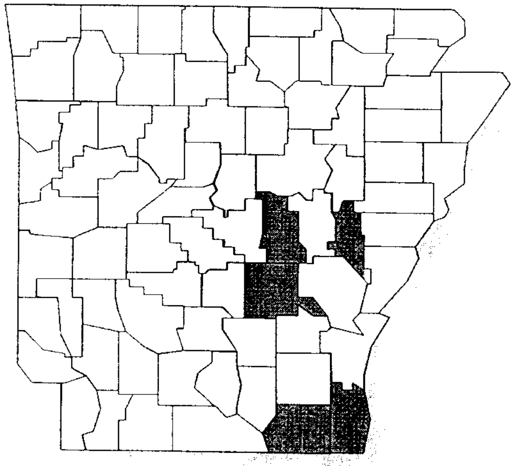

Fig. 3. Counties with significant cotton acreage (>10%) infested by the reniform nematode, 1996.

PIX RECOMMENDATIONS FOR ARKANSAS

C.R. Shumway[1]

INTRODUCTION

PIX (mepiquat chloride) is a plant growth regulator (PGR) that is frequently used in cotton to limit excessive vegetative growth. It was developed out of a small grains research program and has since become a major input in cotton production systems across the Cotton Belt. In 1979 there was an extended use of experimental use permits (EUP) followed by a full label in 1980. Even though we have seen the extensive use of PIX in cotton production systems, we are still trying to develop a more-efficient method for rate determination (Hake et al., 1991).

Cotton plant characteristics associated with the use of PIX are varied. Most research has indicated a significant reduction in vegetative growth (Guthrie et al., 1993). This has included a reduction in both plant height and total leaf area (Oosterhuis et al., 1991; Shumway, 1995). This has led to a more compact canopy with an implication of less boll rot and a more-efficient defoliation. Boll number and yield responses are considered to be variable in respect to PIX use (Cathey and Meredith, 1988; Kerby, 1985; York, 1983). Maturity may be a factor in the use of PIX. Several reports have indicated that an earlier maturity is associated with the use of PIX (Hake et al., 1991; Oosterhuis et al., 1991).

TECHNIQUES FOR THE USE OF MEPIQUAT CHLORIDE

Is there only one way to use PIX? The answer is no. Over the 16 production seasons that PIX has been used, we have seen a number of changes take place in respect to recommendations. These changes have all contributed to a more-efficient use of this PGR (Guthrie et al., 1995). The early development and use of PIX started with the use of standard rates of 8-16 oz/acre applied at or near early bloom. Typically, this was recommended in cotton production that was conducive to excessive growth. The development of the low-rate multiple technology gave the producer a greater level of control and flexibility. PIX applications were initiated at early reproductive development (matchhead square) and continued on a time frame based on anticipated need. However, the key factor to the use of both of these systems was that there was no quantitative measurement. The best-case scenario with these methods was that they were educated guesses.

[1]Associate Professor, Arkansas State University, Jonesboro, Arkansas.

One of the first quantitative methods developed was the height-to-node ratio. This was the relationship between plant height and node production. This was also considered an estimate of vigor (Silvertooth et al., 1996). Plants that are under optimal conditions will continue internode elongation and produce plants with excessive plant height. This may be due to high fertility levels, excessive irrigation or some other factor that produces an optimal production environment. The use of PIX has shown that we can reduce this growth. Since these internodes give us an indication of the plants vigor, work has been accomplished to evaluate specific internodes as a quantitative measure. The fourth internode down from the terminal has been used as such a measure (Guthrie et al., 1993). Its elongation is essentially complete and gives us a history of the plant's vigor status at any given time. We have also seen the development of the PIXSTIK or the MEPRT Stick as an indicator of the height-to-node ratio (Landivar et al., 1996). This technique uses the five uppermost internodes to determine the rate of PIX needed to produce an acceptable plant growth.

Another system that has been used is the mepiquat chloride rate calculation. This has been developed by J. Landivar at Texas A&M University (Silvertooth et al., 1996). This technique is used during the linear phase of plant height development that occurs from 35-40 days (pinhead to matchhead square) after planting to 15-20 days after early bloom. This model calculates the amount of PIX required to maintain a desired main-stem elongation rate. One of the assumptions of the model is that the concentration of PIX in the plant will be reduced as the plant grows. Landivers work has indicated the concentration of applied PIX needed to maintain the desired level of growth suppression (Landivar et al., 1992). The model is an estimate of the plant biomass and calculates the amount of PIX required to get the plant back to a critical level. Factors included in the determination are plant height, main-stem node number, row spacing and plant population.

What may still be the best method for the use of PIX is experience. Most producers have an idea of the productivity of the land and the potential of excessive plant growth. The use of on-farm research conducted by research, extension and crop consultants will continue to add to our understanding of PIX use.

CONCLUSIONS

As we enter our seventeenth year of PIX use, we are at a point at which we better understand the activity and the proper use of this plant growth regulator. However, there are still problems to be addressed. We will have to expand our research into the use of various row spacings, which will include both 30-in. and ultra-narrow-row technology. We also need to evaluate different strategies with the use of transgenics such as Bt, Roundup Ready and BXN systems.

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PHYSIOLOGICAL ASPECTS OF POTASSIUM DEFICIENCY IN COTTON

Derrick M. Oosterhuis[1]

INTRODUCTION

Widespread potassium (K) deficiency has occurred across the U.S. Cotton Belt. However, the explanation for these deficiencies is unclear, and a considerable amount of research and speculation has surrounded this phenomenon (Kerby and Adams, 1985; Oosterhuis, 1995). It has been postulated that the widespread K deficiency in the U.S. Cotton Belt is related to earlier-maturing, higher-yielding, faster-fruiting cotton varieties creating a greater demand than the plant root system is capable of supplying. Cotton appears to be more sensitive to low K availability than most other major field crops and often shows signs of K deficiency on soils not considered K deficient (Cope, 1981). An explanation is needed for the events that occur in the cotton plant during the onset of a K deficiency.

In cotton, tissue tests have become a valuable diagnostic tool for assessing the nutrient status of a crop, for determining fertilizer recommendations during the growing season and for detecting potential K deficiency (Baker at al., 1992). The petiole is generally considered more indicative of plant K status than the leaf blade, partly because of the more rapid decline in K concentration in the petiole, compared to the leaf, during the boll development period (Hsu et al., 1978). However, there is still some question about the appropriate critical or threshold levels for K concentration in the leaf or petiole, as these values may be appreciably altered by the environment, plant genetics and sampling procedure.

This report describes research conducted at the University of Arkansas to investigate changes in cotton during the onset of a K deficiency with regard to partitioning of K in plant components and the accompanying physiological changes. These studies have been previously reported (Bednarz, 1995; Bednarz and Oosterhuis, 1996; Bednarz et al., 1997; Oosterhuis, 1995).

SYMPTOMS OF POTASSIUM DEFICIENCY

Potassium deficiency occurs more frequently and with greater intensity on cotton than on most other agronomic crops (Kerby and Adams, 1985). The widespread K deficiency that has occurred across the U.S. Cotton Belt is related to 1)

[1]Crop Physiologist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

the use of earlier-maturing, higher-yielding, faster-fruiting cultivars (Oosterhuis et al., 1990), 2) planting of cotton on poorer soils low in available K (Kerby and Adams, 1985) and 3) the relative inefficiency of cotton at absorbing K from the soil compared to most other crop species (Cassman et al., 1989). Typical K deficiency symptoms consist of yellowish-white mottling of the leaves that changes to numerous brown specks at the leaf tips, around margins and between veins (Sprague, 1964). The leaf tip and margin curl downwards as the tissue breakdown continues. Finally the whole leaf becomes rust colored and brittle and drops prematurely; this stops boll development, resulting in dwarfed and immature fruit, some of which may not open. These small bolls are a typical symptom of severe K deficiency in cotton. Many of these symptoms are related to the disturbance of tissue water balance, resulting in tip drying, leaf edge curling and early senescence. Potassium deficiency symptoms in cotton are quite distinctive and, due to the characteristic bronzing that occurs, were once termed *cotton rust* before the true cause was known (Kerby and Adams, 1985). The symptoms of K deficiency have been mistaken for Verticillium wilt symptoms as they seem to occur under similar environmental conditions (Weir et al., 1986). Furthermore, the growth and yield of cotton varieties less susceptible to Verticillium wilt are often less affected by late-season K deficiency (Ashworth et al., 1982).

Potassium deficiency symptoms fall into two categories, namely those that occur at the bottom of the plant on the lower, older or mature leaves, and the more recent symptoms (Stromberg, 1960; Weir et al., 1986; Maples et al., 1988) that show up on young cotton leaves at the top of the plant late in the season. The characteristic rusting and premature senescence is the same for both lower- and upper-canopy K deficiencies. However, unlike the lower, older leaf symptoms, researchers have not been fully able to explain the real cause of these new upper-canopy deficiency symptoms, which have aroused much speculation. Current thinking is that modern varieties develop bigger yields over a shorter fruiting period and that K moving upward from the roots is intercepted by the developing boll load at the expense of the upper leaves.

SOIL AND FOLIAR POTASSIUM FERTILIZATION OF COTTON

There have been numerous studies on K fertilization of cotton, but these have often exhibited variable and non-significant results and have not always alleviated K deficiencies. The explanation for this is not clear. The occurrence of mid- to late-season K deficiencies has focused interest on the possible use of foliar applications of K. Preliminary research in 1989 in Arkansas (Oosterhuis et al., 1990) indicated that foliar applications of KNO_3 increased both yield and lint quality. However, the results from foliar application studies have generally been variable and disappointing. For example, in a three-year study at 12 locations across the U.S. Cotton Belt over a range of soil K levels (Oosterhuis et al., 1994) comparing soil versus foliar K fertilization, only 40% of the experiments showed significant responses to foliar K fertilization (Table 1). Similarly in Arkansas, in a four-year, eight-experiment-field study (Oosterhuis 1995; Oosterhuis, et al., 1994) comparing soil and foliar K fertilization on cotton yield, only 50% of the studies showed a significant response to foliar-applied K over the soil-applied K treatment (Table 2). Generally in these experiments there were significant yield increases from soil- and foliar-applied K fertilizer compared to the control. However, the "soil-K plus foliar-K" treatments significantly increased yield above that of "soil-applied K" less than half the time. It appeared possible to achieve the same affect as foliar K by doubling the initial soil K. This may not, however, be practical due to possible salt buildup and K fixation in the soil. These results indicate that information about K nutrition of the cotton plant is limited, especially for predicting the onset of K deficiency and the need for additional K fertilizer.

PARTITIONING OF POTASSIUM IN PLANT COMPONENTS

Field and growth chamber studies were conducted in 1993 and 1994 to determine how K was partitioned during the development of K deficiency symptoms. Both experiments had two treatments: a control and a low-K (field study) or no-K (growth chamber study) treatment.

Growth Chamber Study

In the *growth chamber* study (Bednarz and Oosterhuis, 1996), plants were grown in 8-L pots of sand and watered every other day with 50% Hoagland's nutrient solution, and deionized water on alternate days. At the pinhead square stage, K was withheld from half the pots, and the subsequent partitioning of K into plant components was measured at select time intervals. The onset of a K deficiency was detected four days after withholding K in the upper canopy petioles and subsequently in the mid- to lower-canopy petioles (Fig. 1). The trend with leaf K was similar (data not shown), but the differences were not as great as in the petioles. In the fruit, however, differences in K were not observed until much later, at 28 days after withholding K.

Field Study

In the *field* study (Bednarz, 1995), a control (>217 lb K/acre) and a low-soil-K treatment (>159 lb K/acre) were established. Partitioning of K into plant components was determined at first flower and peak bloom. In contrast to the growth room study, the K deficiency was first detected in the mid-canopy petioles and two weeks later at peak bloom in the upper canopy petioles (Fig. 2). A similar trend was recorded for leaf K concentration (data not shown). Differences in fruit K were observed at both sampling dates.

These contrasting results in the growth chamber (K deficiency first detected in upper-canopy petioles) and field (K deficiency first detected in mid-canopy petioles) could possibly be related to the size of the developing boll load in the two situations. The developing bolls are the main sink for K and constitute a major drain on the plant's K reserves. The larger boll load in the field study (>2 bales lint/acre) may have depleted the plant's K reserves more rapidly in the vicinity of the developing boll load. Another explanation or complicating factor is that cotton plants are able to store K in luxury amounts. It is possible that the field-grown plants were able to store additional K in the lower canopy (for which there was some evidence), whereas in the chamber-grown plants the earlier sampling and more severe K stress may not have permitted any appreciable luxury K storage. Thus once a deficiency started, K was withdrawn from upper, younger plant parts.

PHYSIOLOGICAL CHANGES DURING THE ONSET OF POTASSIUM DEFICIENCY

A pot study was conducted in a controlled environment chamber using *Gossypium hirsutum* L., cv. Deltapine 20. Two K treatments were established to determine the effects of K deficiency on physiological processes and the threshold petiole K concentration for plant growth. Plants were watered every second day with deionized water and with nutrient solution on alternate days. At 14 days after planting (the fourth-true-leaf stage), K was withheld from the nutrient solution used in the no-K treatment, and two treatments were established consisting of 1) continued complete nutrient solution and 2) nutrient solution containing no K. Measurements were taken 13, 19 and 26 days later for organ K concentrations, plant growth parameters, leaf chlorophyll, photosynthesis, ATP and nonstructural carbohydrate concentrations were monitored as plant K deficiencies developed. Details of techniques and specific procedures are given in Bednarz (1995).

Dry Weight and Potassium Partitioning in Plant Components

Significant reductions in tissue dry weight in the no-K treatment were observed in all organs on each analysis date when compared to the plus-K treatment (data not shown). Similar changes/trends were observed in tissue K concentration (Fig. 3). Petiole K showed the biggest change in K with the onset of K deficiency. All organ K concentrations in the no-K treatment were less than 10 g/kg at 19 and 26 days after withholding K. Large numerical differences were observed at 19 and 26 days in leaf area, leaf dry weight, root dry weight and square dry weight (data not shown), but only on day 26 were some significant differences ($P \leq 0.05$) observed. The order of organ sensitivity to K deficiency in cotton was bolls < stems and petioles < leaves < roots (Bednarz and Oosterhuis, 1995).

Visual Symptoms and Chlorophyll Concentration

There were no visual K deficiency symptoms 13 days after withholding K, and leaf chlorophyll concentrations were similar in both treatments (data not shown). However, 19 days after withholding K, slight marginal and interveinal chlorosis was observed in the leaves. Chlorophyll a and total-leaf chlorophyll concentrations from the no-K treatment were also significantly lower. By 26 days after withholding K, severe chlorosis was observed in the tagged leaves, and necrotic areas were also beginning to appear in these leaves, as is typical for K deficiency (Oosterhuis, 1995). Reductions in chlorophyll were also observed in the no-K treatment along with a reduction in the chlorophyll a to chlorophyll b ratio (Ca:Cb), indicating that reductions in chlorophyll a were occurring faster than reductions in chlorophyll b. Various stages of visual leaf K deficiency symptoms were observed in all leaves of the canopy by 26 days after withholding K.

Photosynthesis and Critical Leaf Potassium Concentration

Decreased photosynthesis accompanied the visual K deficiency symptoms and decreased leaf chlorophyll concentration (Fig. 4). At 19 days after withholding K, leaf photosynthesis was significantly reduced by 80% in the no-K treatment and by 95% at 26 days. The critical leaf K concentration has been reported to occur between 1.2 and 0.9% (Baker et al., 1992). However, our data show that leaf photosynthesis did not begin to decline until leaf K concentration fell below 0.95% and petiole K concentration fell below 0.88%.

ATP (Energy) Changes

Some studies have suggested that K deficiency will result in reduced Adenosine Triphosphate (ATP) synthesis (Hartt, 1970). Our results show that leaf ATP concentration increased as the K deficiency became more acute in the no-K treatment at 19 and 26 days after withholding K (data not shown). Therefore, ATP utilization may have been restricted more than ATP formation, which would also agree with the conclusions of Huber (1985).

Leaf Carbohydrates

Leaf hexose (glucose and fructose) from the plus-K treatment remained fairly constant in all samples throughout the sampling period (Fig. 5a). However, at 13 days after withholding K, leaf hexose from the no-K treatment was elevated in samples taken late in the day. Also, at 19 and 26 days after withholding K, hexose concentrations were much higher in leaves from the no-K treatment at both sampling times. Increased leaf hexose concentration may be attributed to decreased activity of K-dependent enzymes such as pyruvate kinase (Evans and Sorger, 1966) or from greater hydrolysis of sucrose by the increased activity of acid invertase or other sucrose metabolizing enzymes (Huber, 1985). Leaf sucrose from the plus-K treatment was also fairly uniform throughout the sampling period (Fig. 5b). Leaf starch was always higher in the samples taken in the evening than in those taken in the morning, regardless of K treatment (data not shown). Again, leaf starch at 19 and 26 days after withholding K was much higher in the no-K samples at both sampling times. Electron micrographs of leaf cross sections confirmed the presence of starch in the no-K treatments but not in the plus-K treatments. Finally, total leaf soluble sugars (glucose, fructose and sucrose) followed the same trends as leaf hexose and sucrose concentrations.

Gas Exchange, Carbon Isotope Analysis, Carboxylation Efficiency and CO_2 Compensation

Analysis of gas exchange and carbon isotope analyses showed stomatal conductance was most limiting to photosynthesis 13 days after withholding K, whereas at 19 and 26 days non-stomatal conductances were most limiting (Bednarz, 1995; Bednarz et al., 1997). Most of the work involving stomatal and non-stomatal limitations of photosynthesis and isotopic fractionation in tissue samples has concentrated on the effects resulting from plant water stress. However, the changes that occur in the photosynthetic apparatus and resulting carbon isotope composition during the development of a K deficiency in cotton have received little or no attention. Our studies document the changes that occur in cotton in photosynthesis, stomatal and mesophyll resistance and carbon isotope discrimination (Bednarz et al., 1997). Accompanying the decreased photosynthesis as K deficiency developed was a decreased carboxylation efficiency and an increased CO_2 compensation point.

Petiole Analysis and Diagnosis

Potassium fertility recommendations based on cotton petiole diagnostic analysis results have been inconsistent, partly because the lowest acceptable petiole K concentration is unknown. Our studies show that reductions in leaf physiological processes and plant growth did not occur until the petiole K concentration fell below 0.88%, and leaf K concentration below 0.95%, on a dry weight basis (Bednarz, 1995). Therefore, reductions in lint yield and quality should not develop until this critical petiole level is attained. These results will improve the efficiency of K fertilizer usage in cotton production. Furthermore, detailed studies of K partitioning in plant parts during the onset of a K deficiency indicated that upper-canopy petioles may not be sufficiently sensitive to a pending K deficiency, whereas mid-canopy petioles may more clearly show the start of the K deficiency. However, results from field tests in 1996 of upper- and mid-canopy petioles for detecting a pending K deficiency were not conclusive.

Luxury Storage of Potassium

Our studies have indicated that the cotton plant stores excess K in luxury amounts, which may serve as a reservoir during a K shortage and boll development (Bednarz and Oosterhuis, 1995). Bennett et al (1965) reported that cotton plants continue to accumulate K at rates above that needed to produce maximum yields, especially prior to the reproductive stage. However, Kafkafi (1990) suggested that luxury consumption of K can be beneficial for high yields and a cheap source of insurance against possible K deficiency problems. It has been suggested (Oosterhuis, 1995) that the luxury storage of K by the cotton plant may explain the apparent inability of researchers to accurately predict the onset of K deficiency from tissue analysis. Luxury storage may also be partly responsible for inconsistent results from soil and foliar K fertilizer applications. It is evident that the K status of a cotton plant cannot be accurately predicted using diagnostic tissue test results of the petioles from a single main-stem upper-canopy location.

SUMMARY

Cotton is more sensitive to low K availability than most other major field crops and often shows signs of K deficiency on soils not considered K deficient. This report describes studies conducted in Arkansas on the K nutrition of cotton. The onset of K deficiency in growth chamber experiments was first detected in roots, followed by stems, petioles and leaves, and then in the fruit. Furthermore, luxury storage of K, prior to peak demand for K by the boll load, could complicate tissue diagnostic recommendations. In growth chamber experiments, visual K deficiency

symptoms were first observed 19 days after K was withheld, along with reductions in leaf chlorophyll concentration and significant reductions in leaf photosynthesis. However, leaf ATP and nonstructural carbohydrate concentrations were higher 19 days after withholding K than in the control, which may have been the result of reduced utilization and translocation of these metabolites. Gas exchange studies and carbon isotope analyses showed that stomatal conductance was initially the most limiting resistance to net photosynthesis but that non stomatal conductances became more important as the severity of the K deficiency increased. Our studies show that reductions in leaf physiological processes and plant growth did not occur until the petiole K concentration fell below 0.88% on a dry weight basis. These findings will be useful for interpreting plant analyses for a timely response with soil or foliar K applications before a pending deficiency could decrease growth or yield.

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Table 1. Mean seedcotton yields averaged for each year over 12 sites across the U.S. Cotton, 1991-1993.

Treatment	Seedcotton 1991	1992	1993	Mean
	----------	---------- kg/ha	----------	----------
Control	3421	3497	2569	3162
Low soil K*	3601	3609	2609	3273
High soil K	3654	3662	2668	3328
Low soil K + foliar K†	3661	3674	2709	3348
High soil K + foliar K	3589	3800	2666	3352

*Low soil K was according to soil test recommendations, and high soil K was twice soil test recommendations.

†The foliar rate was 10 lb KNO_3/acre in 10 gal water.

Table 2. The effect of soil- and foliar-applied potassium on cotton lint yield averaged over five locations in Arkansas 1989 to 1993.

Treatment	Lint yield*
	lb lint/acre
Control	988 a
Low soil-applied KCl†	1019 ab
High soil-applied KCl‡	1072 bc
Low soil-applied KCl + foliar-applied KNO_3§	1082 c
High soil-applied KCl + foliar-applied KNO_3	1087 c

*Numbers within a column followed by the same letter are not significantly different (P=0.05).

† 30 lb K/acre.

‡ 60 lb K/acre.

§ The foliar rate was 10 lb KNO_3/acre in 10 gal water.

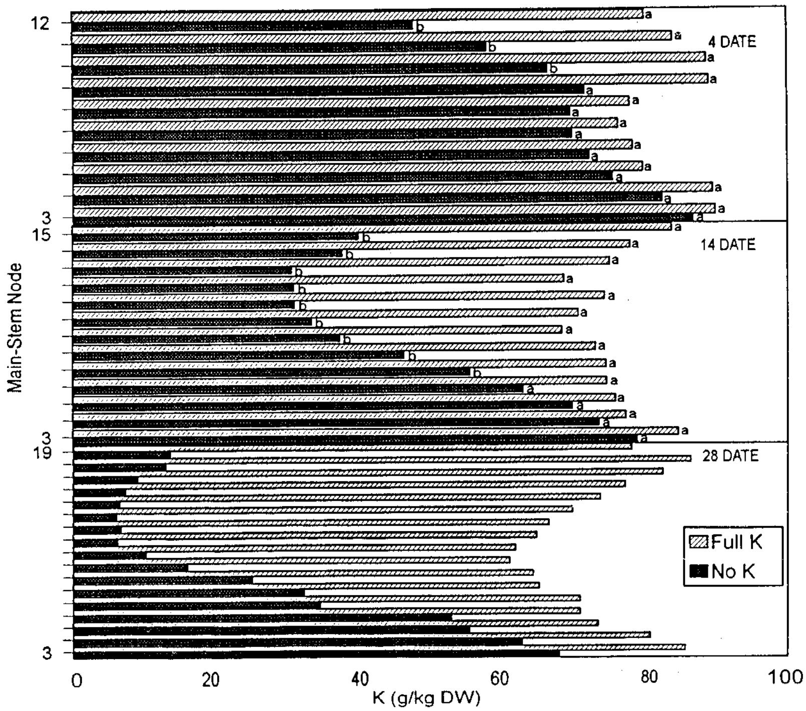

Fig. 1. Growthroom study of petiole K concentration at each main-stem nodal position at 4, 14 and 28 days after withholding K. Horizontal bars followed by the same letter within a day and main-stem node are not significantly different (P=0.05). Mean separations are not shown for day 28 sampling due to space limitations, but all observations were significantly different. (From Bednarz, 1995)

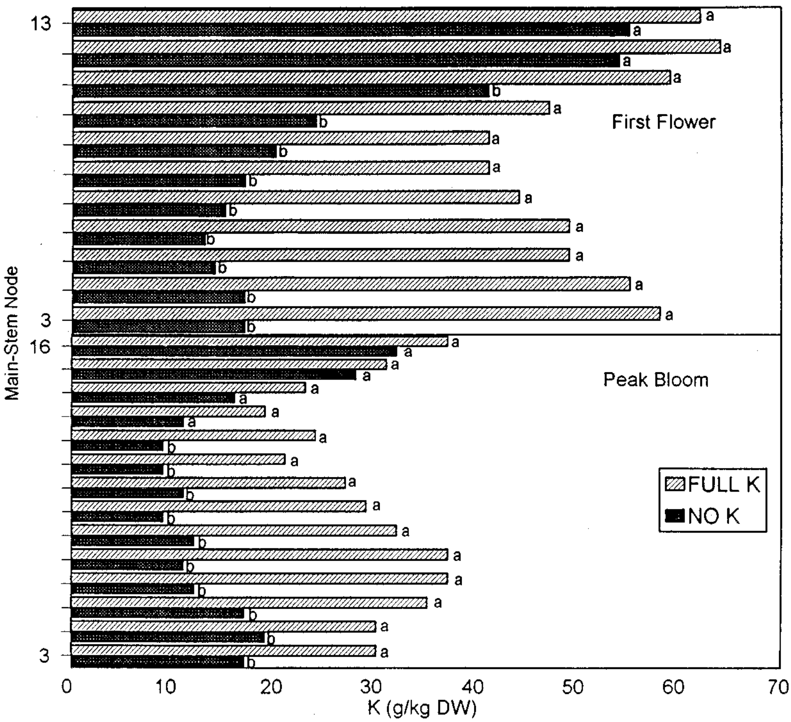

Fig. 2. Field study of petiole K concentration at each main-stem nodal position at first flower and peak bloom. Horizontal bars followed by the same letter within a day and mainstem node are not significantly different (*P*=0.05). (From Bednarz, 1995)

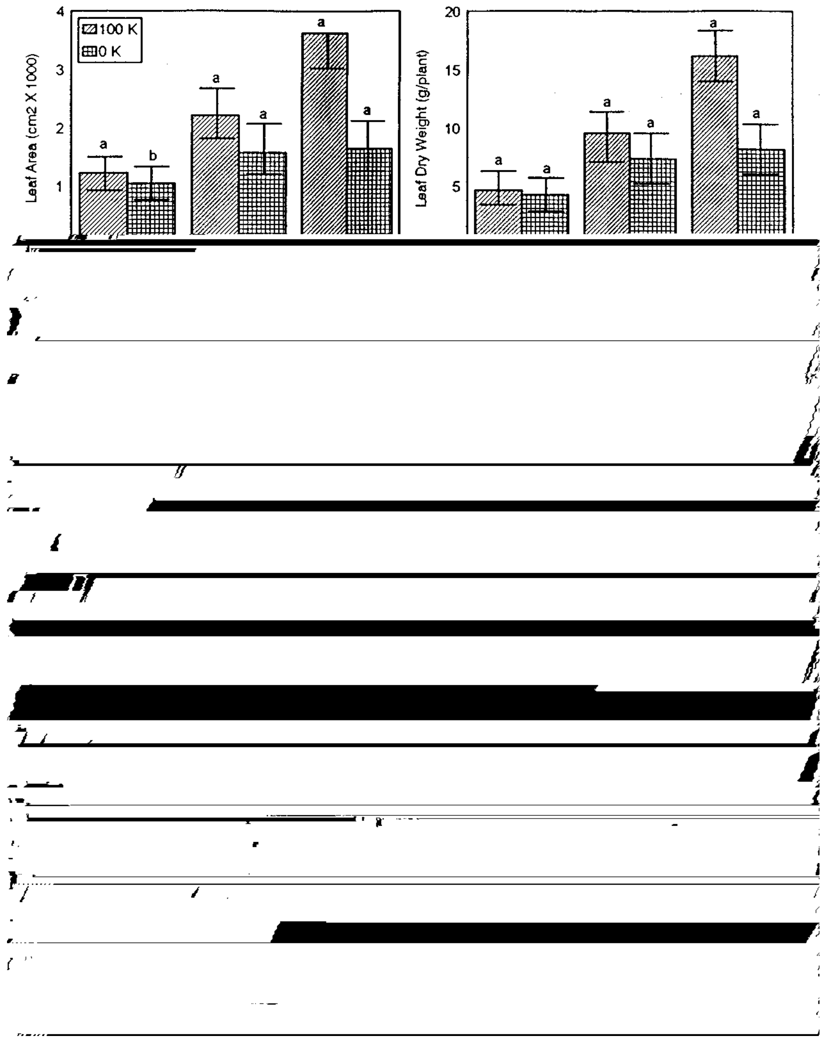

Fig. 3. Plant growth analysis results at 13, 19 and 26 days after withholding K from the K stress treatment. Vertical bars (± S.E.) followed by the same letter within a date and plant parameter are not significanlty different (*P*=0.05). (From Bednarz, 1995)

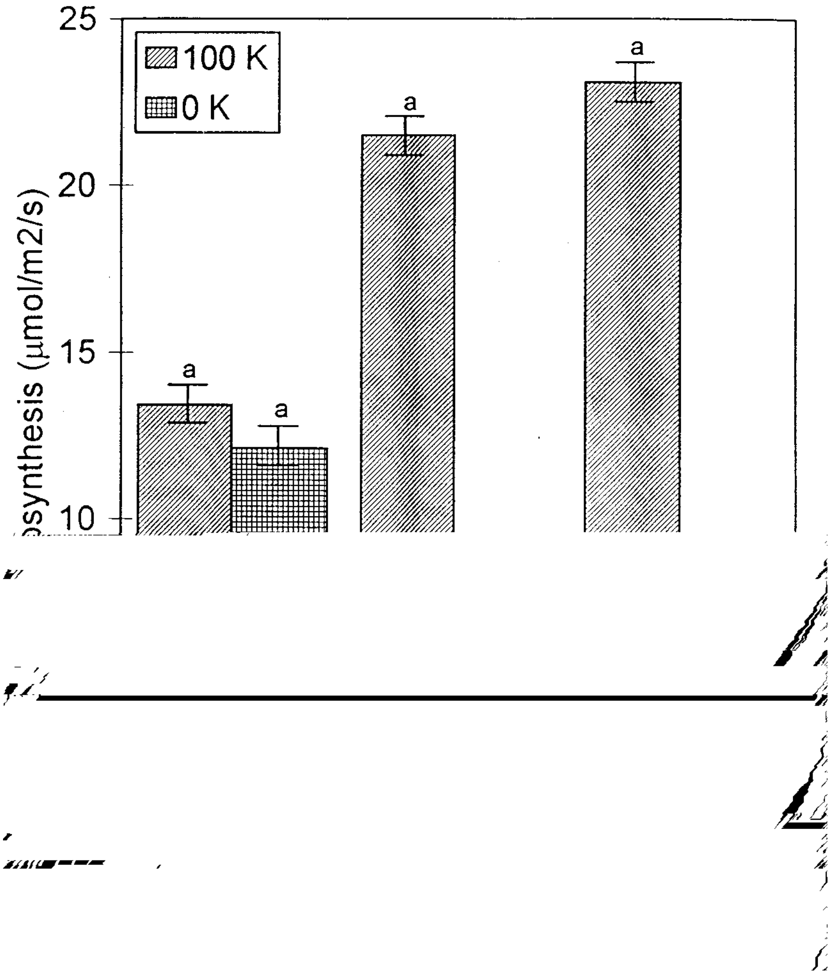

Fig. 4. Leaf photosynthesis at 13, 19 and 26 days after withholding K from the K stress treatment. Vertical bars (±S.E.) followed by the same letter within a date are not significantly different (*P*=0.05). (From Bednarz, 1995)

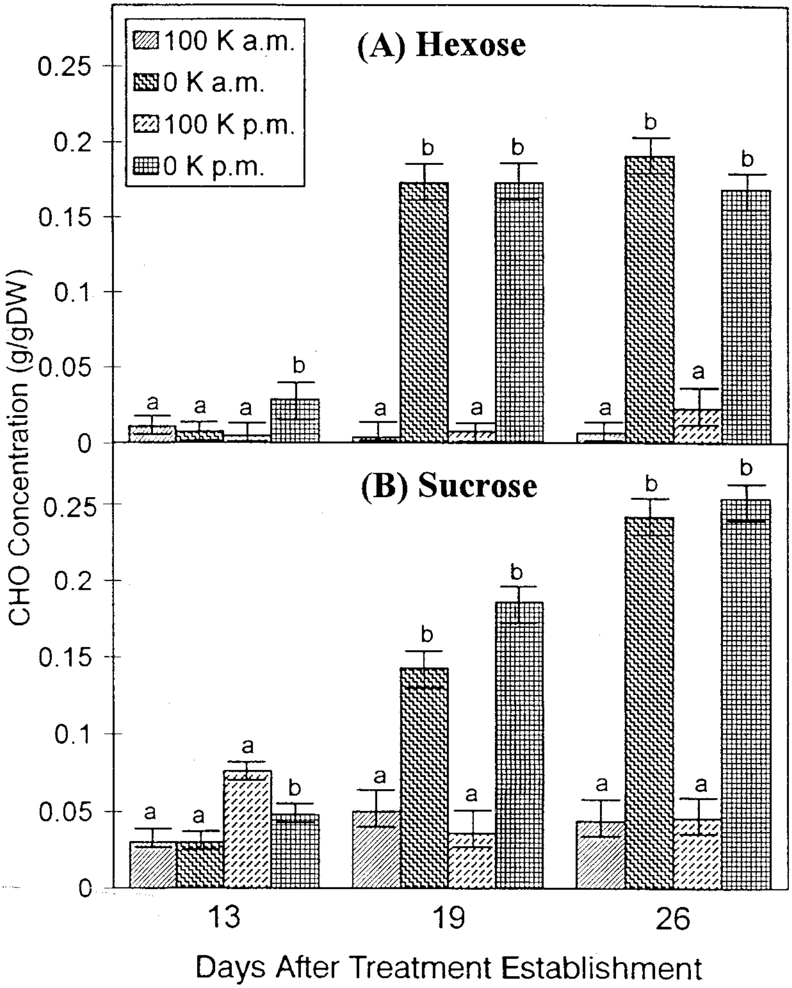

Fig. 5. Leaf hexose and sucrose concentrations at 13, 19 and 26 days after withholding K from the K stress treatment. Vertical bars (± S.E.) followed by the same letter within a date, sugar and time are not significantly different (*P*=0.05). (From Bednarz, 1995)

COTTON INSECT SITUATION IN SOUTHEASTERN ARKANSAS

Charles T. Allen[1]

INTRODUCTION

This paper is a status report of the cotton insect situation in southeastern Arkansas. The emphasis is on the current situation, but the opportunities and directions for future cotton integrated pest management systems are also discussed. The primary database is the 1996 Cotton Insect Loss Report, from the 1997 Beltwide Cotton Conference (Williams, 1997). The Cotton Insect Loss Report for Arkansas was compiled from surveys sent to cotton entomologists, county agents and consultants from across the cotton-growing areas of the state.

Cotton production and cotton pest management in Arkansas and across the Cotton Belt are in a state of transition. The price for cotton lint is increasingly free market driven, and producers must increasingly rely on their production and marketing skills to survive. In the pest management area, new chemical and bioengineered products are providing opportunities for growers to make fundamental and far-reaching changes. Boll weevil eradication provides growers with the opportunity to make still greater change a reality. In order to stay in business, cotton growers must quickly adapt to the changes and take advantage of the opportunities.

DISCUSSION

Insect Control Costs

Insect pests are a serious concern on cotton in Arkansas. The 1996 Cotton Insect Loss Report estimated the foliar insecticide costs per acre at $101.09 and $26.53 for southeastern Arkansas and northeastern Arkansas, respectively (Fig. 1). Growers farming the 400,000 acres in the southeastern part of the state put 3.8 times more dollars into foliar insecticide treatments (including application costs) than those farming the 600,000 acres in the northeastern Arkansas Delta. On foliar sprays alone, southeastern Arkansas cotton growers spent an estimated $40/acre on boll weevil control, $33/acre for bollworm and budworm control and $21/acre for plant bug control. In contrast, northeastern Arkansas cotton growers spent about $5.50/acre on boll weevil control, $13/acre on bollworm and budworm control and $4/acre on plant bug control. Figure 1 adequately defines the relative status of the various pests in the southeastern Arkansas production system. It is

[1]Extension Entomologist, Arkansas Cooperative Extension Service, Southeast District, Monticello, Arkansas.

clear that in southeastern Arkansas, the three primary pests are boll weevil, the bollworm/tobacco budworm complex and plant bugs (primarily the tarnished plant bug).

The total expenses for insect control are given in Fig. 2. In addition to the foliar sprays shown in Fig. 1, Fig. 2 shows the dollars spent (on a per-acre basis) in each region for Bt cotton technology and for at-planting soil insecticides. These additional expenditures brought the total insect control costs to $124.30 and $35.54 for southeastern and northeastern Arkansas, respectively. Total insect control costs were 3.5 times higher in southeastern Arkansas than in northeastern Arkansas.

Insect Losses

Insect loss estimates provide further insight concerning the relative status of insect pests and in Arkansas (Fig. 3). An estimated $89.44 was reported lost from all pests in the southeastern zone; $64.17 was reported lost in the northeastern zone. Losses reported in the southeastern zone were as follows: $33.91/acre to boll weevil, $26.25/acre to bollworm/budworm and $21.88/acre to plant bugs. In northeastern Arkansas, reported losses were $13.30/acre to boll weevil, $23.21/acre to the bollworm/budworm complex, $15.34/acre to plant bugs and $9.07/acre to thrips.

Figure 4 provides a comparison of the crop value and value of insect damage plus control costs in southeastern versus northeastern Arkansas in 1996. Although the sum of losses and control costs were over $113/acre higher in southeastern Arkansas as compared with northeastern Arkansas, cotton gross returns differed by only $32.20/acre. After out-of-pocket expenses associated with pest insect control were paid (not including consultant fees), $435.61/acre was returned to other expenses in southeastern Arkansas, and $492.26/acre was returned to other expenses in northeastern Arkansas. This represents a $56.65/acre advantage to producers in northeastern Arkansas.

Boll Weevil Eradication

The boll weevil eradication controversy is alive and well in Arkansas. The questions, “Can we eradicate?” “Should we eradicate?” and “How can we afford to eradicate?” continue to be asked. Figure 5 provides information estimating the treatment costs and dollar losses caused by boll weevil in 1996. In southeastern Arkansas, the combined losses and costs of boll weevil control had a value of $73.97/acre. For northeastern Arkansas, the combined costs plus losses were $18.86/acre. The differences in dollar impacts between the areas, $55.11/acre, are indicative of the poorer boll weevil habitat generally available in the northeastern delta of Arkansas. Furthermore, these impacts might be considered a “best-case scenario” due to the relatively harsh winter of 1995/1996. These data provide excellent support for the argument that boll weevil eradication must be undertaken as quickly as possible in the southeastern delta of Arkansas if cotton production is to remain competitive. Obviously, boll weevil eradication is a less-demanding concern in the northeastern delta, but even though the impact of the weevil was considerably lower in the northeastern delta, the overall impact of boll weevil there was an estimated $11,544,000 (cost plus loss) on these 600,000 acres of cotton in 1996. In the southeastern delta, 1996 costs plus losses were estimated to be $29,984,000. State-wide, the boll weevil in 1996 had a direct on-farm impact (without economic multipliers) of $41,528,000.

Cotton producers no longer have the price supports and other economic “safety nets” of the past. The free market economy is driven by competition. The economic rewards will go to those producers who can produce a pound of cotton most inexpensively. Recent history has proved that, in areas that have eradicated boll weevil, growers have seized the opportunities provided by weevil-free fields (higher yields and lower costs). In general, cotton acreage in eradicated states has increased more than five-fold. In states that have not yet eradicated the boll weevil, the industry has experienced declining cotton acreage and increased economic stress among growers as cotton acreage increases in the weevil-free area and cotton prices react to these increases. The stability of the cotton industry in Arkansas has already been affected. We can expect continued economic instability as long as we continue to compete with those areas of the Cotton Belt who no longer bear the costs and losses associated with boll weevil.

Bollworm/Budworm Complex

The 1996 cotton production season was unique in that we saw the first large-scale use of Bt transgenic cotton. Some 158,000 acres, 16% of the crop, was planted with Bt cotton in Arkansas. ‘NUCOTN 33b’ was, by far, the predominant variety planted. Over 95% of the Bt transgenic cotton planted was in southeastern Arkansas, and it was primarily used in fields that had been plagued by insecticide-resistant tobacco budworms. Tobacco budworm pressure in 1996 was abnormally light. Some experts believe Bt cotton played a part in the lower tobacco budworm populations experienced in 1996. Bollworm populations occurred on the Bt transgenic cotton. Bloom eggs and small worms were found previously in a few fields, but the populations disappeared within four to five days without causing any economic damage. More serious and widespread problems began occurring about peak bloom. At that time, bollworm moths were laying large numbers of eggs deep in the canopy at or just below the first position white bloom (in both Bt and non-Bt cotton). Worm survival may have been somewhat lower in Bt cotton than in untreated non-Bt cotton, but it was unacceptably high in some fields. Small boll damage levels reached as high as 25% of the bolls present in some fields. Bollworms survived in large numbers in a few fields in white blooms, in pink blooms, under stuck dried blooms and in small bolls. Growers learned that they could not ignore bollworm infestations deep within the cotton canopy with Bt cotton. They learned that these bollworm populations could be controlled fairly easily with pyrethroid insecticides. And they learned that the damaging bollworm populations were restricted only to the three to four weeks of peak bloom. Damaging bollworm infestations on Bt cotton did not occur before or after peak bloom.

In short, Bt cotton failed to live up to grower expectations with respect to bollworm control. However, it met all expectations in effectively removing tobacco budworm from Bt cotton fields. If it contributed to the very low tobacco budworm populations experienced throughout the region, as many think it did, the Bt cotton far exceeded what entomologists expected it to provide in tobacco budworm suppression.

A second major disappointment with the Bt transgenic cotton was the erratic agronomic characteristics of the most widely used variety, NUCOTN 33b. Although NUCOTN 33b generally grew and yielded satisfactorily on poorer land, it did not perform consistently on the good cotton land. It tended to grow excessively and required large amounts of mepiquat chloride to keep plants from excessive growth. Yields were highly erratic on the better cotton lands.

In 1997, at least one new bollworm/budworm insecticide will be available to Arkansas cotton growers. DowElanco's new insecticide, Tracer®, labeled in February 1997, will provide new and effective chemistry for worm control. Though most effective on tobacco budworm, Tracer also has good activity against bollworms and beet armyworms. Tracer supplies will be limited in 1997, but it and other new products that will soon be available will be instrumental in combination with transgenic cottons for worm control.

Seizing Opportunities and Technology

In 1997, Arkansas cotton producers have several new and exciting insect management technologies available that can improve the economic stability of the industry in this state. It is important that growers carefully consider these management options and choose wisely. The available technology provides an opportunity to eradicate boll weevil. It is providing new, highly effective controls for the caterpillar pests through new insecticides and transgenic plants. Looking to the future, if growers choose to take advantage of eradication opportunities and embrace the new worm control options, they will enjoy the advantages of farming cotton with much reduced concern about two of the three major cotton pest insects in the region. In the Extension component of my job, I will be working to help growers understand these programs and technologies and implement those components that will provide benefits. Since the technology to accomplish these goals is already available, my insect control/management research in southeastern Arkansas will have an implementation focus with respect to boll weevil and the bollworm/tobacco budworm complex. However, my research will have more of a discovery/development slant with respect to the increasing problem with insecticidally resistant populations of the tarnished plant bug.

Tarnished Plant Bug

As with the other major cotton pests, we have new technology and will soon have other new products available to help growers manage difficult populations of the tarnished plant bug. Provado® is a relatively new insecticide marketed by Bayer Corp. that is useful in plant bug management. Regent® (fipronyl) is another new insecticide in development by Rhone-Poulenc Ag. Co. that has good tarnished plant bug (and boll weevil) activity. However, neither these nor other products currently on the market provide outstanding or long residual control. Insecticide resistance and continual migration into fields from weedy turn-rows, roadsides and ditches make management of these pests challenging. In the insecticide arena, more information on efficacy, effects of insecticide treatments on beneficial arthropod populations and insecticide resistance management strategies is needed. In addition, more information about the build up of plant bug populations on non-cotton host plants, their movement to cotton, the damage capabilities of plant bugs after peak bloom and other biological/management is needed.

Extension education priorities with respect to the tarnished plant bug include developing and disseminating management information and resistance management plans and incorporating plant bug management strategies into overall crop management strategies.

Interdisciplinary Teams

Farmers grow crops by putting together information and technology from hundreds of sources. The nature of what they do is interdisciplinary.

Research and Extension work is organized along discipline lines. This organization has served us well. It has allowed us to carve small, solvable problems out of the production system and develop solutions. Practically all of our sucesses have come from this organization.

Today, the cotton industry in Arkansas is faced with increasing production costs coupled with yields and prices for cotton that are not increasing. The problems farmers face are interdisciplinary. They can be most quickly and effectively addressed by teams of research and Extension people working together on them. A commitment to this kind of organization of work has been, and is being, made among the research and Extention scientists in the University of Arkansas.

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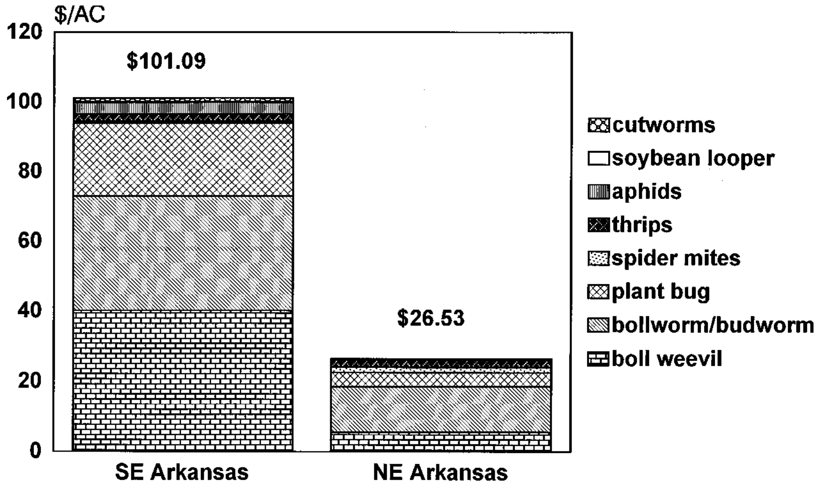

Fig. 1. Costs of foliar insecticide sprays in Arkansas in 1996.

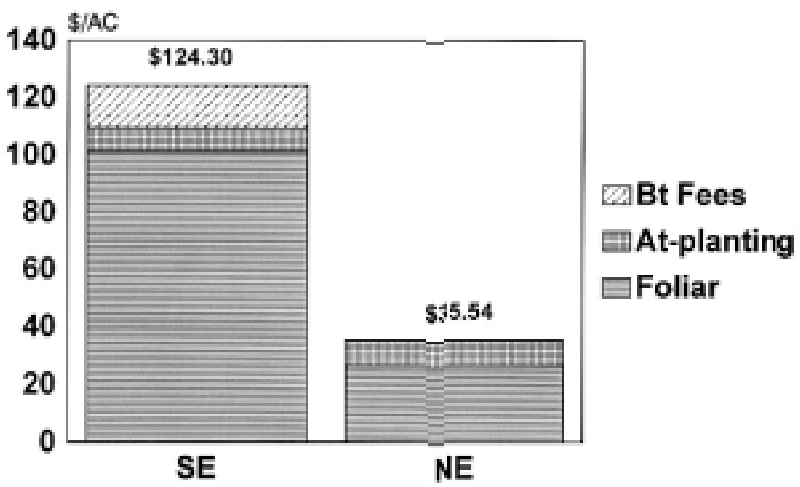

Fig. 2. Total costs for insect control technologies, 1996.

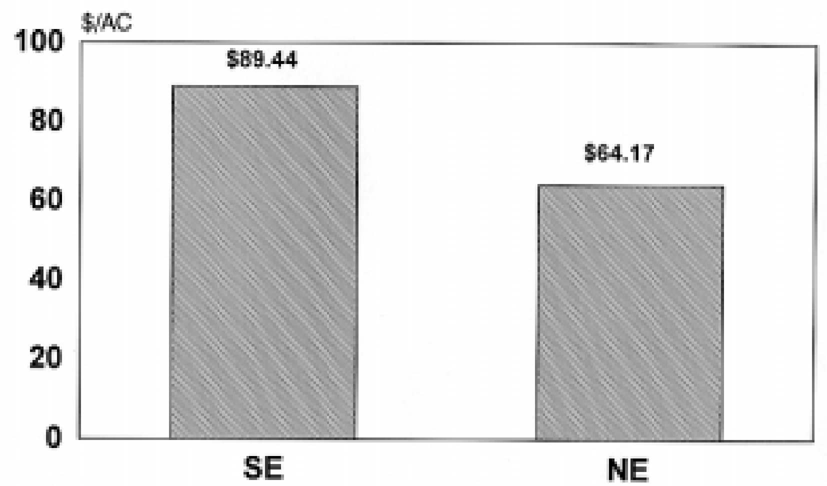

Fig. 3. The value of cotton lost despite treatment, 1996.

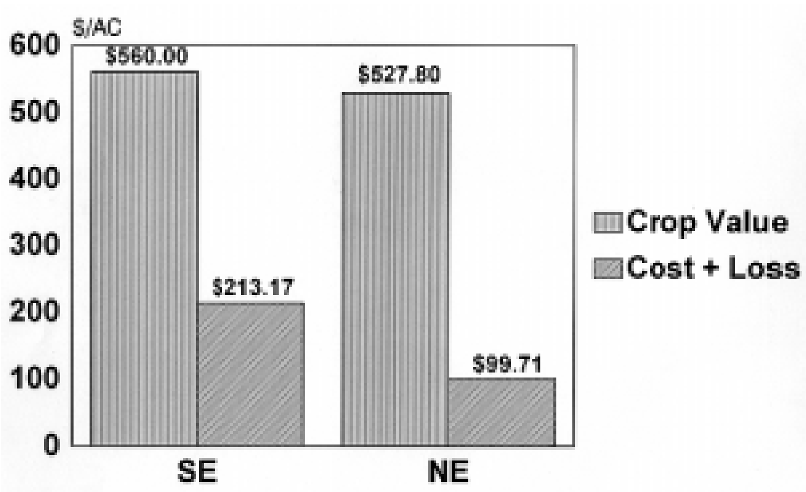

Fig. 4. Crop value versus combined costs of insect control and lost yield.

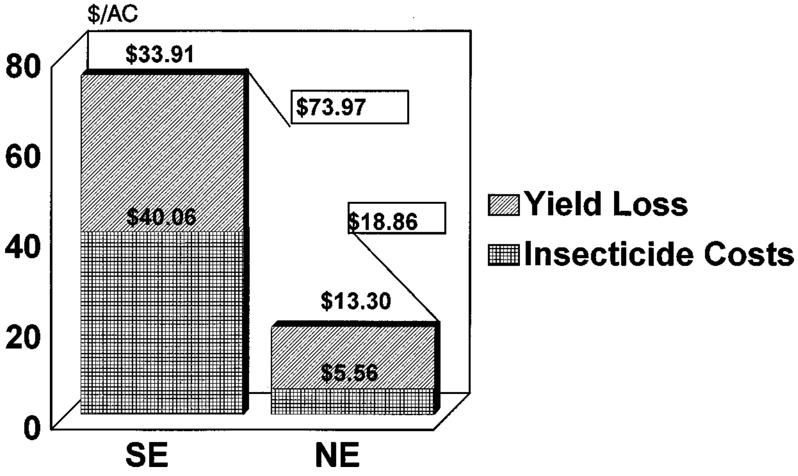

Fig. 5. Boll weevil control costs and yield losses, 1996.

WINTER AND BOLL WEEVILS: TEMPERATURES ASSOCIATED WITH DIFFERENT OVERWINTERING HABITATS

T.G. Teague and N.P. Tugwell[1]

INTRODUCTION

Survival of boll weevil through winter in the Mid-South is dependent on several fators, including the severity of the winter and the availability of overwintering habitat. Well-drained, wooded habitats with a dense ground cover of fallen leaves provide the greatest protection for overwintering in adults (Phrimer and Merkl, 1981; Slosser et al., 1984). Boll weevils also can overwinter in grassy areas or on ditch banks with few trees, but these habitats may lack the insulating capacity to protect the insects through severely cold winters. A greater understanding of how well overwintering habitats in Arkansas insulate weevils from extreme winter temperatures will increase our capacity to anticipate where weevils will be originating in the spring. This information is important for implementation of alternative boll weevil eradication tactics such as trap crops, border sprays, bait sticks and pheromone traps.

Boll weevils originally are from the tropics and are killed if ice crystals form in their tissues. Laboratory studies have shown that freezing occurs at around 28°F if there is water present and around 6°F in dry conditions (Sorenson and George, 1996). We monitored temperatures in northeastern Arkansas through the winter of 1995-96 and 1996-97 in a variety of different habitats to contrast ambient air temperatures with those temperatures to which boll weevils likely would be exposed in their overwintering quarters. Preliminary data from these studies were reported last year (Teague and Tugwell, 1996). Those data along with comparisons with 1997 measurements and 1996 pheromone trap catches are reported here.

MATERIALS AND METHODS

The study site was the edge of a dense, unmanaged patch of oak and elm trees on the Arkansas State University Research Farm in Jonesboro, Arkansas. Small, matchbox-sized temperature loggers inside waterproof canisters were used to monitor temperatures (Hobo Temp temperature logger, Onset Computer Corp., Pocasset, Massachusetts). Three temperature loggers were placed in different habitat types

[1]Associate Professor of Entomology, University of Arkansas, Agricultural Experiment Station, Arkansas State University, Jonesboro, Arkansas; and Professor of Entomology, Entomology Department, University of Arkansas, Fayetteville, Arkansas.

including 1) dense (4-in.) leaf litter under trees approximately 20 ft from the field margin, 2) tall, unmowed Bermudagrass, 3) mowed grass and 4) burned grass. For 1996-97, treatments were somewhat different and included 1) dense (4-in.) leaf litter, 2) 1.5-ft-high switch grass planted in 3-ft-wide strips through the field, 3) fence row in a continuous row of deciduous trees, heavy undergrowth and a 2-in. accumulation of litter and 4) the fence row with litter burned off just prior to study initiation. Temperature readings were made every 1.5 hours beginning in early November continuing through March and April for both years. Ambient air temperatures also were monitored with similar loggers located in standard weather station housing 3 ft above the ground.

Spring surveys following winter 1995-96 using pheromone traps were conducted in 24 fields in Craighead, Mississippi and Poinsett Counties in northeastern Arkansas. Each of the fields had either low- to medium- or high-quality overwintering habitat adjacent to one side of the field. The low- to medium-quality habitats generally were drainage ditches with light to medium herbacious undergrowth with few deciduous trees and light litter accumulation. Farmers and consultants familiar with these fields considered these areas to have low boll weevil pressure, meaning that spring trap catches rarely exceeded treatment thresholds for pinhead square applications. The fields associated with high-quality habitat were characterized by farmers and consultants as fields that required sprays every year for overwintered weevils. These fields had woodlots adjacent to them with deep litter accumulations or they occurred along the St. Francis River with its extensive levee system, tree border and deep litter accumulations. For each field there were five to six traps located between the overwintering habitat and the cotton field. Traps were surveyed weekly, and pheromone chips (10 mg) were changed every two weeks.

RESULTS AND DISCUSSION

Temperature data collected in different boll weevil overwintering habitats clearly show the different insulative capacity of each of the habitat types (Fig. 1 and 2). Differences in amplitude of temperature changes between the different habitat types and air temperature were similar in both years. Temperatures in deep litter in the coldest period of 1996 did not drop below 30.1°F, but temperatures in grassy areas and in mowed and burned grassy areas dropped as low as 14.1°, 6.6° and 3.9°, respectively. The lowest air temperature during this period was recorded as -2.1°F. Readings for the 24-hr period of the coldest period in the winter of 1996-97 indicate that minimum temperatures in the litter never fell below 31.9°F while minimum air temperatures were recorded at 4°F. Temperatures in the fence row and the grass did not drop below 27°F and 17°F, respectively.

Conditions in January and February in 1996 and 1997 were such that weevil mortality due to freezing would not have been high in areas with deep litter compared to more marginal habitats. The litter would have provided insulation to protect from cold temperatures. In 1997, there was snow and ice cover during the first three weeks of 1997 in the study site. This likely contributed to the insulating properties of each habitat type (Sorenson and House, 1995).

In 1996 pheromone trap catches from fields adjacent to high-quality habitat were 10- to 40-fold higher than those associated with low-quality habitats (Fig. 3). Other pheromone trapping data from northeastern Arkansas showed similar trends, indicating that the winter of 1995-96 severely impacted boll weevil overwintering survival, particularly in low-quality habitats (Yearian et al., 1997). Trap data indicate that weevil mortality was not as high in areas with deep leaf litter compared to grass habitats. The areas with deep, well-drained litter provided protection from cold temperatures.

Boll weevils can overwinter in a variety of habitats, but probability of surviving a moderate to severe winter in Arkansas is dependent on the drainage characteristics and the insulating capacity of the overwintering habitat. Our temperature monitoring program and trapping will continue as we work to make accurate qualitative and quantitative approasials of habitats required for successful overwinter survival by diapausing boll weevils. Additional data from drainage assessments and farmer/ consultant surveys also will be used to make these determinations. Information on habitat quality and boll weevil history will be used to link the appropriate supression tactic with the expected threat of weevils.

ACKNOWLEDGMENTS

This project was made possible through support from the Arkansas Cotton State Support Committee of Cotton Incorporated.

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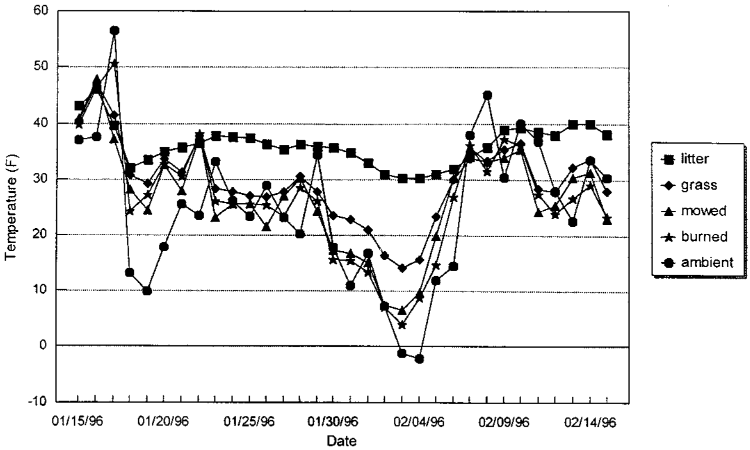

Fig. 1. Minimum daily temperatures observed in leaf litter, tall grass, mowed grass, burned grass and ambient air for January and February 1996 in Jonesboro, Arkansas.

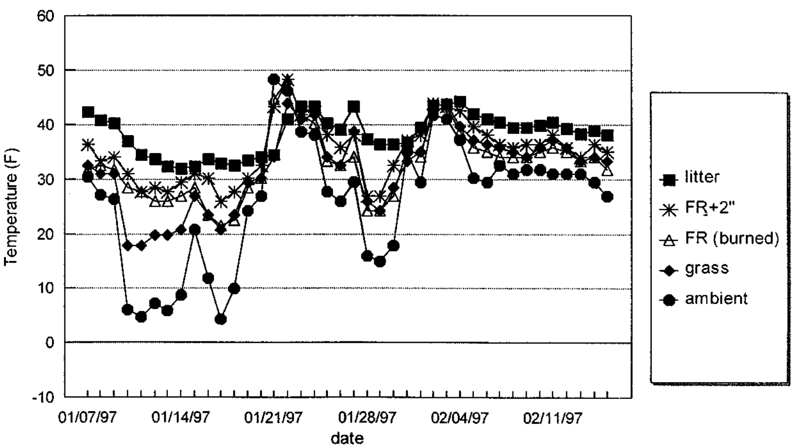

Fig. 2. Minimum daily temperatures observed in deep leaf litter, tall grass, fence row with tree line and light leaf litter, fence row with tree line and burned litter and ambient air for January and February 1997 in Jonesboro, Arkansas.

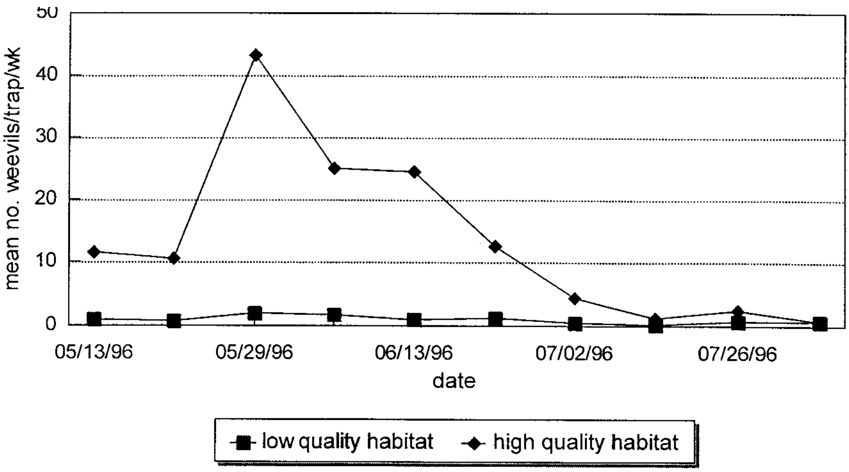

Fig. 3. Boll weevil pheromone trap catches from fields associated with "low-" and "high-" quality overwintering habitats in spring 1996 in Mississippi, Craighead and Poinsett Counties, Arkansas.

IRRIGATION AND TILLAGE RESEARCH AT THE UNIVERSITY OF ARKANSAS

J. Scott McConnell[1]

SCIENTISTS CONDUCTING IRRIGATION AND TILLAGE RESEARCH

Nine University of Arkansas, Agricultural Experiment Station scientists and Extension Service faculty conduct most of the research and producer educational programs in either irrigation or tillage technology for cotton.

- Fred M. Bourland. Agronomy Department, Fayetteville.
- Terry C. Keisling. Northeast Research and Extension Center, Keiser.
- Robert E. Frans (retired). Agronomy Department, Fayetteville.
- Marilyn McClelland. Agronomy Department, Fayetteville.
- J. Scott McConnell. Southeast Research and Extension Center, Monticello.
- Derrick M. Oosterhuis. Agronomy Department, Fayetteville.
- Craig S. Rothrock. Plant Pathology Department, Fayetteville.
- Phil L. Tacker. Cooperative Extension Service, Little Rock.
- Earl D. Vories. Northeast Research and Extension Center, Keiser.

IRRIGATION RESEARCH

Irrigation technology has increased dramatically in recent years. Advents such as overhead irrigation, polypipe, tensiometers and computer programs that mimic soil water content and crop requirement have made irrigation a viable economic option in producing cotton. Irrigation has been shown to increase yields and influence plant development.

Some recent results indicate that proper irrigation interacts with other production factors to alter the growth and yield of cotton. In long-term studies, nitrogen fertilization requirements have been found to be less under dryland conditions than under irrigated production conditions (Table 1). Varieties may respond differently to irrigation techniques and methods. Varietal yield response under dryland conditions was found to be non-significant some years, but significant differences may be observed with irrigation (Table 2). Irrigation was also found to impact on crop maturity in these studies (Table 3). At the Southeast Branch Ex-

[1]Associate Professor, Agronomy Department, Southeast Research and Extension Center, Monticello, Arkansas.

periment Station (SEBES), Rohwer, Arkansas, a conventional earliness response to irrigation was observed; as irrigation was delayed, open bolls increased. The test at the Northeast Research and Extension Center (NEREC), Keiser, Arkansas, was late in developing, and later irrigations were found to delay earliness.

Observations from the Arkansas cotton varieties tests tend to support the studies at SEBES and NEREC. Generally, late-maturing varieties are higher yielding under dryland conditions on clay soils. Presumably, the extra vegetative growth exhibited by late-maturing varieties increases their drought tolerance. Cotton grown on coarser-textured soils was found to behave differently. Timely rainfall on silt loam and coarser soils may produce lush growth even under dryland conditions. The same varieties tend to be high yielding whether irrigated or dryland on these soils.

The roles of physiological plant process in water utilization and drought tolerance of cotton are also being studied. Specific areas currently being investigated include:

- Root growth as a function of water stress;
- Characterization of drought tolerance;
- Potassium nutrition and water stress;
- Pix applications and water stress.

These topics will not be discussed in this overview.

COTTON IRRIGATION DEMONSTRATIONS AND APPLICATIONS

The University of Arkansas is providing irrigation technology to cotton producers. The Irrigation Scheduler Program estimates the soil water content, plant consumption and evaporation. Based on these estimates, irrigations are recommended for the cotton crop.

Demonstrations are underway to determine the viability of border irrigation in ultra-narrow-row cotton production. Border irrigation utilizes low berms that are built in the same direction as the slope of the field. A flush of water is released into the field and flows down hill within the berms.

TILLAGE RESEARCH

Tillage research for cotton being conducted by University of Arkansas faculty may be divide into two broad areas. The first area is deep or subsoil tillage. The second area is conservation tillage.

Subsoil or Deep Tillage

Few deep-tillage studies have been conducted, even though the presence of a plow pan has been shown to reduce yields and profits on two typical, coarse-textured cotton soils (Table 4). A yield reduction of as high as 40% was observed without subsoil tillage to shatter the plow pan.

More recently, research at NEREC indicates that cotton yields may be increased with subsoil tillage on fine-textured soils (Table 5). Although the presence of plow pans is very unlikely in clayey soils, water infiltration and storage may be enhanced by subsoil tillage of clay soils. All tillage implements and timings increased lint yield compared to the conventionally tilled control, although not all differences were significant.

Conservation Tillage

Cotton tends to be one of the more heavily tilled crops in the Mississippi River Delta. Tillage operations are used to prepare beds, incorporate fertilizers and herbicides and control weeds. Conservation tillage experiments conducted by University of Arkansas faculty have focused on reducing tillage in cotton and lowering soil losses to erosion. Protection of the soil from erosion has now become mandated by Federal law in soils classed as highly erodible.

Two recent studies have been conducted to determine the viability of cover crops in cotton production. A study conducted at SEBES determined that there was usually no significant yield reduction with conservation tillage. This was especially true under irrigated conditions. Wheat and rye covers were found to immobilize soil nitrogen and make it less available for crop uptake. Vetch, clover and native winter weeds as cover crops gave the highest yield and were not significantly different for any year of the study.

A combination of cover crops (wheat and clover) produced the greatest yields in a cover crops and tillage experiment at the Delta Branch Station (DBS) in Clarkedale. The two lowest-yielding cover crops were vetch and native winter weeds. Conventionally tilled cotton did not yield significantly less than cotton grown under conservation tillage.

A primary obstacle for producers in utilizing conservation tillage is weed control. Studies conducted at the Cotton Branch Station (CBS) in Marianna have concluded that early-spring and pre-plant burn-down herbicide treatments are required for cotton. Herbicides such as cyanazine (Bladex®) and oxyflourfen (Goal®) increased control of certain weeds. Further, like the other two studies, conservation tillage cotton yields were approximately equal to conventionally tilled cotton.

Table 1. Lint yield response of cotton to nitrogen (N) fertilization under irrigated and dryland conditions at the Southeast Branch Experiment Station, Rohwer, Arkansas during 1995.

	Lint Yield	
N-Rate	Furrow Irrigated	Dryland
lb N/acre	------------------------ lb lint/acre	---------------------------
0	995	663
30	1374	867
60	1436	911
90	1596	957
120	1531	825
$LSD_{(0.05)}$	185	133

Table 2. Lint yield of five cotton varieties grown under dryland conditions and irrigated anytime needed after emergence, first square and first flower at the Southeast Branch Experiment Station, Rohwer, Arkansas during 1996.

	Lint Yield			
Variety	Dryland	First Flower	First Square	After Emergence
	---------- lb lint/acre ----------			
Stoneville 474	841	1612	1530	1428
Stoneville 132	859	1424	1437	1483
Deltapine 20	828	1323	1344	1211
Stoneville LA 887	835	1377	1312	1302
Deltapine 5690	908	1358	1243	1169
$LSD_{(0.05)}$	NS	76	65	120

Table 3. Fraction of late-season open bolls (earliness estimation) of five cotton varieties grown under dryland conditions and irrigated anytime needed after emergence, first square and first flower at SEBES and NEREC* during 1996.

	Open Boll Fraction	
Irrigation	NEREC	SEREC
	---------- % ----------	
Dryland	86	92
Emerged	78	85
First Square	72	88
First Flower	69	89
$LSD_{(0.05)}$	9	3

*SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.

Table 4. Yield response of cotton grown on two silt loam soils with plow pans to spring subsoil tillage in Ashley County, Arkansas, in 1986.

Soil Series	Tillage	Yield	Return
		lb lint/acre	$/acre
Rilla	Subsoil	890	164
Rilla	Non-Subsoil	558	--
Hebert	Subsoil	752	150
Hebert	Non-Subsoil	446	--
$LSD_{(0.05)}$		75	

Table 5. Cotton yield response to subsoil tillage methods on a clay soil at the Northeast Research and Extension Center at Keiser, Arkansas, during 1994 and 1995 (two-year mean).

Subsoil tillage Implement	Manufacturer	Timing	Yield
			lb lint/acre
Ripper-Hipper	W&A	Spring	681
Ripper-Hipper	W&A	Fall	665
Paratill	Tye Inc.	Fall	661
Tiger Point	DMI	Fall	654
None (Conventional)	--	--	629
$LSD_{(0.05)}$			33

WHAT HAPPENED IN 1996

W.C. Robertson[1]

This year a little more stability was seen in cotton production in Arkansas. Since 1992 we have ridden a rollercoster ride of yields with record highs in 1992 and 1994 and near-record lows in 1993 and 1995. Yields in 1996 are currently projected at 776 lb/acre, about 50 lb greater than our five-year average. The brighter points of this year included reasonably good prices for cotton and a reduction in production cost, primarily from reduced insecticide use.

We got off to a good start with most fields planted statewide by 10 May. Because of a cold front that passed through the state after 10 May, the earlier-planted cotton seemed to fare better all season. Flooding and hail reduced the 1,000,000 planted acres to a harvested acreage of 990,000. We experienced many days early spring in which wind speeds were high. Most fields exhibited some degree of early-season stress, due in part to the windy conditions. I visited fields that exhibited symptomology from every herbicide used in that field and in neighbor's fields downwind. Activity of most preemerge compounds was high. We also experienced more response to some of the over-the-top herbicides than we expected.

Acreage in Arkansas is fairly evenly divided between north and south with the southern part of the state having slightly more acreage. The Bollgard variety 'DPL NuCOTN 33B' was planted on about 160,000 acres and was located almost exclusively in the southern half of the state. By early bloom, July 4th for many, the irrigation systems were in full force. For the most part, those who waited till flowering to initiate irrigation lost yield. Generally at this point, fruit set was good, and insect pressures were light.

The previous winter appeared to have an impact on boll weevil populations with many areas requiring only strip treatments along areas adjacent to the most favorable overwintering habitat. Strip treatment for weevil resulted in high levels of beneficials occurring in most fields. Aphids were generally not a problem with the exception of some weevil-treated strips. By mid-July, cotton bollworm numbers were building, and within days they were causing concern in conventional and Bt varieties. In some areas of the state, Bt cotton received numerous bollworm treatments; in other areas none were needed. Tobacco budworm populations never reached predicted levels.

[1]Extension Agronomist - Cotton, University of Arkansas Cooperative Extension Service, Little Rock, Arkansas.

Rainfall and cooler temperatures were abundant as July departed and August arrived. At this point most areas of the state were almost two weeks ahead of schedule; however, this soon faded, particularly for those in southeastern Arkansas, with numerous rain showers and boll rot "inching up the plant" with each rain. Boll rot occurred in every corner of the state in which cotton was produced but was most prevalent in southeastern and southwestern Arkansas. Boll weevil and especially plant bug numbers increased toward the end of the season.

The wet conditions and high insect numbers late in the season resulted in many fields with "buggy whips" or "lighting rods." By the end of August and first of September, a great deal of hope and optimism was evident for some growers while for others the harvest would be only average. Near-record yield projections were forecast statewide but declined to just better than average in September and October.

Fiber quality of Arkansas cotton was good with 79.7% of the crop tenderable. The average staple was 35, and micronaire was 4.5 with only 1.8% and 12.5% of the crop discounted for low or high micronaire, respectively. Approximately 42% of the crop received a color grade of 31 or higher with an additional 35% receiving a color grade of 41. Approximately 20% of the crop was Light Spotted.

EFFECT OF TEMPERATURE EXTREMES ON COTTON YIELDS IN ARKANSAS

Derrick M. Oosterhuis[1]

INTRODUCTION

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). Furthermore, the past five years have provided extreme year-to-year variability in yields, which is a major point of concern with cotton producers. Two out of the past four seasons (1993 and 1995) have been extremely disappointing with unusually low yields. The 1995 crop was one of the poorest in Arkansas in recent history, and much of this was related to extreme weather conditions and insect infestations late season (Oosterhuis, 1996). Generally, the cotton crops each year appear to have good potential at mid-season, 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. In 1993, the extremely low yields were associated with a series of stresses, including unfavorable planting conditions, poor root growth, insects, periods of drought and high temperatures that never allowed the crop to fully recover or to develop to its optimum capacity (Oosterhuis, 1995). In 1995, the extremely low yields appear to have been mainly associated with unusually high insect pressures (Robertson et. al., 1996) and the development of the boll load during an exceptionally hot, dry August (Oosterhuis, 1996).

Long-term Weather Pattern

The 40-year average, long-term weather pattern for Rohwer, Arkansas, is presented in Fig. 2. Maximum temperature climbed from the mid 70s at the beginning of May to a maximum of about 93°F in mid-July, and then declined slowly late in the season. The pattern for minimum temperatures was similar but about 20 degrees lower.

Yields and High Temperatures

Although cotton originates from hot climates, it does not necessarily grow best at excessively high temperatures. There is a strong correlation between yield and temperature in August, with high temperatures being associated with lower yield,

[1]Crop Physiologist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

and low maximum temperatures being associated with higher yields (Fig. 3). This correlation was strongest in August but also applied to a lesser extent in July.

Effect of the Hot, Dry Period During Boll Development

Reddy et al. (1991) reported that the ideal temperature range for cotton was from 68 to 86°F. 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 74-90°F with the optimum for photosynthesis of 82°F (Burke et al., 1988). Average daily maximum temperatures in August in Arkansas are always at or above 90°F, above the optimum for photosynthesis.

High, above-average, temperatures during the day can decrease photosynthesis and carbohydrate production. Hot *night* temperatures increase respiration and photorespiration with an additional loss in carbohydrates. The overall result is that there will not be enough carbohydrate produced to satisfy all the plant's needs. This was reflected in 1995 in increased boll shedding, smaller boll size and decreased lint percentage. This situation was particularly evident with full season varieties and in late-planted cotton. This will be particularly important in August when the boll load is in its maximum (exponential) phase of development. Cotton fiber consists predominantly of carbohydrate. A decreased availability of carbohydrate can also be manifested in a lower gin turnout. Under normal conditions cotton seed, properly fertilized with adequate water, produce about 12,000-21,000 fibers per seed. High temperatures and decreased carbohydrate can reduce the number of fibers per seed, as well as the boll size. This was the situation in Arkansas in 1995.

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, the stomates, on the leaves. These stomates are also important for permitting the entry of carbon dioxide for photosynthesis. When water is available to the plant, the evaporative process 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 for boll growth. 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 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.

It is worth mentioning that when we calculate heat units (maximum + minimum temperature, divided by two, minus the base temperature of 60° F), we take the lower threshold temperature for growth of 60°F into consideration, but 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. Research is needed in Arkansas to address this.

Insect Pressures

Insect infestations, particularly in southeastern Arkansas, have been unusually high in recent years with an increased number of sprays needed, resulting in higher production costs. This is an important impediment to high yields and profits and has been addressed by Robertson et al. (1996).

CONCLUSIONS AND REMEDIES

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

There is no obvious immediate remedy to the problems associated with high temperature. However, genetic selection for varieties more tolerant to high temperatures during boll development, possibly through less temperature sensitivity of photosynthesis or carbohydrate translocation, may be one solution. As far as management goes, attention should focus on producing an early crop (e.g., effective and timely insect and weed control, attention to water availability and judicious fertility) to ensure a decent crop. Use of the new crop monitoring techniques, e.g., COTMAN (Cochran et al., 1996) to follow square and boll dynamics should also help to ensure timely management inputs and an early crop. Plant growth regulators should be used to enhance early fruit set and early maturity e.g., PIX (Oosterhuis et al., 1991). Also there is some recent evidence that PGR-IV may help under a *mild* stress (Zhao and Oosterhuis, 1994) through improved translocation of carbohydrates to the developing bolls. However, in spite of best management efforts, the occurrence of untimely and severe weather and insect attacks can still adversely affect cotton growth and yield.

ACKNOWLEDGMENT

My thanks to Adele Steger for help in compiling and plotting the yield and temperature data.

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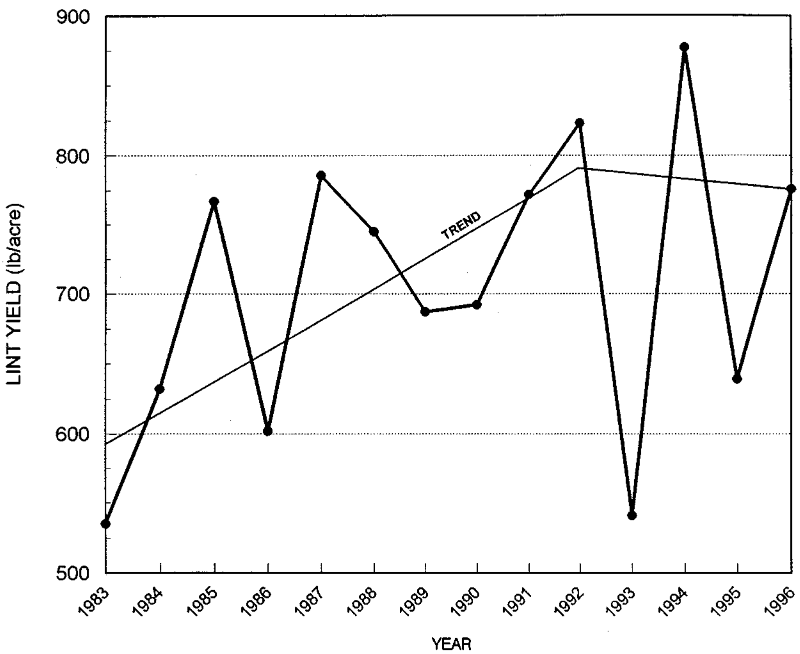

Fig. 1. Cotton lint yield in Arkansas 1983 to 1996.

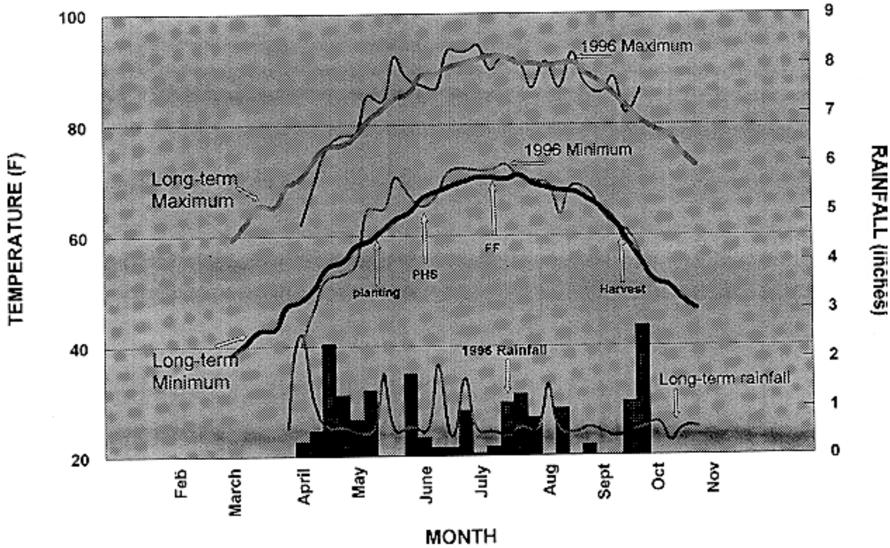

Fig. 2. Maximum and minimum temperatures for the 1996 growing season compared to the forty-year averages for Rohwer, southeastren Arkansas.

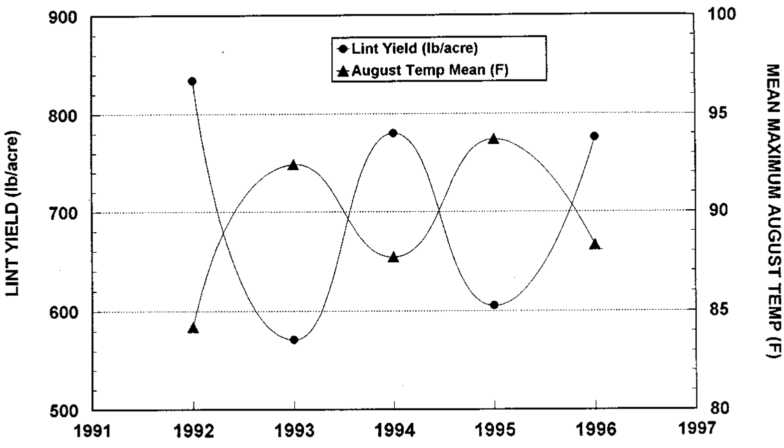

Fig. 3. Inverse relation between the mean state yield 1992 to 1996 and mean maximum temperatures in August.

1997 SUMMARIES OF COTTON RESEARCH IN PROGRESS

ADVANCES IN THE ARKANSAS COTTON BREEDING PROGRAM, 1996

F.M. Bourland[1]

RESEARCH PROBLEM

Development of new, well-adapted genotypes is essential to the success of the cotton industry in Arkansas. With emphasis on the development of transgenic cotton genotypes by private industry, the rate of genetic improvement for agronomic traits has lessened (Meredith et al., 1997). Public breeding programs are needed to develop, evaluate and provide new sources of cotton genotypes.

BACKGROUND INFORMATION

Research in cotton breeding was initiated at the University of Arkansas in the 1920s and has continued with an emphasis on the development of host plant resistance (Bourland and Waddle, 1988). The current cotton breeding program began in 1988 (Bourland, 1988), and an update of the program was given in 1996 (Bourland, 1996).

RESEARCH DESCRIPTION

In 1996, cotton breeding lines were evaluated at five research stations in Arkansas and at one site in Arizona (Table 1). In addition, selected advanced lines were evaluated at multiple sites across the Cotton Belt in the Regional High Quality Strain and Regional Short Season Strain Tests. The breeding program consists of a stepwise progression from initial crosses to the release of germplasm and cultivars.

Performance, in terms of response to pests and environmental problems, is used to select/discard genotypes in all stages of the breeding program. Routine screens and selection criteria include:

- Resistance to seed deterioration. F_2 seed are hot-water treated and planted, and the most vigorous seedlings are selected. New and Advanced strains are evaluated to determine progress for increased resistance to seed deterioration and the relative permeability of their seed coats.
- Resistance to bacterial blight. The selected, vigorous F_2 seedlings are inoculated with multiple races of *Xanthomonus campestris* pv. *malvacearum*. All susceptible plants are discarded. Resistance is confirmed in progenies.

[1]Plant Breeder, University of Arkansas, Fayetteville, Arkansas.

- Morphological traits. Bacterial blight-resistant F_2 seedlings are evaluated for morphological traits, and ones possessing undesired traits are discarded. Traits are confirmed in all subsequent generations.
- Visual performance. Progenies are selected for maturity and agronomic appearance.
- Resistance to Fusarium wilt. Selected Advanced Strains are evaluated for resistance to Fusarium wilt in the Regional Test at Tallassee, Alabama.
- Resistance to tarnished plant bug (TPB). New and Advanced Strains are seeded at Fayetteville with no in-furrow insecticide and with mustard seeded in alleys to encourage TPB populations. Anther damage, maturity and performance ratings are used to assess TPB injury.
- Heat resistance. Advanced Strains are evaluated for yield in Arizona to provide insight on their tolerance to heat.
- Yield. Consistent yield over contrasting environments (wide adaptability) is a major selection criteria throughout the program. Yield is determined by machine harvesting in all strain tests.
- Maturity. Relative maturity is determined by visually estimating percentage of open bolls prior to defoliation in all tests.
- Fiber quality. Fiber quality is determined by a breeders' fiber test for all selected progenies and by HVI for entries in all strain tests. Consistent, superior fiber quality over generations is required for strains to be kept in the program.

Final selection within each generation is subjective, with priority given to high yield (and yield stability), improved fiber quality and early maturity.

RESULTS AND DISCUSSION

Ninety of the 139 strains that were evaluated at multiple locations in 1996 were discarded (Table 1). Of the 49 strains that were kept, 40 will be evaluated again in 1997, and nine will be considered for release as germplasm lines. The primary reasons for discarding strains were inconsistent or low yields and/or undesirable fiber quality. Eight-four of the 949 progenies in 1996 will be evaluated as preliminary strains in 1997. The primary reasons for discarding progenies included susceptibility to bacterial blight and/or tarnished plant bugs, morphological traits, less-than-optimum fiber quality, late maturity and poor visual performance.

Visually superior, individual plants were selected from seed increase plots of seven F_5 strains, which had previously had only one selection cycle (Table 1). Individual plants were selected from F_2 and F_3 populations on the basis of resistance to seed deterioration, resistance to bacterial blight, morphological traits and visual appearance. The selections from strains and F_3 populations will be evaluated as advanced progenies in 1997 at multiple locations. The selections from F_2 populations will be evaluated at one location in 1997, with superior progenies evaluated at multiple locations in 1998.

The F_1 populations were from 1995 crosses of superior strains, most of which are now advanced strains. Most of the crosses made in 1996 included one nectariless parent and at least one smooth leaf parent. A primary goal of these crosses is to develop well-adapted superior genotypes that possess improved resistance to tarnished plant bug.

PRACTICAL APPLICATION

The proportion of discarded genotypes indicates the selection pressure that is being placed upon each generation. The breeding program depends upon the development and use of experimental procedures, which will identify genotypes that provide host plant resistance and are highly adapted to the cotton growing environments of Arkansas. Continued success of the Arkansas cotton industry is insured by the development and release of these genotypes.

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Table 1. Number of breeding lines associated with the University of Arkansas Cotton Breeding Program in 1996.

		Number of breeding lines		
Test description	Locations*	Tested	Kept or released	
Germplasm Release Strain Test, S7	KCMRF	19	13	advanced strains
Advanced Strain Test, S6	KCMRF AZ	18	12	advanced strains
New Strain Test, S5	KCMRF	24	10	advanced strains
Preliminary Strain Tests, S1, S2, S3	MR	78	24	new strains
Re-selected progeny evaluation, Be	CF	470	48	preliminary strains
Progeny evaluation, Be	CF	479	36	preliminary strains
F_5 Strains re-selected	R	7	140	plant selections
F_3 populations	R	16	222	plant selections
F_2 populations	R	24	609	plant selections
F_1 populations	R	14	14	populations
Crosses	R	36	36	populations

*Breeding material was evaluated on Arkansas research stations near Keiser (K), Clarkedale (C), Marianna (M), Rohwer (R) and Fayetteville (F), and at one site in Arizona (AZ).

GROWING PROFITABLE COTTON: THE 1996 CRVT PROGRAM

D.E. Plunkett, K.J. Bryant and W.C. Robertson[1]

RESEARCH PROBLEM

The Cotton Research Verification Trials (CRVT) have been conducted since 1980 by the Cooperative Extension Service, University of Arkansas. The program is designed to take research-based recommendations to Arkansas cotton producers in an effort to make profitable crops. The program also aims to provide cotton expertise to county Extension agents. The information gained through the program is also useful in county and state educational programs. Profitability is determined by production practices, direct expenses, fixed expenses and yield data, which are then processed by computer by means of a budget generator.

BACKGROUND INFORMATION

Nine irrigated fields and one dryland production field were in the 1996 CRVT program. Fields were located in nine counties in Arkansas located from Lake Village (Chicot County) to Mounds (Greene County). All fields were enrolled by the cooperator in the Cotton Nutrient Monitoring (CNM) program. Each irrigated field was entered by the county Extension agent into the computerized Irrigation Scheduling Program. Herbicide programs for each field were determined based on weed species normally encountered, as well as by weed species and pressure found in the field after planting. Variety selection was determined by the grower with Extension agent and/or CRVT coordinator guidance toward high-yielding varieties with a proven history. A transgenic Bt cotton (Deltapine 'NuCOTN 33B') was used in three fields while conventional varieties were used in the seven other fields. Fertility programs were determined by routine soil test recommendations based on samples taken in the fall, winter or spring prior to planting. Subsoil nitrate soil tests in the spring allowed refinement of soil-applied nitrogen (N) in almost all fields.

RESEARCH DESCRIPTION

Each CRVT field was monitored twice weekly during the growing period by the designated county Extension agent and once weekly by the CRVT coordinator. Fields were monitored at least once weekly for irrigation needs, and petiole samples

[1]Cotton Verification Coordinator, Farm Mangement Specialist and Extension Agronomist-Cotton, Cooperative Extension Service, University of Arkansas, Little Rock.

were pulled once weekly for analysis through the CNM program. When the analysis called for foliar N, CRVT cooperators applied a foliar material (normally with an insecticide application if also called for). Insect counts, as well as plant monitoring information, were collected twice weekly during each field visit. When insect pressure met Extension economic threshold levels for any given field, treatment was called for with an appropriate insecticide. Weed pressure was similarly treated. Plant growth regulators were used when needed to shorten cotton plants as determined by height-to-node ratio, or average length of the top five (ALT5) internodes. Growth enhancing plant growth regulators were used if called for in the COTMAN (COTton MANagement) pilot project, available from the University of Arkansas.

RESULTS AND DISCUSSION

Nine of the 10 CRVT fields in the 1996 CRVT program showed a positive economic advantage and profit potential, including the one dryland field (Table 1). The average breakeven price needed to cover all specified expenses for the ten CRVT fields was $0.44/lb of lint. If a land charge (rent) was added (assuming a crop share of 25%), the breakeven price totalled $0.59/lb of lint across all fields. The one unprofitable field had a low yield due to delayed irrigation, overwatering and prolonged saturation of soil caused by frequent rainfall in July and August. This field would have required $0.94/lb of lint to breakeven if a land charge was added in.

Insect pressure was lighter than that experienced in 1995 and lighter than normal for the average of years. In 1996, Gaucho seed treatment was used in three fields for thrips suppression. An application of an in-furrow insecticide was used in the remaining seven fields. Boll weevil numbers were lower in the spring than normal, as determined through boll weevil pheromone trapping. However, both Jefferson County fields had heavy in-season pressure after two spring suppression insecticide applications. Cotton boll worm and tobacco budworm (CBW/TBW) pressure was much lighter than in 1995. The Jackson County field required the most CBW treatments, possibly due to nearby corn production.

Excess soil N was found in most of the 1996 CRVT fields. Subsoil nitrate levels allowed for lower soil-applied N with an average of 67 lb N/acre applied as a sidedress/topdress for all fields. This refinement was offset to some degree with foliar N applications as a result of N deficiency found through petiole analysis. Where found, N deficiency analysis followed an irrigation or was found after frequent high rainfall amounts occurred on fields. Total N averaged 101 lb/acre for all fields with 14 lb N applied before or at planting.

Weed control was made somewhat easier in a few fields through use of the new over-the-top herbicide Staple. Banding this material greatly reduced the cost of application. Use of a two-nozzle spray rig was more effective in weed control/suppression in 1996 CRVT fields than was the one-nozzle over-the-row approach.

The COTMAN computer program was used as a guide in crop termination—both for insects and for defoliation. Most field insecticide applications were terminated when the field reached cut-out plus 350 heat units (H.U.). Nodes above white flower equals five (NAWF = 5) was the basis for determining cut-out on seven of the fields. The three fields that were determined through COTMAN to be late were placed under the weather-oriented rules of COTMAN. Heat unit accumulations for the late fields were based on the latest possible cut-out date (LPCD) for the area in which they were grown.

Defoliation in each field was based on the grower's defoliation and picking schedule. Recommendations for defoliation were determined by boll slicing, nodes above cracked bolls (NACB) counts and heat unit accumulations of 850 H.U. beyond NAWF = 5. Recommended defoliation materials were chosen on a field-by-field basis; most fields had excessive growth and required a two-shot defoliation approach. Applications of boll opening rates of ethephon were made with the first defoliation on five fields.

Harvest was initiated 23 September in the Jefferson-North and Lee CRVT fields. Each was stopped by rainfall, but completion of the first harvest was finished 25 September 1997 in both fields. All other fields began harvest in October. Once-over harvest was accomplished in Crittenden, Greene, Lee, Monroe and Poinsett CRVT fields. All other fields required a second pick.

PRACTICAL APPLICATION

By using Extension's research-based cotton production recommendations, a profitable yield can be attained when costs are figured on a production unit basis, i.e., cost per pound of lint. High costs of inputs can be decreased by banding pesticides rather than broadcast applications. Reduced trips across fields can decrease cost of production. Using low rates of products can reduce production costs as well.

Use of subsoil nitrate testing can allow for reductions in total fertilizer input cost for nitrogen. Manipulating the N rate can also allow growers to reduce the amount of plant growth regulators needed to reduce plant height. Heavy irrigations or rainfall can cause N deficiency to occur and increase the cost of foliar N applications.

Use of the COTMAN computer program can provide quick analysis of cotton plants and allow for fast response to early-season insects, water needs or fertility needs. Observation of the plant height-to-node ratio can allow timely application of plant growth regulators. COTMAN observations can be used to aid in crop termination and reduce late-season input costs.

Table 1. Cost of production, 1996 CRVT fields.

County	Total Direct Expenses	Total Fixed Expenses	Total Specified Expenses	Breakeven Price Over Direct Expenses	Breakeven Price Over Total Expenses	Breakeven Price Over Total Exp. and Rent*
Chicot	310.07	74.27	384.34	0.32	0.39	0.52
Crittenden	322.78	33.83	356.61	0.33	0.36	0.48
Greene	264.83	105.17	370.00	0.31	0.44	0.58
Jackson	343.54	85.18	428.72	0.33	0.41	0.55
Jefferson-North	374.16	88.80	462.96	0.57	0.70	0.94
Jefferson-South	309.46	86.13	395.59	0.33	0.42	0.56
Lee	310.31	61.89	372.20	0.35	0.42	0.56
Monroe	280.60	65.19	345.79	0.35	0.43	0.57
Phillips	297.99	74.24	372.23	0.35	0.44	0.59
Poinsett	336.86	92.83	429.69	0.35	0.44	0.59
Average	310.87	81.96	392.83	0.35	0.44	0.59

*Rent is expressed as a 25% crop share. This does not imply that this is the agreement by which any field is actually rented.

EFFECT OF FOLIAR-APPLIED NUTRIENTS ON SQUARE DEVELOPMENT OF COTTON

J.K. Keino, C.A. Beyrouty, E.E. Gbur and D.M. Oosterhuis[1]

RESEARCH PROBLEM

The study was conducted to evaluate the influence of different foliar-applied salts on square development of two cotton cultivars that differ in maturity and root morphology. Understanding the effects and forms of foliar nutrients on square development will aid in maximizing cotton production under field conditions.

BACKGROUND INFORMATION

In recent years, foliar application of potassium (K) has been used to offset plant K deficiencies. Currently in Arkansas, foliar K is widely used to correct mid-season deficiency symptoms (Oosterhuis, 1995). The effects of foliar applications on cotton yield are well understood (Miley and Oosterhuis, 1993). Although the application of foliar KNO_3 has been shown to increase the number of squares (Keino et al., 1996), it was uncertain whether this effect was due to the K^+ or the NO_3^-. Further studies were needed to determine the effects of other K salts on square development.

RESEARCH DESCRIPTION

The study was conducted using an early-maturing ‘Deltapine 20’ (DPL20) and a late-maturing ‘Deltapine 90’ (DPL90) cotton cultivar grown in nutrient solution in a growth chamber prior to application of foliar treatments. Twenty-one days after planting (DAP), plants were transferred to a K-free nutrient solution, and one of the following compounds, KNO_3, K_2SO_4 or NH_4NO_3, was applied to the leaves with a paint brush at an equivalent rate of 11.2 kg/ha KNO_3 (10 lb/10 gal water/acre). Control plants were painted with an equivalent volume of water without nutrients. At 25 DAP, plants were harvested, and square number and square dry weight were measured from each pot. The study was conducted in a randomized complete block design with three replications.

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[1]Graduate Assistant, Soil Chemist, Statistician and Crop Physiologist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

RESULTS AND DISCUSSION

When averaged over treatments, the early maturing DPL20 had significantly more squares than DPL90 (Fig. 1A). Similarly, greater square dry weights were observed for DPL20 (Fig. 1B). There were no cultivar by square number or cultivar by square weight interactions, indicating that the cultivars responded similarly to foliar treatments. These results were consistent with those reported in an earlier study (Keino et al., 1996) and demonstrate the more rapid development of DPL20.

Application of foliar K to the cotton plants had a dramatic effect on square development. Significant differences in number of squares were measured among the foliar treatments four days after application (Fig. 2). The application of foliar KNO_3 increased the number of squares by 31, 29 and 49%, compared to H_2O, K_2SO_4 and NH_4NO_3, respectively. This finding suggests that K^+, not NO_3^- is responsible for the improved square development with foliar-applied KNO_3.

PRACTICAL APPLICATION

Results from this study suggest that foliar K application could be used to stimulate square development. It also shows that it is the K in KNO_3 and not N that enhanced square development. Thus, application of KNO_3 several days before square development could result in increased square number if K is limiting. These data confirm earlier studies that KNO_3 appears to be a superior salt in foliar application where a response to K is desired.

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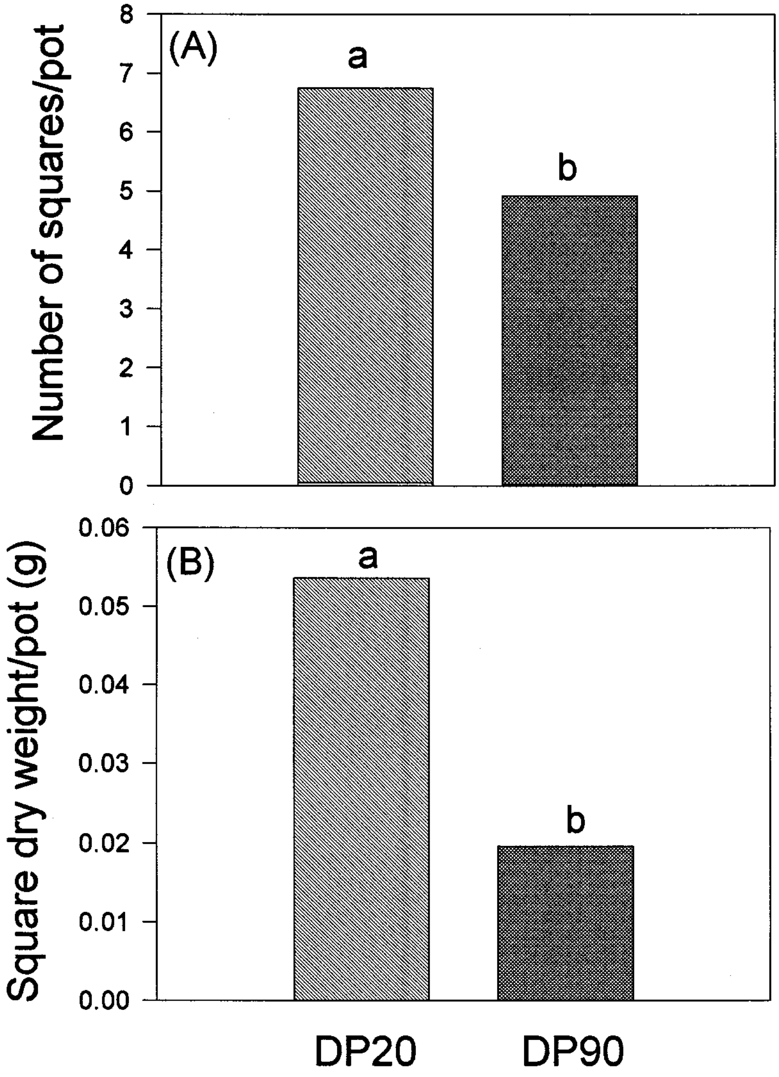

Fig. 1. Difference in (A) number and (B) weight of squares for two cotton cultivars averaged over foliar treatments. Means followed by the same letter are not significantly different at *P* = 0.05 using a protected LSD.

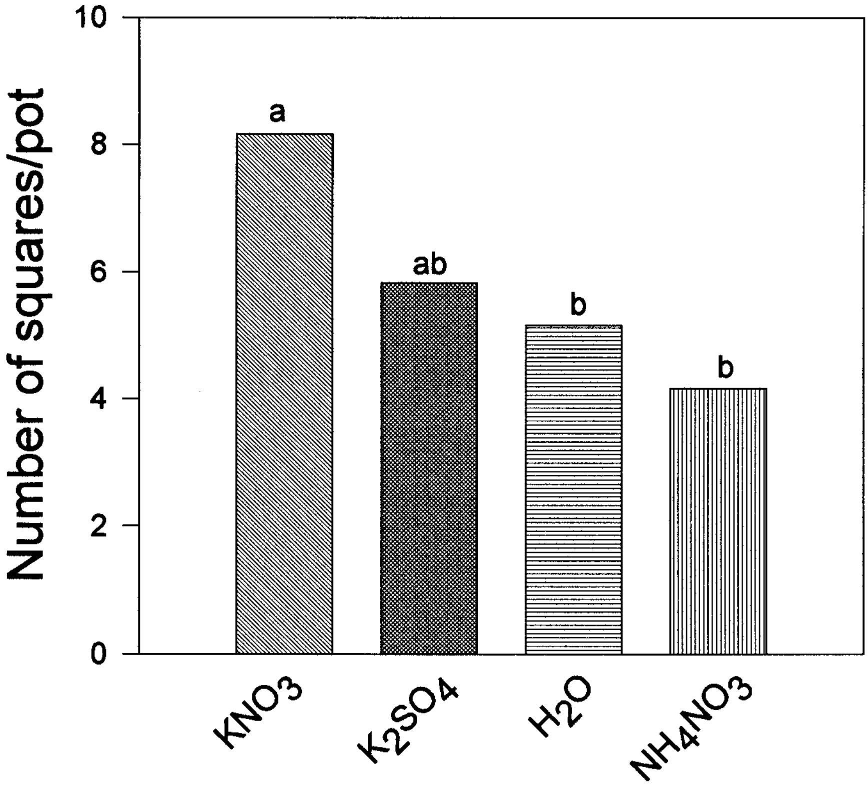

Fig. 2. Effect of foliar-applied nutrients on square formation. Means followed by the same letter are not significantly different at *P* = 0.05 using protected LSD.

EFFECT OF SHADE ON PETIOLE NUTRIENT CONCENTRATION OF FIELD-GROWN COTTON

Duli Zhao and Derrick Oosterhuis[1]

RESEARCH PROBLEM

The nutrient analysis of cotton petioles is widely used to monitor the nutrient status of plants. Cloudy, overcast weather in the Mid-South region frequently occurs during the growing season and affects growth and yield of cotton. However, little is known about the effect of low light intensity on petiole nutrients. Therefore, a better understanding of the effects of shading on petiole nutrient concentrations of field-grown cotton plants may help to improve fertilizer management efficiency and explain yield variability in cotton.

BACKGROUND INFORMATION

Soil fertility and fertilizer application directly affect plant mineral nutrient concentrations. The petiole NO_3-N test and determination of mineral nutrients in plant samples have been used to monitor the status of nitrogen and other nutrients in cotton plants for diagnostic purposes (Oosterhuis and Morris, 1979; Sabbe and Zelinski, 1990). Recent studies have shown that shade during flowering and fruiting decreased lint yield (Pettigrew, 1994; Zhao and Oosterhuis, 1994) and fiber quality (Pettigrew, 1995; Zhao and Oosterhuis, 1996) of field-grown cotton. However, it is not clear if low light conditions affect the nutrient status of cotton plants. A two-year study was conducted to determine the effects of shading (63% light reduction) at different growth stages on nutrient concentrations in petioles of field-grown cotton.

RESEARCH DESCRIPTION

The experiment was conducted at the Arkansas Agricultural Research and Extension Center, University of Arkansas in Fayetteville, in 1993-1994. Cotton (*Gossypium hirsutum* L.) cultivar Deltapine 20 was planted 26 May 1993 and 17 May 1994. Plots consisted of five rows 5 m in length, spaced 1 m apart, with nine plants/m. Preplant fertilizer was applied at a rate of 45-30-75 kg N-P-K/ha, and an additional side-dressing of 56 kg N/ha was given on 13 July 1993 and 28 June 1994 at the early square stage. Control of insects and weeds and furrow irrigation were given as needed during the growing season according to Arkansas cotton production recommendations.

[1]Graduate Assistant and Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

Five treatments consisted of 1) a no-shade control, 2) shade at the pinhead square (PHS) stage, 3) shade at the first flower (FF) stage, 4) shade at the peak flower (PF) stage (12 days after FF) and 5) shade at the boll development (BD) stage (24 days after FF). The duration of the applied shade in all cases was eight days. The shade shelters were made from PVC pipe with the black shade cloth providing a 63% sunlight reduction. The shelters were 5 m in length and width and 1.9 m in height. The experiment was arranged in a randomized complete block design with three replications.

During the shading treatments, ten petioles from the uppermost fully expanded main-stem leaves from each plot were sampled at 1:00 p.m. at 2, 4, 6 and 8 days after the initiation of shade treatments. Petiole nitrate-nitrogen (NO_3-N), phosphorous (P), potassium (K) and sulfur (S) were determined at the Soil Testing and Research Laboratory, Marianna, Arkansas.

RESULTS

Petiole NO_3-N, P, K and S concentrations declined sharply with plant age under normal growing conditions (Fig. 1). Shading at any growth stage significantly increased petiole NO_3-N concentration ($P < 0.05$~0.001). The petiole NO_3-N concentration for no-shade control plants at the FF, PF and BD stages was 6.8, 1.6 and 0.07 g/kg DW, respectively, but increased to 13.2, 3.6 and 0.2 g/kg DW, respectively, for shaded plants. Under shading conditions, petiole P concentration increased 10% at the FF stage ($P < 0.01$), 26% at the PF stage ($P < 0.001$) and 15% at the BD stage ($P < 0.05$). Petiole K concentration did not statistically differ between the no-shade control and shaded plants at the FF stage but increased 36% at the PF and BD stages ($P < 0.01$~0.001). Petiole S concentration of plants shaded at FF increased 43% ($P < 0.001$). Shading at the PF stage did not significantly affect the S concentration, and plants shaded at the BD stage showed a significant decline in petiole S concentration ($P < 0.05$) compared with the no-shade control plants.

The time course of changes in petiole nutrient concentration after initiation of shade at the FF stage is shown in Fig. 2. An eight-day period of shade at the FF stage significantly increased the NO_3-N concentration of shaded plants within two days of initiation of shade treatment compared to the no-shade control plants. The differences in petiole P and S concentrations between shaded and unshaded plants also increased rapidly as the length of the shading time increased, and shaded plants had significantly higher petiole P and S concentrations than the unshaded control plants at six and eight days after the initiation of shade. The K concentration showed no statistical difference between two treatments during shading at FF.

PRACTICAL APPLICATION

Petiole nutrient concentrations are closely associated with soil fertility and fertilizer application. Our study indicated that the amount of light available to the crop was also an important factor influencing the nutrient concentrations of field-grown cotton. Under shade conditions, petiole NO_3-N was doubled, and P, K and S were also significantly increased. Therefore, sampling petioles on overcast days may cause non-representative nutrient analyses and erroneous diagnostic recommendations. Time of sampling during the day and weather conditions must be considered when sampling cotton petioles for reliable and accurate nutrient analysis diagnoses.

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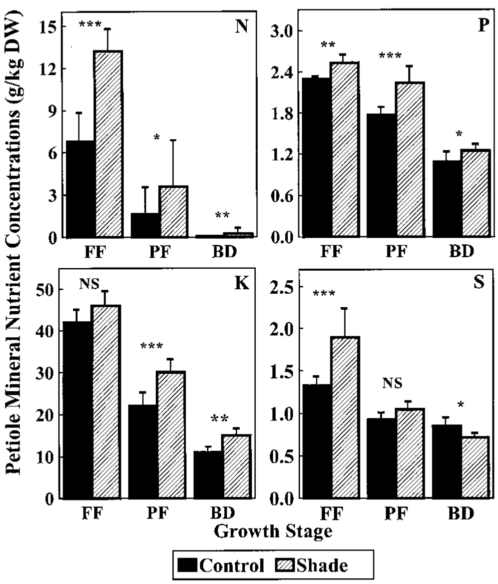

Fig. 1. Effects of shade at different growth stages on petiole NO_3-N, P, K and S concentrations of field-grown cotton plants. Data are means ± SD of 1993 and 1994 over four sampling times (2, 4, 6 and 8 days) in three replications (n = 24). FF, PF and BD are first flower, peak flower and boll development, respectively. NS = not significant (P > 0.05), * = P ≤ 0.05, ** = P ≤ 0.01 and *** = P ≤ 0.001.

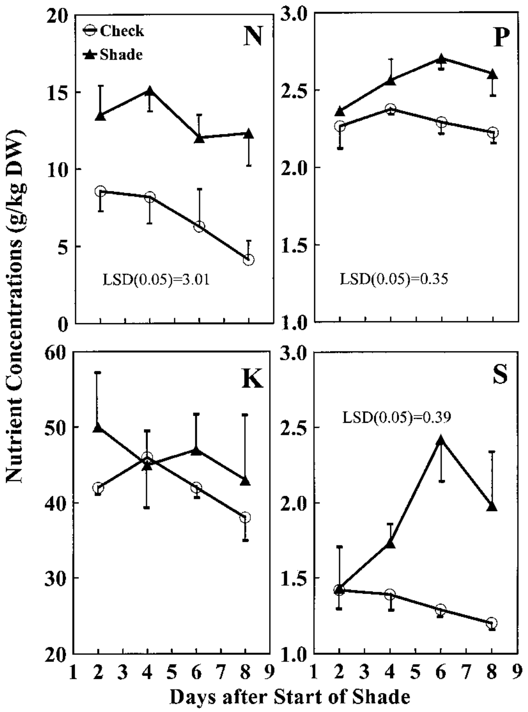

Fig. 2. Changes in petiole NO_3-N, P, K and S concentrations of no-shade control and shaded cotton plants during an eight-day period of shade at the first flower stage. Data are means ± SD of 1993 and 1994 (n = 6).

PHYSIOLOGICAL RESEARCH ON POTASSIUM NUTRITION OF COTTON

Derrick Oosterhuis, Adele Steger and Craig Bednarz[1]

RESEARCH PROBLEM

Potassium (K) deficiencies in Arkansas field-grown cotton (*Gossypium hirsutum* L.) often occur in mid to late season when root growth is reduced and developing bolls become strong sinks for available K. Present tissue sampling techniques can give unreliable results in determining whether there is sufficient K available in the plant. Soil K availability and boll load can also affect petiole K status. The objectives of the current research are to observe the effect of soil K fertilization versus foliar fertilization, the timing of foliar fertilization, the effect of soil K status and boll load on petiole K status and yield and physiological changes during the onset of K deficiency.

BACKGROUND INFORMATION

In recent years, the occurrence of K deficiencies across the Cotton Belt has increased, and signs of K deficiencies are appearing on young leaves at the top of plants with a heavy fruit load. Previously, deficiency symptoms were associated with older, mature leaves due to the mobility of K within the plant. In situations in which a heavy fruit load exists, decreased root growth and a high demand for K may cause K to be depleted from plant tissue at a faster rate than uptake occurs. Accurate detection of a pending K deficiency at an earlier stage of growth may serve to improve fertilizer efficiency, lint yield and lint quality.

RESEARCH DESCRIPTION

Growthroom and field studies were used. The growthroom, at the Altheimer laboratory in Fayetteville, Arkansas, was programmed for 12-hour light periods and 30/25°C day/night temperatures with a relative humidity of about 60%. A field site at the Arkansas Agricultural Research and Extension Center, University of Arkansas, Fayetteville, with replicated low- and high-K plots has been established over the past three years. Preplant soil K levels were 155 kg/ha and 107 kg/ha at the 0- to 6-in. and 6- to 12-in. depths, respectively, in the high-soil-K plots and 131 kg/ha and 104 kg/ha at the 0- to 6-in. and 6- to 12-in. depths, respectively, in the low-soil-K plots. Potassium chloride was broadcast in the high-soil-K plots in

[1]Professor and Research Specialist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas; and Assistant Professor, University of Georgia, Tifton, Georgia.

the Soil K/Boll Load Size Study, three weeks after planting in order to raise soil K levels. At mid-season, soil K levels were 334 and 148 kg/ha at the 0- to 6- and 6- to 12-in. depths, respectively. On 10 May 1996, the cotton cultivar DPL 20 was planted into a moderately well-drained Captina silt loam soil (fine-silty, mixed, mesic Typic Fragiudult).

Physiological Changes During the Onset of Potassium Deficiency

In growthroom studies K was withheld from the plants starting two weeks after planting. Changes in dry matter of plant components, photosynthesis, carbohydrates, chlorophyll and ATP were monitored at weekly intervals for four weeks during the onset of K deficiency.

Soil vs. Foliar-Applied Potassium Study

A field study was conducted comparing single applications of soil and foliar-applied K during early flowering. The soil-applied K was given at one week after first flower (FF) at 33.6 kg K/ha. The foliar-applied K was given at the same time as the soil treatment at 11.2 kg K/ha. The design was randomized complete blocks with three replications.

Soil K Status and Boll Load Size on Petiole Potassium Status

A field study with low- and high-soil-K status (main plot) and low and high boll load (split plot) was conducted. Low boll load was achieved by weekly hand removal of two bolls smaller than 1 in. in size per plant. High boll load was as developed on the plant. The design was randomized complete blocks with three replications.

Timing Foliar-Applied Potassium

A field study was conducted to determine optimum period for foliar application of K. Treatments consisted of 1) a control with no foliar-applied K, 2) an early treatment with 15 kg/ha K_2SO_4 foliar applied at FF+1wk, FF+2wk and FF+3wk, 3) a midseason treatment with 15 kg/ha K_2SO_4 foliar applied at FF+3wk, FF+4wk and FF+5wk and 4) a late treatment with 15 kg/ha K_2SO_4 foliar applied at FF+5wk, FF+6wk and FF+7wk.

Petiole Sampling for Potassium Deficiency

The study was superimposed on the Soil K/Boll Load Study described above. Petioles were sampled weekly at main-stem node 4 (currently recommended petiole for analysis) and main-stem node 8 (research has indicated that this petiole may be more indicative of a pending K deficiency) beginning at first flower in the high and low soil K/boll load plots and analyzed for % K.

Two-meter lengths of row from each plot within each study were handpicked to determine final yield and boll weight.

RESULTS

Physiological Changes During the Onset of Potassium Deficiency

In the growthroom experiment, dry matter and K concentration were significantly decreased seven days after K was withheld from the plants. This was followed by significant changes in leaf photosynthesis, chlorophyll and soluble carbohydrates. The decreases in photosynthesis and the build up of sugars in the leaf resulted in higher levels of ATP. The actual sequence of events occurring during the onset of a K deficiency is difficult to portray. However, it is apparent that by the time a visual deficiency shows, growth and productivity have already been significantly decreased.

Soil- vs. Foliar-Applied Potassium Study

Petiole K concentration (%) was consistently higher in the foliar treatment throughout the sampling period. Petiole sampling showed a positive response (higher % K) to the foliar K application within four days after treatment application. There was no clear response in petiole K status to the soil application. Lint yield (kg/ha) was numerically higher in the foliar treatment when compared with the soil-applied treatment. Boll weight (g) and the number of open bolls at harvest were also higher in the foliar-applied treatment.

Soil Potassium Status and Boll Load Size on Petiole Potassium Status

Higher petiole K levels were observed in the high-soil-K/high-boll-load plots at both nodes 4 and 8 (Fig. 1). Lint yield, boll weight and open boll number were also greatest in these plots. Lint yield was significantly higher than the high-soil-K/low-boll-load and the low-soil-K/low-boll-load plots (P = 0.05).

Timing Foliar-Applied Potassium

No significant yield differences were observed among the treatments although the late-season foliar application had a numerically higher yield than all other treatments.

Petiole Sampling for Potassium Deficiency

Petiole K concentration was consistently lower at node 8 throughout the growing season in all plots. In the high-soil-K/high-boll-load plots, petiole K was substantially lower (53%) at node 8 at two weeks after first flower.

PRACTICAL APPLICATIONS

Mid- and late-season potassium deficiencies continue to be a problem for many growers across the Cotton Belt. Sufficient soil K levels and timely fertilizer applications can alleviate symptoms; however, knowledge of petiole K status and boll load are also necessary. Physiological responses to K deficiency help define optimum sampling methods to predict a pending K deficiency. Petiole sampling from node 8 (lower in the canopy) rather than from node 4 may better signal an impending K deficiency when there is high demand due to developing bolls.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the Phosphate and Potash Institute, the Soil Testing Research Program, the Great Salt Lake Mineral Corporation, the Fluid Fertilizer Foundation and the Arkansas Cotton State Support Committee.

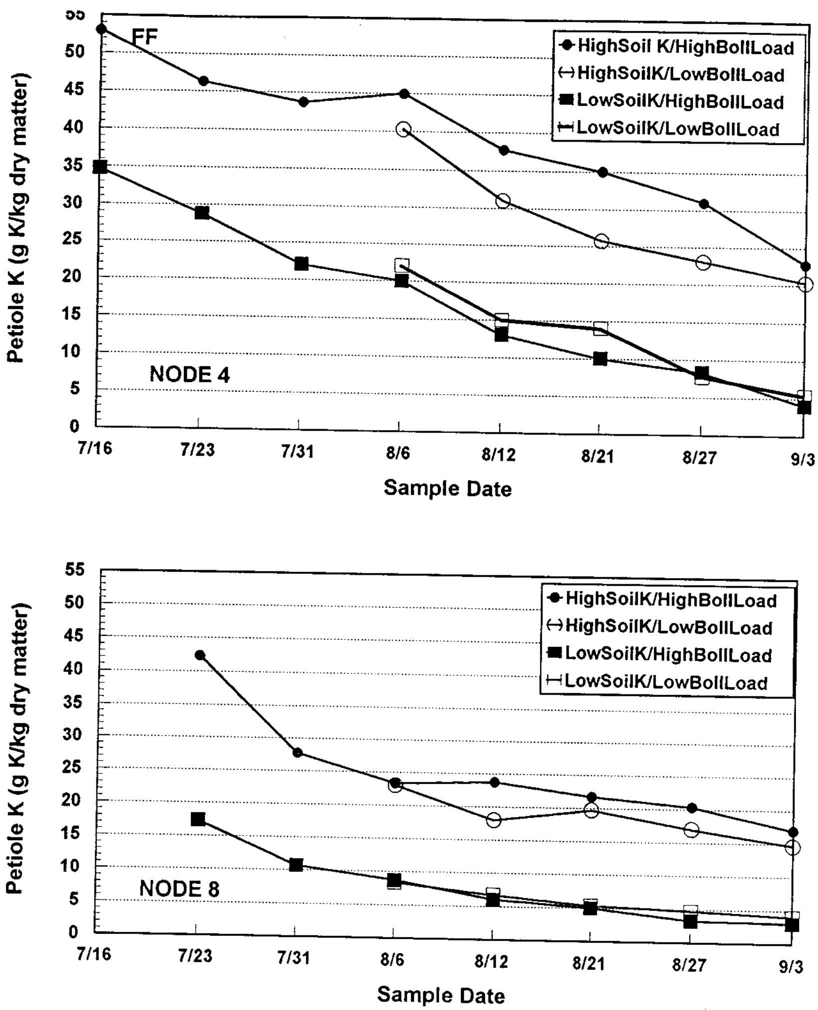

Fig. 1. Effect of boll load and soil K on petiole K status, soil K - boll load study, Fayetteville, Arkansas, 1996.

SLOW RELEASE SOIL FERTILIZER STUDIES

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

RESEARCH PROBLEM

Current fertilizer practices involve applying fertilizer to the soil at or prior to planting, with additional applications made during the growing season. A programmed release fertilizer could increase efficiency by releasing nutrients according to crop requirements while at the same time reducing traffic across the field. The objectives of the current research are to evaluate new programmed release nitrogen and potassium fertilizers for use in cotton production. These fertilizer products release their nutrients as temperatures increase during the season at the same time as crop requirements increase. The products have the potential advantages of: 1) less ground water contamination, 2) one-time fertilization, 3) custom design for release according to the crop requirements for more efficiency and 4) more efficient return per dollar spent on fertilizer.

BACKGROUND INFORMATION

Traditionally, fertilizer is applied to soil at planting and sidedressed later in the season, necessitating additional costs to the grower and wheel traffic with compaction in the field. Due to potential problems with salinity and seedling growth, the entire amount of fertilizer cannot be placed at planting. A programmed slow release fertilizer would allow for a one-time fertilizer application and a more efficient return per dollar spent.

RESEARCH DESCRIPTION

Two field studies were conducted at the Southeast Branch Station in Rohwer, Arkansas. Preplant soil K levels were 192 lb/acre and 163 lb/acre at the 0- to 6-in. and 6- to 12-in. depths, respectively. On 6 May 1996, the cotton cultivar ‘Suregrow 125’ was planted into a moderately well-drained Hebert silt loam soil (fine-silty, mixed, mesic Typic Fragiudult). Plots consisted of four rows spaced 38 in. apart and 40 ft in length. Insect and weed control were according to standard cotton recommendations. The trials were furrow irrigated as needed. Fertilizer was applied to the treatments listed below.

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[1]Professor of Crop Physiology and Research Specialist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

Slow Release Nitrogen Fertilizer

Fertilizer for K and P was applied uniformly according to soil test results. Treatments consisted of: 1) a control with conventional tillage and full N treatment (110 lb N/acre), 2) Meister mixture of T15 (full N treatment), 3) Meister mixture of T15 (80% of full N) and 4) Meister mixture of T15 (60% of full N).

Slow Release Potassium Fertilizer

Fertilizer for N and P was applied uniformly according to soil test results. Treatments consisted of 1) a control with conventional tillage and full K treatment (60 lb K/acre), 2) Meister mixture of T20 (full K treatment), 3) Meister mixture of T20 (80% of full K) and 4) Meister mixture of T20 (60% of full K).

The in-furrow planting fertilizer application of Meister was made according to treatment using special planter boxes constructed by Dr. Howard (University of Tennessee). Petiole analysis was conducted weekly from pinhead square to four weeks after first flower using five petioles/plot, pooled across replications. Soil maximum and minimum temperatures were recorded daily. The experiment was defoliated at 60% open boll and mechanically harvested.

RESULTS

Slow-Release Nitrogen Fertilizer

The control treatment had a consistently lower concentration of petiole NO_3-N when compared with all other treatments (Table 1). At the end of the sampling period, the Meister treatment receiving 80% of total N had the highest concentration of petiole NO_3-N.

Lint yield among treatments is shown in Table 1. The Meister treatments with reduced total N (80 and 60% of total N) yielded similar to the control, indicating the potential value of less total fertilizer N when it becomes available during peak demand.

Slow-Release Potassium Fertilizer

The Meister treatment receiving 80% of total K at planting had the highest concentration of petiole K at the end of the sampling period (Table 2). The control treatment had the lowest concentration when compared with all other treatments.

Lint yield results (Table 2) are difficult to explain. The control and the Meister treatment receiving 60% total K at planting produced significantly higher (P = 0.05) yields than all other treatments.

PRACTICAL APPLICATIONS

This study provides data showing that a programmed release, soil-applied fertilizer can potentially provide a one-time fertilizer application at planting with no detrimental effect to seedling growth and yield. Furthermore, fertilizer available (slow/programmed release) during the main period of crop requirement means more efficient use of the fertilizer and less total (e.g., 60-80%) N or K fertilizer used. Also, reduced traffic can help to alleviate soil compaction and man hours in the field.

ACKNOWLEDGMENT

The authors gratefully acknowledge the support of the Helena Chemical Company.

Table 1. Lint yield and petiole NO_3 concentration with Meister Programmed Release N Fertilizer.

Treatment	Lint Yield	Petiole NO_3 June 13	Petiole NO_3 July 31
	lb/acre	ppm	ppm
Full N (110 lb N/acre)	1630 a*	24,700	659
Meister mixture T15 Full N	1562 a	30,300	6,000
Meister mixture T15 80% Full N	1693 a	32,000	6,400
Meister mixture T15 60% Full N	1675 a	34,200	4,350

*Numbers followed by same letter within a column are not significantly different (P = 0.05).

Table 2. Lint yield and petiole potassium concentration with Meister Programmed Release K Fertilizer.

Treatment	Lint Yield	Petiole K June 13	Petiole K August 7
	lb/acre	ppm	ppm
Full N (110 lb N/acre)	1648 a*	6.92	3.09
Meister mixture T15 Full N	1489 b	7.24	4.05
Meister mixture T15 80% Full N	1531 ab	7.39	3.69
Meister mixture T15 60% Full N	1636 a	7.44	3.54

*Numbers followed by same letter within a column are not significantly different (P = 0.05).

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

J.S. McConnell and W.H. Baker[2]

RESEARCH PROBLEM

The recommended timing of early-season 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 is to determine when is 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 pre-plant N application. The first soil application of nitrogen 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 is being utilized 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 are being tested. The experiment is duplicated under both furrow-irrigated and dryland conditions. First N applications were made approximately two to four weeks pre-plant. 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, but the typical large increases in yield from the use of irrigation were not observed (data not shown).

Response to the N treatments was similar in the irrigated and dryland blocks (Table 1). The unfertilized control was the lowest yielding treatment. The 100-lb

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[1]This article has been published in the Soil Fertility Research Series #455, 1997. pp. 27-29.

[2]Associate Professor, Agronomy Department, Southeast Research and Extension Center, Monticello, Arkansas; and Research Assistant Professor, Soil Test Laboratory, Marianna, Arkansas.

N/acre pre-plant treatment was the next lowest yielding and not significantly different from the unfertilized control. The other four treatments were not significantly different in yield. A trend of lower yield was observed with the treatment that included a 50-lb N/acre application, compared to the treatments that had later applications of N fertilizer. This trend is consistent with lack of yield increase from the 100-lb N/acre pre-plant treatment. A possible explanation for the ineffectiveness of the pre-plant treatments could be the spring weather conditions that were experienced in 1995. 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 pre-plant 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 pre-plant applications. Because these are first-year results and very preliminary, 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 six early season soil applied nitrogen (N) treatments under furrow irrigation and dryland conditions in 1995.

Soil N-Rate				
PP*	AE*	FS*	Irrigated	Dryland
---------- lb N/acre ----------			---------- lb lint/acre ----------	
0	50	50	1068	909
50	0	50	990	877
0	0	100	1086	915
0	100	0	1020	869
100	0	0	714	718
0	0	0	707	681
LSD $_{(0.05)}$			158	145

*Pre-plant (PP), After Emergence (AE), First Square (FS).

FOLIAR NITROGEN FERTILIZATION OF COTTON IN SOUTHEASTERN ARKANSAS[1]

J.S. McConnell, W.H. Baker, B.S. Frizzell and C.S. Snyder[2]

RESEARCH PROBLEM

Early-season, soil-applied 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 is to determine when an increase in yield may be realized from foliar N applications to cotton.

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 utilized 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 pre-plant and first square application totaling 120 lb N/acre or less in 1993 (Table 1). Although the foliar N x soil N interaction was

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[2]Associate Professor, Agronomy Department, Southeast Research and Extension Center, Monticello, Arkansas; Research Assistant Professor, Soil Test Laboratory, Marianna, Arkansas; Research Assistant, Southeast Research and Extension Center, Monticello, Arkansas; and Extension Soil Specialist, University of Arkansas Cooperative Extension Service, Little Rock, Arkansas.

not significant for yield in 1994 or 1995, the foliar N treatments significantly increased yields (Tables 2 and 3). Trends in the 1994 and 1995 results were similar to those observed in 1993.

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 and 3). 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).

Primary differences in petiole NO_3^--N concentrations were due to the soil-applied N fertilizer (Table 3). Foliar treatments tended to raise petiole NO_3^--N levels in cotton fertilized with 150 and 90 lb N/acre in 1994 and after period 3 in 1993. Cotton that received no soil applied N had greater petiole NO_3^--N levels without foliar N. The reason for the low values of petiole NO_3^--N levels in cotton that received no soil N but did receive foliar N is unknown.

PRACTICAL APPLICATIONS

Preliminary results indicate that foliar N applications may increase cotton lint yield when soil applied N is low. Petiole NO_3^--N concentations were primarily dependant on soil-applied N fertilizer. Because these results are preliminary, testing should be continued before final conclusions are drawn.

ACKNOWLEDGMENTS

Support for this research was provided by Cotton, Inc.

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Table 1. Lint yield response of cotton growth 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 1993.

Soil N-Rate			Irrigated			Dryland		
PP*	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 $_{(0.05)}$				216			204	
‡LSD $_{(0.05)}$				351			334	

*Pre-plant (PP), First Square (FS) and First Flower (FF).

†LSD $_{(0.05)}$ for comparing two soil applied fertilization means within the same foliar fertilization (either Foliar or Untreated) in the same irrigation.

‡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 growth 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*	FS*	FF*	Fol†	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			129
Mean			1567	1481		1337	1312	
‡LSD $_{(0.05)}$				351			NS	

*Pre-plant (PP), First Square (FS) and First Flower (FF).

†No significant soil N X foliar N interactions were observed.

‡LSD $_{(0.05)}$ for comparing foliar applied fertilization treatment means.

Table 3. Lint yield response of cotton growth 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*	FS*	FF*	Fol†	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 $_{(0.05)}$					127			
§LSD $_{(0.05)}$						240		
¶LSD $_{(0.05)}$						193		
Mean			1276	1217		856	892	
¤LSD $_{(0.05)}$			28					

*Pre-plant (PP), First Square (FS) and First Flower (FF).

†No significant soil N X foliar N interactions were observed.

‡LSD for comparing soil N treatment means in the irrigated test.

§LSD for comparing foliar N means in the same soil N treatment in the dryland test.

¶LSD for comparing foliar N means in different soil N treatment in the dryland test.

¤LSD for comparing foliar fertilization means in the irrigated test.

Table 4. 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) in 1993, 1994 and 1995.

Soil N-Rate				Sample Period						
PP*	FS*	FF*	Fol N	1	2	3	4	5	6	7
-- lb N/acre --				ppm NO_3^--N						
1993										
50	50	50	Yes	18,765	6,771	10,100	7,074	12,242	6,771	949
50	50	50	No	19,339	5,898	10,378	4,175	10,663	5,898	1,039
45	45	0	Yes	14,652	5,281	6,789	3,009	2,211	5,281	581
45	45	0	No	11,747	5,480	7,210	1,190	516	5,480	578
0	0	0	Yes	3,440	968	1,440	410	348	968	287
0	0	0	No	8,491	2,014	1,546	2,055	4,455	2,014	287
1994										
50	50	50	Yes	10,166	10,715	11,072	13,901	8,104	2,912	393
50	50	50	No	7,378	8,231	7,978	13,201	8,116	3,201	300
45	45	0	Yes	4,639	6,193	3,643	1,460	227	101	268
45	45	0	No	3,768	5,266	2,564	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	11,190	13,720	7,453	11,374	4,338	2,399	674
50	50	50	No	15,071	13,024	5,657	7,639	4,220	552	161
45	45	0	Yes	11,201	7,848	1,380	522	321	122	66
45	45	0	No	---	8,109	810	500	565	16	20
0	0	0	Yes	1,321	1,159	447	20	591	64	20
0	0	0	No	879	3,364	14	20	96	9	14

*Pre-plant (PP), First Square (FS) and First Flower (FF).

IRRIGATION METHODS AND NITROGEN FERTILIZATION RATES IN COTTON PRODUCTION[1]

J.S. McConnell, W.H. Baker and B.S. Frizzell[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 southeastern 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 Branch Experiment Station, Rohwer, Arkansas, 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 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

Irrigation generally increased cotton yields except during an unusually wet growing season (1989, data not shown); when the crop was planted too late (1991); or when verticillium wilt was prevalent (1990-1992 and 1994) (Table 2). The method of irrigation for maximum lint yield varied year-to-year and, therefore, appeared to be less important than irrigation usage.

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[2]Associate Professor, Agronomy Department, Southeast Research and Extension Center, Monticello, Arkansas; Research Assistant Professor, Soil Test Laboratory, Marianna, Arkansas; and Research Assistant, Southeast Research and Extension Center, Monticello, Arkansas.

Generally, lint yield was found to increase with increasing N fertilization (data not shown). The N treatments that usually resulted in the greatest lint yields were applications of 90 to 150 lb N/acre, depending upon the irrigation treatment. Exceptions were found for the 150-lb N/acre treatment (75 lb N/acre PP and 75 lb N/acre FS), which was found to decrease lint yield in some irrigation blocks, and the High Frequency Center Pivot block in 1990-1992 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 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 Methods	Duration	Tensiometer Threshold	Tensiometer Depth	Water Applied
		cbar	in.	in.
High Frequency	Planting to P.B.*	35	6	0.75
Center Pivot	P.B. to Aug. 15	35	6	1.00
Moderate Frequency Center Pivot	Planting to August 15	55	6	1.00
Low Frequency	First Irrigation	55	12	1.00
Center Pivot	Until August 15	55	6	1.50
Furrow Flow	Until August 15	55	12	Not Precise
Dryland	Not Irrigated	--	--	--

*P.B. = Peak Bloom.

Table 2. Lint yield response of cotton to five irrigation methods in 1988, 1990, 1991, 1992, 1993, 1994 and 1995.

Method	1988	1990	1991	1992	1993	1994	1995
High Frequency Center Pivot	1567	1118	1051	1181	1103	1317	1113
Moderate Frequency Center Pivot	1410	1461	----	1632	1342	----	----
Low Frequency Center Pivot	1620	1442	1334	1460	1112	----	----
Furrow Flow	1370	1511	1231	1367	1241	1478	1217
Dryland	1271	915	1308	1246	1067	1353	892
$LSD_{(0.05)}$	159	67	77	66	66	83	59

FIELD EVALUATION OF PLANT GROWTH REGULATORS IN 1996

D.M. Oosterhuis, A. Steger and J.S. McConnell[1]

RESEARCH PROBLEM

Cotton (*Gossypium hirsutum* L.) is perennial with an indeterminate growth habit. 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 PGR compounds have been developed and tested on field-grown crops. The objective of this study was to evaluate new and existing PGRs for effects 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 ten years (Urwiler et al., 1989; Oosterhuis and Janes, 1994; Oosterhuis et al., 1996). Recent research has focused on the physiological effects and underlying mechanisms of PGRs (Guo et al., 1994) in order to be able to adapt their use to the growth requirements of specific crops. The investigation of the effects of PGRs on plant growth promotes our understanding of the mode of action of PGRs and assists with recommendations regarding current cotton production systems in Arkansas.

RESEARCH DESCRIPTION

A field experiment was planted into a Hebert silt loam soil at the Southeast Branch Experiment Station, Rowher, Arkansas, on 6 May using the cotton cultivar Suregrow 125. Treatments consisted of an untreated control, Atonik, Maxon, Early Harvest, PGR-IV, PHCA, Cytokin, Crop^{+2}, Pix and a late application of PGR-IV. 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 and weed and insect control measures were according to Extension Service recommendations. Plots were furrow irrigated as needed throughout the growing season.

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[1]Crop Physiologist and Research Specialist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas; and Agronomist, Southeast Research and Extension Center, University of Arkansas, Monticello.

RESULTS

Nodes Above White Flower (NAWF)

Nodes above white flower measurements showed that the Pix treatment was significantly lower (*P* = 0.05) than all other treatments at each sampling date. Plants in the Pix treatment reached physiological cutout (NAWF = 5) approximately eight days earlier than the untreated control. However, there was not a clear trend towards early cutout between any other PGR and the control.

Maturity

Open boll counts taken at the end of the growing season (seven and eight weeks after first flower) showed Maxon treatment as having a significantly higher (*P* = 0.05) number of open bolls when compared with PGR-IV, PHCA, Crop^{+2} and the late application of PGR-IV at seven weeks after first flower. There were no significant trends among treatments at eight weeks after first flower.

Lint Yield

The effect of PGRs on lint yield from 1992 until 1996 is shown in Table 2. In 1996, only Pix and the PGR-IV treatments had significantly higher (*P* = 0.05) yields than the control treatment. A high plant population, lodging at the end of the growing season and a heavy boll load may have contributed to a lack of yield differences among treatments.

PRACTICAL APPLICATION

The primary objective of this study was to evaluate and compare new and existing PGRs under field conditions. Even though climatic conditions affect the growth and development of cotton, making year-to-year results variable, there is a clear trend towards increased yields and more controlled crop growth with foliar applications of PGRs.

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Table 1. Treatments, timing and rates of PGR applications.

Treatment	Timing	Rate
Control	no foliar spray	----
Atonik	PHS*, FF†, FF + 3 wk	500 ml/acre, 600 ml/acre, 600 ml/acre
Crop+2	4 leaf stage, PHS, FF	16 oz/acre, 16 oz/acre, 16 oz/acre
Cytokin	PHS, FF, FF + 3 wk	4 oz/acre, 8 oz/acre, 8 oz/acre
Early Harvest	IF‡, PHS, FF	2 oz/acre, 4 oz/acre, 4 oz/acre
Maxon	IF, PHS, FF	2 oz/acre, 2 oz/acre, 4 oz/acre
PGR-IV	IF, PHS, FF	2 oz/acre, 4 oz/acre, 4 oz/acre
late PGR-IV	FF + 3 wk	4 oz/acre
PCHA	PHS, FF, FF + 3 wk	8 oz/acre, 8 oz/acre, 16 oz/acre
Pix	PHS, FF	8 oz/acre, 8 oz/acre

*FF = first flower.

†PHS = pinhead square.

‡IF = in-furrow at planting.

Table 2. Effect of plant growth regulators on lint yield in Arkansas 1992-1996.

PGR	1992	1993	1994	1995	1996	Mean
	--------------------------------lb lint/acre----------------------------------					
Control	833	790	1094	1100	1297	1023
Atonik	881	850	1153	1070	1245	1040
Crop+	862	941	1124	1064*	1339*	1066
Cytokin	870	879	1161	1028	1266	1041
Early Harvest†	----	----	----	----	1308	----
Maxon†	----	----	----	----	1328	----
PGR-IV	982	906	1169	1121	1374	1110
PHCA	862	975	1159	1151	1308	1091
Pix	844	960	1129	1027	1389	1070
LSD $_{(0.05)}$	53	73	54	142	69	----

*Crop+ was changed to Crop+2 in 1995.

†Maxon and Early Harvest were included only in 1996.

DURATION OF ACTIVITY OF THE PLANT GROWTH REGULATORS PGR-IV AND MEPIQUAT CHLORIDE

A.L. Nepomuceno, D.M. Oosterhuis and A. Steger[1]

RESEARCH PROBLEM

Foliar spray applications of plant growth regulators (PGRs) such as mepiquat chloride (MC) and PGR-IV have been shown to affect plant growth and lint yield in cotton (*Gossypium hirsutum* L.). However, little is known about the duration of activity of these PGRs. Understanding how long the activity of a PGR persists in plants will make it possible to maximize the cost benefit from the application. This information is crucial to decide the best time to spray and how frequently to spray when calling for multiple applications. The objective of this study was to investigate the duration of activity of PGR-IV and MC after a foliar application.

BACKGROUND INFORMATION

Plant growth regulators have been widely used in cotton to control growth and enhance yield. In the past decade many field experiments have been conducted to evaluate the effect of PGRs on growth and yield (Urwiler et al., 1989; Oosterhuis et al., 1996), to optimize the use of PGRs in cotton and to understand the physiological mechanisms activated after application of a PGR (Guo et al., 1994; Oosterhuis, 1996). However, information on the duration of activity of PGRs in cotton is limited. Landivar et al. (1992) related the activity of MC to its concentration in the plant. Oosterhuis (1995) showed that the effect of PGR-IV on photosynthesis declined 13 days after application. Additional research is needed to document the length of time for which a PGR is active before an additional application may be necessary.

RESEARCH DESCRIPTION

A field experiment was planted at the Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 10 May 1996 into a Captina silt loam soil using the cotton cultivar DPL 20. Treatments, rates and timing of applications are shown in Table 1.

Treatment applications were made with a CO_2 backpack sprayer calibrated to supply 10 gal/acre of solution. The experimental design was a randomized com-

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[1]Graduate Assistant, Professor and Research Specialist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

plete block with three replications. Plot size was four rows by 16.4 ft with 38-in. row spacing. Preplant fertilizer consisted of N:P:K applied at 50-50-50 lb/acre. Additional nitrogen was added at pinhead square at a rate of 50 lb/acre. Furrow irrigation was applied as needed throughout the growing season. Weed and insect control measures were according to Extension Service recommendations for optimum cotton production in Arkansas.

Measurements

Plant height, main-stem node number, leaf length, petiole nutrient concentration and leaf photosynthesis were measured on control, MC and PGR-IV plots in three replications at 1, 4, 6, 14 and 20 days after foliar application of treatments. In addition, in the PGR-IV plots, square and boll shed were also measured. Photosynthesis measurements were made at midday on the uppermost fully expanded main-stem leaf using a LICOR 6200 photosynthesis system. Seedcotton was hand picked in two 1-m row lengths to determine yield, boll weight and boll number.

RESULTS

Photosynthesis Rate

Figure 1 shows that one day after the foliar application, photosynthesis rates were higher in both PGR-IV and MC when compared with the control. PGR-IV caused a peak in the photosynthesis rate at nine days after the application, whereas MC peaked 13 days after application. The photosynthetic rates of both PGR-IV and MC treatments were similar to the control about two weeks after foliar application. Increased photosynthesis following MC or PGR-lV application has been previously reported (Zhao and Oosterhuis, 1995) and associated with increased sugar translocation and boll load.

Plant Height, Number of Nodes and Number of Fruits in the First Position

Plant height after application of MC or PGR-IV showed no significant differences (P = 0.05). However, early after application, PGR-IV appeared to slightly increase plant height (data not shown).

The number of fruits at the first position and number of main-stem nodes also showed no significant differences among the treatments after application of PGR-IV and MC. The small differences observed were more related with the experimental error than with real differences among treatments (data not shown).

Leaf Extension Growth

There were no significant differences in leaf extension growth among the treatments (Fig. 2). There was, however, a numerical trend for more rapid increase in leaf length, and larger final length, in the PGR-lV treated plots.

Petiole Nutrient Concentration

Differences in petiole nutrient concentrations among the treatments were not significant (data not shown).

Lint Yield and Yield Components

No significant differences were observed in lint yield, open boll number and boll weight with foliar application of PGR-IV and MC (Table 2). However, there was a numerical trend for MC to increase yield (by 12% over the control).

PRACTICAL APPLICATION

This study was not conclusive but supplied some indication that the activity of MC and PGR-IV in the cotton plant declined about two weeks after foliar application. This preliminary conclusion supports previous observations. This information is needed to help optimize the timing of PGRs in relation to when their desired effect is needed. It is also important to know the duration of activity of a PGR for timing a second application when multiple applications are called for.

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Table 1. Treatments, rates and timing of PGR applications.

Treatment	Rate	Timing
Control	untreated	----
PGR-IV	4 oz/acre	FF*
PIX	8 oz/acre	FF

*FF = first flower.

Table 2. Lint yield and yield components among treatments.

Treatment	Lint yield*	Open Boll Numbers	Boll Weight
	lb/acre	bolls/acre	g
Control	993 a	304,453 a	4.31 a
PGR-IV at FF	984 a	298,785 a	4.37 a
PIX at FF	1127 a	325,506 a	4.59 a

*Numbers within columns followed by the same letter are not significantly different (P = 0.05).

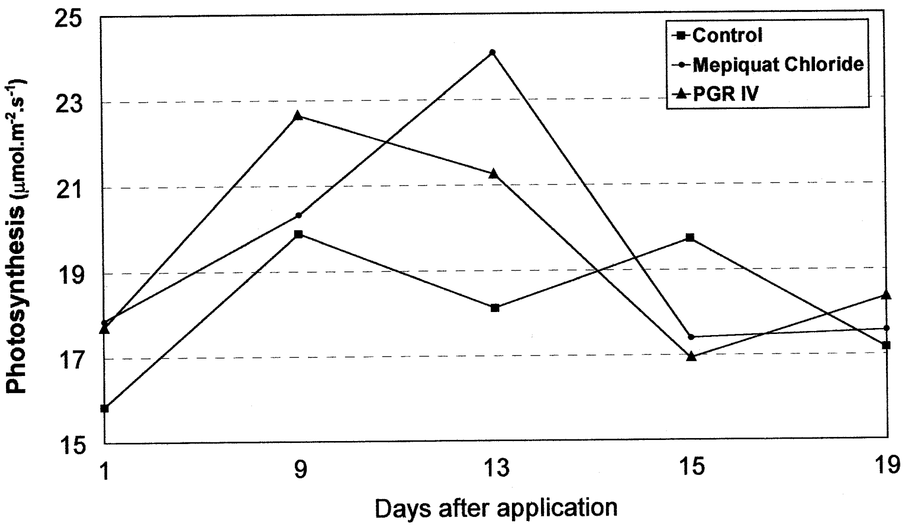

Fig. 1. Net photosynthesis in cotton plants with time in days after application of PGR-IV and Mepiquat Chloride.

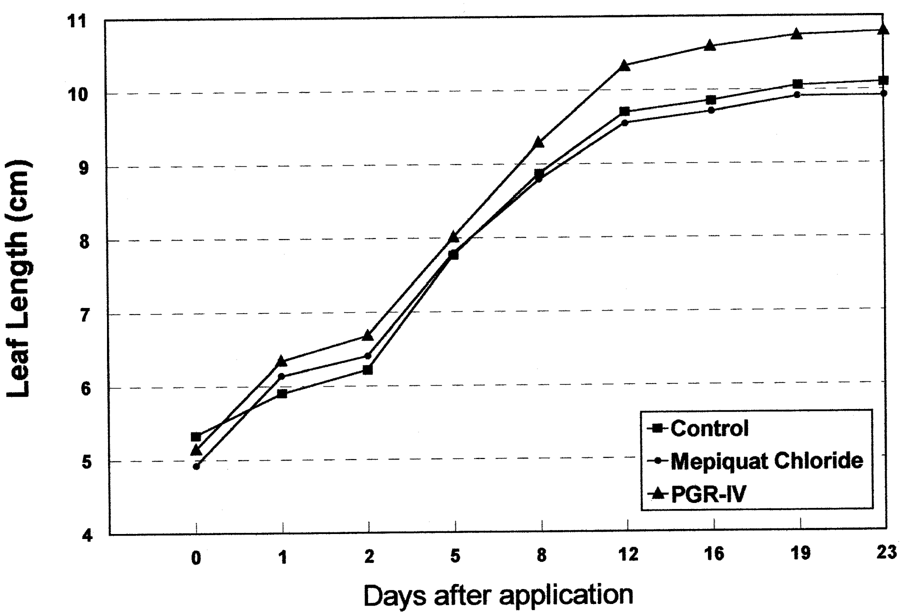

Fig. 2. Changes in leaf length uppermost unfurled cotton leaves with days after foliar application of Mepiquat Chloride and PGR-IV.

EFFECT OF PIX™ RATE ON COTTON DEVELOPMENT AND YIELD POTENTIAL

C.R. Shumway[1]

RESEARCH PROBLEM

Cotton production systems typically involve the use of plant growth regulators (PGR). The most frequently used PGR has been PIX™. Previous reports have indicated the effect of PI on cotton development (Oosterhuis et al., 1991; Shumway, 1995). A question still in need of evaluation is the rate required to produce a plant with the desired characteristics. Several methods have been described previously (Guthrie et al., 1995; Silvertooth et al., 1996) The objective of this research was to evaluate the efficacy of PIX application using both standard low-rate-multiple rates and the PIXstik method (Landivar et al., 1996).

MATERIALS AND METHODS

The research was conducted at two locations. The Judd Hill, Arkansas, location was a Dundee silt loam soil. The variety was 'Stoneville 474' with two plant densities (normal at 36,537 and high at 63,800 plants/acre). The Leachville, Arkansas, location was a Routon-Dundee-Crevasse soil complex. The variety was 'DPL51' with a density of 38,758 plants/acre. Treatments for this evaluation were 1) low-rate multiple (4 oz/acre x four applications at seven- to 10-day intervals) 2) Pixstik rate (as determined using internode length for rate determination) and 3) untreated check. PIX treatments were initiated at MHS. Application was accomplished using a CO_2 backpack sprayer with a carrier volume of 20 gal/acre. At maturity, plant samples were harvested for determination of plant height and boll number. Yield determination was accomplished by hand harvesting 20 ft of row/plot.

RESULTS AND DISCUSSION

Application rates with the Pixstik varied due to location. The Judd Hill location required 18 and 22 oz/acre, respectively, for the normal and high populations. The Leachville location required a rate of 20 oz/acre. When compared to the control plants, PIX applications significantly reduced plant height and main-stem node number at both locations. Applications using the Pixstik resulted in a reduced plant height. Evaluation of bolls per acre and seedcotton yield indicated no significant difference at either location.

[1]Associate Professor, Arkansas State University, Jonesboro, Arkansas.

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Table 1. Effect of PIX and plant density on plant height, node number, boll number and seedcotton. Variety Stoneville 474, Judd Hill, Arkansas.

Treatment	Population	Plant Height	Number of Nodes	Boll Number	Seedcotton Yields
		in.	#/plant	bolls/acre	lb/acre
Standard	N*	28.3	20.0	413,153	3,613
	H	23.7	18.2	372,681	3,616
Pixstik	N	23.5	17.9	386,593	3,756
	H	25.1	18.3	396,711	3,628
Control	N	34.0	20.8	422,006	3,577
	H	27.8	18.5	372,259	3,648
$LSD_{(0.05)}$		4.1	0.8	NS†	NS
CV (%)		23.3	14.3	17.27	15.5

*Normal population and high population are 36,537 and 63,800 plants\acre, respectively.

†NS = nonsignificant.

Table 2. Effect of PIX and plant density on plant height, node number, boll number and seedcotton. Variety DPL 52, Leachville, Arkansas.

Treatment	Plant Height	Number of Nodes	Boll Number	Seedcotton Yields
	in.	#/plant	bolls/acre	lb/acre
Standard	28.8	19.9	426,223	3,675
Pixstik	26.4	19.7	432,546	3,684
Control	41.3	22.4	416,105	3,232
$LSD_{(0.05)}$	2.2	1.0	NS*	NS
CV (%)	17.6	12.8	16.0	11.7

*NS = nonsignificant.

EVALUATION OF ASIATIC COTTON VARIETIES FOR PRODUCTION IN ARKANSAS

James McD. Stewart[1]

RESEARCH PROBLEM

Non-woven uses of cotton have been increasing for several years, and such uses are projected to continue to increase. The fiber characteristics best suited for these uses are provided in the diploid Asiatic cottons; however, these are not grown in this country except as a curiosity. Thus, no adapted varieties have been developed, and essentially nothing is known about the yield or quality potential of these cottons in the U.S. The objective of this project is to evaluate a wide selection of Asiatic varieties to determine if any have sufficient yield and quality potential for economic production in Arkansas.

BACKGROUND INFORMATION

Approximately 5,000 bales of Asiatic diploid cottons are imported into the U.S. each year for use in garment padding, quilting and other non-woven applications. Asiatic cotton is suitable for these applications because the high micronaire of the fiber (6-8+) provides good resiliency or absorbency, depending on the application. While the market is not large, it is of sufficient size for the development of a domestic niche enterprise for contract production. There is also interest in increased use of high micronaire cotton in other non-woven uses such as carpets, if reliable supplies of raw stock with the necessary fiber characteristics were available.

In recent years the Cotton Germplasm Enhancement Program at the University of Arkansas evaluated approximately 300 varieties of Asiatic cotton for resistance to various pests. During this process, the fiber quality of many of the genotypes was determined.

RESEARCH APPROACH

Seventy-three lines were selected for preliminary yield evaluation based on the line having a micronaire of 7.0 or greater from a previous test and the availability of sufficient seed for a row. These lines were grown at the Southeast Branch Station at Rohwer, Arkansas, in single 40-ft rows spaced 38 in. apart. Plant spacing was 2-3 plants/ft. Management practices recommended for Upland cotton were

[1]Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

used, except that no PGRs were applied. Two 5-ft sections of each row were hand-picked and the two samples averaged to estimate yield. Field data taken included mature plant height and number of locks on the ground, and yield and quality parameters included seedcotton/acre, lint/acre, lint percent and HVI measurements on the fiber.

RESULTS AND DISCUSSION

Most of the Asiatic cottons are tall. Height among lines ranged from a low of 4 ft to approximately 9 ft. This characteristic presented a lodging problem in several of the lines that had weak stems. In the short term, height of the plants possibly can be controlled with PIX, but ultimately breeding should reduce the height. Because of the short, course fiber and the widely flared nature of the bur, many of the Asiatic lines tended to drop locs from the boll. This characteristic makes several of the lines unacceptable for U.S. production, especially during mechanical picking. The micronaire values were somewhat lower than expected, but several of the varieties still have acceptably high micronaire. The yield of the 73 genotypes ranged from a low of 218 lb/acre to a high of 4500 lb/acre of seedcotton. Lint yield ranged from 68 lb/acre to 1575 lb/acre. Characteristics of the 10 most productive varieties are given in Table 1.

PRACTICAL APPLICATION

This first comparative test of the yield potential and quality of Asiatic cotton varieties indicates that lines are available with the yield potential for economic production in Arkansas. Based on one year's data, the micronaire values were lower than expected, but they may be acceptable. Agronomic characteristics need to be improved through management and breeding.

ACKNOWLEDGMENT

This research was conducted with the support of Acme Pad Corporation, Baltimore, MD.

Table 1. Yield and properties of nine Asiatic cottons with potential for production in Arkansas.

Line	Height	Lint Yield	Mic	Lint %	Loc Drop
	ft	lb/acre			No./acre
A-34	6.2	1,576	7.0	40.7	53,600
A-12	5.7	1,524	6.6	33.7	33,700
A-43	6.0	1,429	6.4	34.8	99,000
A-32	6.8	1,234	6.5	42.3	89,400
A-66	7.0	1,215	6.2	41.1	264,000
A-37	6.5	1,164	6.0	37.9	161,000
A-58	6.0	1,160	6.4	36.9	56,000
A-50	5.0	1,153	6.4	41.3	5,800
A-64	6.8	1,142	6.4	43.7	593,000

EFFECT OF ALIEN CYTOPLASMS ON BOLL TRAITS AND FIBER QUALITY IN *GOSSYPIUM BARBADENSE* L.

Jinfa Zhang, J. McD. Stewart and Gwen Coyle[1]

RESEARCH PROBLEM

In a preliminary study, Zhang et al. (1997) observed that cotton lines containing the cytoplasms of wild species related to cotton generally had increased leaf photosynthetic rate, while cytoplasms from cultivated or tetraploid cottons had less effect on photosynthesis. Stomatal conductance of the leaves in these lines was consistently increased by alien cytoplasms and appeared to account for the apparent increase in photosynthesis. Variation in a number of traits is possible when the cytoplasm of cotton is replaced by ones from related species. Since the genus *Gossypium* comprises 49 species in nine genomic groups, extensive possibilities for cytoplasmic replacement are available to create a diversity of cytoplasmic effects in cultivated cottons. The objective of this investigation was to evaluate the effects of alien cytoplasms on fiber quality and other parameters.

BACKGROUND INFORMATION

All upland cottons (*Gossypium hirsutum* L., AD1) grown in the world, with the exception of a few hybrid varieties, share a common cytoplasm (maternal inheritance, i.e., chloroplast and mitochondria genomes). Based on chloroplast DNA analysis (Wendel and Albert, 1992), the cytoplasm of *G. barbadense* (AD2) is very similar to that in upland cotton. Since photosynthesis and respiration are functions of chloroplasts and mitochondria, respectively, the genes on these two organelle genomes, and their interaction with nuclear genes, play an important role in energy conversion. The effects of several cytoplasms, A1 (*G. herbaceum*), A2 (*G. arboreum*), B1 (*G. anomalum*), D2-2 (*G. harknessii*), F1 (*G. longicalyx*), AD2 and AD3 (*G. tomentosum*), have been investigated on upland cotton background (Meredith et al., 1979; Bourland and Mahill, 1985). Those investigations included the induction of male sterility and external ovules and alternations in anther number, seed quality, yield and pest resistance. Additional cytoplasmic lines have since been developed by Stewart (1990). The cytoplasms in these experiments were from the species *G. arboreum* (A2), *G. anomalum* (B1), C1 (*G. sturtianum*), *G. harknessii* (D2-2), *G. davidsonii* (D3-d), *G. trilobum* (D8), *G.*

[1]Graduate Assistant, Professor and Research Specialist, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

stocksii (E1), *G. longicalyx* (F1), *G. hirsutum* race palmeri (AD1), *G. tomentosum* (AD3), *G. mustelinum* (AD4) and *G. darwinii* (AD5), each in the *G. barbadense* (AD2) nuclear background.

RESEARCH DESCRIPTION

The cytoplasmic substitution lines in the AD2 (Pima 57-4) nuclear background were developed by Stewart (1990). These lines were grown in a field of Captina Silt Loam at the Agricultural Research and Extension Center at Fayetteville in a randomized complete block design with three replications. The following traits were measured: 1) boll size (g); 2) lint percent (%); 3) fiber length (inches); 4) fiber uniformity (%); 5) fiber strength (tex/g); 6) fiber elongation (%); 7) micronaire; and 8) anther number. For the anther number measurement, additional cytoplasmic lines containing the cytoplasms of A2, B1, F1, AD3 and AD4 on Sev7 (a virescent-leaf line with semigamy expression) nuclear background were sampled together with the recurrent Sev_7 parent.

RESULTS

Effect of Alien Cytoplasms on Anther Number

D2-2, AD3 and AD5 cytoplasms significantly increased anther number, while A2, B1, D8, E1 and F1 cytoplasms significantly decreased anther number. Although C1 and D3-d cytoplasms reduced the anther number to some extent, the difference was not significant. AD1, AD2 and AD4 cytoplasms had similar effects on anther number.

Effect of Alien Cytoplasms on Boll Size and Lint Percentage

The C1 and D2-2 cytoplasms, both of which confer male sterility, significantly (P = 0.05) decreased boll weight by 30.1% and 22.5%, respectively, while D3-d and E1 cytoplasms increased the boll size by 14.4% and 22.5%, respectively. Interestingly, D8 cytoplasm, which also expresses male sterility, did not affect boll size. The lines with A2, D8, AD1, AD5 cytoplasms were not significantly different from AD2, the recurrent parent, in boll size or lint percentage. Other cytoplasmic lines including C1, D2-2, D3-d and E1 showed a significant reduction in lint percentage.

Effect of Alien Cytoplasms on Fiber Quality

The A2, D8 and AD5 cytoplasmic lines had no significant difference from the recurrent parent (57-4) in fiber quality. The C1 and D2-2 cytoplasms increased fiber length; however, C1 cytoplasm also reduced fiber elongation without affecting fiber strength. The D3-d and E1 cytoplasms decreased micronaire, indicating that both cytoplasms could be useful for increasing fiber fineness in cotton.

PRACTICAL APPLICATION

The genes carried in the cytoplasm must interact with those of the nucleus for the plant to function properly and efficiently. The results show that the cytoplasm of a cotton variety can influence quantitative traits. In this experiment, one nucleus was used to compare nine cytoplasms to obtain a preliminary assessment of the effects of specific cytoplasms. With other nuclear backgrounds the results may vary, however, some of the cytoplasms appear detrimental while others may have potential to positively influence some traits without being detrimental to others.

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Table 1. Influence of alien cytoplasms on agronomic and fiber quality parameters of long staple cotton.

Cytoplasm	Anther Number	Boll wt.	Lint %	Fiber strenth	Fiber strength	Elongation	Mic
A2	-	0	0	0	0	0	0
C1	0	-	-	+	0	-	0
D2-2	+	-	-	+	0	0	0
D3-d	0	+	-	0	0	0	-
D8	-	0	0	0	0	0	0
E1	-	+	-	0	0	0	-
AD2*	CK	CK	CK	CK	CK	CK	CK
AD5	+	0	0	0	0	0	0
AD1	0	0	0	0	0	0	0

*AD2 = Pima 57-4.

SEGREGATION PATTERNS OF MOLECULAR, MORPHOLOGICAL AND QUANTITATIVE TRAITS IN A TRISPECIES F_2 COTTON POPULATION

M.K. Altaf, R.G. Cantrell, Jinfa Zhang and J. McD. Stewart[1]

RESEARCH PROBLEM

A project is under way to develop genetic linkage maps of *Gossypium arboreum* and *G. trilobum* relative to *G. hirsutum* via morphological and molecular markers, including Random Amplified Polymorphic DNAs (RAPDs), Amplified Fragment Length Polymorphisms (AFLP) and some qualitative traits on an F_2 population derived from a trispecies hybrid *G. arboreum* (A_2) x *G. trilobum* (D_8) x *G. hirsutum* (AD_1) cv T-586. Objectives are 1) to determine the genetic efficiency of the synthetic tetraploid bridge strategy for transferring traits into cotton as described by Stewart (1995); 2) to investigate the inheritance of morphological, molecular and qualitative traits in the segregating trispecies F_2 population; and 3) to use informative markers to establish linkage maps among the three genomes (A_2, D_8 and AD_1).

BACKGROUND INFORMATION

Many molecular marker systems including Restriction Fragment Length Polymorphism (RFLP), AFLP, RAPD and Simple Sequence Repeats (SSR) are in common use for genetic mapping. RAPD markers are simpler to assay than RFLPs and can detect polymorphisms in both low-copy and repetitive DNA sequences (Williams et al., 1990). AFLP, developed by Zabeau and Vos (1993), is an efficient Polymerase Chain Reaction (PCR)-based technique used to generate a large number of polymorphic DNA fragments. Like RAPDs, most of the AFLP markers are dominant and show Mendelian inheritance.

RESEARCH APPROACH

Three different species parents were used to obtain the interspecific hybrid population. First, *G. arboreum* cv. 'Nanking' was crossed with *G. trilobum* to get an (A_2 x D_8) hybrid, and colchicine was used to double the chromosome number.

[1]Graduate Student, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas; Professor, Agronomy and Horticulture Department, New Mexico State University, Las Cruces, New Mexico; and Graduate Assistant and Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

This synthetic allotetraploid was crossed with the *G. hirsutum* cv. 'T-586', a multiple dominant marker line. An F_2 population of 90 plants from a single trispecies F_1 hybrid was grown and maintained in the greenhouse. DNA was prepared according to the protocol developed by Altaf et al. (1997). Morphological and quantitative data were obtained for each plant. Self-pollinated progeny of five plants from each of the three parental genotypes, as well as the single F_1 plant, were used for preliminary survey of DNA polymorphisms.

RESULTS AND DISCUSSION

Morphological traits including plant color, plant hair and seed fuzz were scored on each of the three parental lines, the synthetic allotetraploid, the trispecies F_1 hybrid and the 90 F_2 plants. The three morphological markers showed normal 3:1 segregation ratios. Out of 90 F_2 plants, 72 plants bloomed, and 43 plants produced various numbers of mature bolls and seed under open pollinated conditions, indicating that most of the genetic recombination could be advanced into the next generation. For quantitative data, 12 botanical and agronomic traits were measured to determine chromosomal areas contributing to specific quantitative traits (quantitative trait loci or QTLs). All of the quantitative traits measured showed high genetic variation.

Sixty percent of the molecular markers, both RAPD and AFLP, scored in the trispecific F_2 population, showed significant deviation from the expected 3:1 dominant segregation ratio at $P < 0.01$ in the F_2 population. At the chromosomal level, hybrids of *G. arboreum* lines form 13 pairs at meiosis. The chromosomes of the *G. hirsutum* A subgenome and *G. arboreum* differ by three reciprocal translocations involving chromosomes 1-5, thus one ring of four and one of six chromosomes occur frequently at meiosis in AD x A hybrids (Menzel et al., 1982). These three naturally occurring reciprocal translocations cause chromosomal duplications and deficiencies leading to pollen abortion that would result in skewed segregation of affected loci in the trispecific F_2 population. Other possible reasons for high abnormal segregation ratios could be evolutionary divergence of the three species that would result in areas of low recombinations between the genomes.

The combined data comprising molecular, morphological and quantitative traits will be used for linkage and QTL analyses to construct genomic maps of the three species.

PRACTICAL APPLICATION

Development of a genetic linkage map is the first step toward the detection of factors that control the expression of economically important traits. Much of the effort in constructing such a map is directed toward identifying useful polymorphic markers, and, once identified, these markers can be used in numerous other pedigrees and related taxa. This project was initiated to develop maps of *G. arboreum* and *G. trilobum* relative to *G. hirsutum*. Markers derived from this project will be useful to identify alien introgressions and economically important traits in this and other cotton populations.

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USE OF RAPD MARKERS TO ANALYZE GENOMIC AFFINITY AMONG AUSTRALIAN *GOSSYPIUM* SPECIES

M.K. Wajahatullah, J. M. Stewart and J. Zhang[1]

RESEARCH PROBLEM

The phylogenetic relationships among the Australian wild relatives of cotton are not completely understood. Inasmuch as these are part of the germplasm pool available for cotton improvement, the diversity among them should be documented to avoid duplication in utilization. An analysis based on Random Amplified Polymorphic DNAs (RAPDs) was conducted in an effort to resolve some of the questions.

BACKGROUND INFORMATION

Over one-third of all known *Gossypium* species are indigenous to Australia (Craven et al., 1995). All of these species belong to subgenus *Sturtia*, which is divided into three sections, *Sturtia*, *Hibiscoidea* and *Grandicalyx*. One species, *G. bickii*, has the nuclear genome of one section and the cytoplasm of another (Wendel et al., 1991). Taxonomically *G. bickii* belongs to Section *Hibiscoidea*; morphologically it is related to the other two *Hibiscoidea* species, *G. australe* and *G. nelsonii* (Stewart et al., 1987). Edwards and Mirza (1979), on the basis of chromosome karyotype, established a new genomic group (G) to accommodate *G. bickii*; however, partially fertile hybrids among the three species have been reported (Stewart and McCombie, 1991). The cytoplasm of *G. bickii*, unlike that of other *Hibiscoidea* species, is closely related to *G. sturtianum* in Section *Sturtia*. *Gossypium nandewarense* is very similar to *G. sturtianum*, and there is some question concerning its distinctiveness as a species (Craven et al., 1995). *Gossypium* species in the Section *Grandicalyx* are morphologically distinct; however, two species were included in this investigation because of their occurrence in Australia. Fryxell (1984) in past taxonomic treatments of *Gossypium* classified *G. triphyllum* with the *Hibiscoidea* even though it is an African species.

RESEARCH DESCRIPTION

The species and accessions examined are listed in Table 1. In addition to the species mentioned above, *G. longicalyx* was included as an out group for comparison. Total genomic DNA was isolated and purified for each accession. The poly-

[1]Visiting Scholar, Professor and Graduate Assistant, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

merase chain reactions (PCR) used to generate the RAPDs were primed with 10-mer random primers. Amplifications were performed in a thermal cycler programmed for initial 2 min denaturation at 94°C, followed by 45 cycles of 15 sec at 94°C, 30 sec at 40°C and 5 min at 72°C. PCR products were separated by electrophoresis on 1.4% agarose gels and strained with ethidium bromide. A data matrix was created for all genotypes and analyzed with the Numerical Taxonomy and Multivariate Analysis System (NTSYS-pc), version 1.8 (Rohlf, 1993) to generate similarity coefficients. The similarity coefficients were used to construct a dendrogram using the unweighted pair method with arithmetic averages.

RESULTS

Twenty-four of 32 primers examined yielded useful product in the PCR reaction. From the 24 informative primers, a total of 622 fragments were scored, and 606 of these showed DNA polymorphism in at least one pairwise comparison among the 14 genotypes. The two non-Australian species (*G. triphyllum* and *G. longicalyx*) accounted for 20% of the total polymorphism. Some species-specific bands were observed, as well as one Australian species-specific band. As expected, genomic affinities within species were high compared to between species. The dendrogram showed eight groups corresponding to eight of the nine species. All accessions of a particular species fell in their respective groups with the exception of *G. nandewarense,* which clustered with the *G. sturtianum* accessions. These results confirm that the taxon referred to as *G. nandewarense* is a variant of *G. sturtianum* and does not merit species rank. The African species *G. triphyllum* has no affinity to the *Gossypium* species in section *Hibiscoidea*. *Gossypium bickii* clustered approximately at the mid-point between sections *Sturtia* and *Hibiscoidea*. This probably reflects its hybrid origin. Species in section *Grandicalyx* reflected and confirmed their distinctness from the other Australian *Gossypium* species.

PRACTICAL APPLICATION

Classification of species that contribute to the cotton germplasm pool is based on morphological characters that may or may not reflect major differences in the genetics of two taxa. Molecular analyses allow direct comparisons of plants at the DNA level, hence giving a more accurate assessment of the diversity. As a result of this study, we need no longer maintain *G. nandewarense* as a separate species for germplasm purposes. Also, we can treat *G. triphyllum* as a germplasm resource completely separate from the Australian species.

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Table 1. *Gossypium* species and accessions used in this study.

Section	Species/Accession	Genome	Description
Sturtia	*G. sturtianum* G5068	C1	Transcentral arid zone
	G. sturtianum 464863	C1	"
	G. nandewarense	C1-n	NSW, Queensland
Hibiscoidea	*G. australe* 464842	G	Trans-Australia, north arid zone
	G. australe 478751	G	"
	G. australe 499758	G	"
	G. nelsonii 499782	G	Central Australia arid zone
	G. nelsonii 499783	G	"
	G. bickii BW-12	G1	"
	G. bickii BW-12x464843	G1	"
Grandicalyx	*G. anapoides* NWA-24	K	Wet/dry tropics, North Kimberley
	G. enthyle NWA-59	K	"
Gossypium	*G. triphyllum*	B2	Namibia, Africa
Longiloba	*G. longicalyx*	F1	East Central Africa

SURVEY OF COTTON GERMPLASM FOR TERPENOID ALDEHYDES IMPORTANT IN HOST PLANT RESISTANCE

M.K. Altaf, J.M. Stewart and J.B. Murphy[1]

RESEARCH PROBLEM

In cotton, gossypol and related terpenoid aldehydes (TAs) are the principal allelochemicals involved in defensive mechanisms against insects. Thus, glandless varieties devoid of "gossypol glands" are extremely susceptible to foraging insects (Jenkins et al., 1966), and genotypes with high "gossypol" have a greater degree of resistance. The main TAs of cotton are gossypol (G), heliocides (H_1, H_2, H_3 and H_4) and hemigossypolone (HGQ). Information is limited on the ratios of the TAs in cotton leaves, on the relative effectiveness of the individual TAs, or on the diversity in TAs in the cotton germplasm pool. A research project was initiated to determine the amount of variation in terpenoid aldehydes (TAs) among a broad set of *Gossypium* species in the cotton germplasm pool. Identification of germplasm with high levels of specific TAs could be useful as a source of genes to increase the expression of selected TAs in cotton.

BACKGROUND INFORMATION

Terpenoid aldehydes such G, H_1, H_2, H_3 and H_4 and HGQ have been bioassayed against *Heliothis virescens* and other insect pests in artificial diets (Hedin et al., 1981). The heliocides H_1--H_4, and G retard growth of *H. virescens* about equally, while HGQ is slightly less effective (Stipanovic et al., 1988). Genetic research has shown that these lysigenous compounds are amenable to selection, and their level can be increased to enhance resistance to insects.

Overall insect toxicity can vary greatly among individual TAs. For breeders and geneticists who wish to manipulate the terpenoid chemistry of cotton, the important tissues are the plant parts directly under attack from major target pests. Thus, they can select for higher terpenoid levels in leaves and flower buds to increase host-plant resistance (Altman et al., 1989). Improved analytical methods have become available for detecting and quantitating individual cotton terpenoids. These methods include nuclear magnetic resonance (NMR) (Waiss et al., 1978) and high-performance liquid chromatography (HPLC) (Khan et al., 1993).

[1]Graduate student and Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas; and Professor, Department of Horticulture, University of Arkansas, Fayetteville, Arkansas.

We undertook this study, using HPLC, with the objective to determine if the quality and quantity of TAs in the leaves of *Gossypium* species reveal differences in biosynthetic end points among and within the different genomic groups. This information will assist in evaluating the potential for HPR germplasm enhancement using these TAs.

RESEARCH DESCRIPTION

Plant Material

Samples of mature leaves were taken from 41 genotypes grown in a greenhouse at the University of Arkansas Research and Extension Center, Fayetteville. Thirty species of *Gossypium* and one of *Thespesia* were represented. All samples were washed, blotted dry, frozen at -80°C, freeze-dried and ground with a Wiley mill to pass a 20-mesh screen.

HPLC Method

The procedure outlined by Stipanovic et al. (1988) was used for these analyses with minor modifications. Duplicate HPLC analyses were made on all samples. Standard curves for G, HGQ, H1, H2 and R were constructed from three replications each at concentrations of 0.05 mg/ml, 0.25 mg/ml, 0.01 mg/ml and 0.005 mg/ml. Standard curves for H1 and H2 were used for quantification of H4 and H3, respectively.

RESULTS

Gossypium mustelinum had the highest leaf concentration of H_1, H_4 and total TAs among the genotypes examined, while H_2, H_3 and HGQ were in highest quantity in *G. capitis-viridis*, *G. lobatum* and *G. nobile*, respectively. Gossypol was highest in a *G. laxum* accession. A unique TA, raimondal (R), was the principal TA in *G. raimondii* with low quantities of G and H_1 as the only other TAs. Species in the B, C, G, K and F genomes had very low concentrations of G compared to other TAs. In most of the D genome species, G was the principal foliar TA, whereas in the AD genome, with some exceptions, all six TAs occurred. Three distinct patterns were observed among accessions taxonomically designated as *G. laxum*. Group A had G, H_1, H_2 and H_4, group B had H_1 and H_2, and group C had only G in high quantities in the foliage. A relative of *Gossypium*, *Thespesia thespesioides*, had a higher concentration of G compared to *Gossypium* species. Most of the species with lower quantities of the six TAs analyzed usually had higher quantities of unknown compounds.

PRACTICAL APPLICATION

Genetic alteration of the major terpenoids in cotton pigment glands potentially could result in improved insect resistance for the whole plant. Breeding strategies for greater insect resistance often are based on elevated foliar terpenoid production. The diversity in biosynthesis and accumulation of TAs among the species should provide useful material to study the metabolic pathways and regulatory mechanisms controlling the occurrence of these compounds. The high concentrations of TAs in *G. mustelinum* make it a good choice for breeding material because it is a tetraploid plant similar to cotton.

ACKNOWLEDGMENT

We are grateful to Dr. R.D. Stipanovic for providing the gift of standards.

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A METHOD OF DNA ISOLATION AND PURIFICATION FROM *GOSSYPIUM* SPECIES FOR MOLECULAR STUDIES

M.K. Wajahatullah, M.K. Altaf, J.M. Hoyt and J.M. Stewart[1]

RESEARCH PROBLEM

The isolation of good-quality genomic DNA in sufficient quantity is a prerequisite for molecular studies. Extraction of high-quality genomic DNA from cotton plants suitable for digestion with restriction endonucleases is difficult because they have high levels of phenolic compounds, polysaccharides and other organic constituents that make DNA extraction difficult. Plant systematic and molecular studies in *Gossypium* have been restricted by the lack of an efficient DNA isolation protocol that gives good-quality DNA from a wide range of *Gossypium* species. To obtain accurate results from molecular studies, it is necessary to isolate DNA that is relatively free from the many contaminants found in *Gossypium* species.

BACKGROUND INFORMATION

High endogenous levels of polysaccharides, phenolics and other organic constituents, which form a sticky, brown gelatinous matrix during DNA isolation, interfere with the separation and digestion of genomic cotton DNA (Dabo et al., 1993). Previous protocols for cotton DNA extraction are time consuming and expensive and often require ultracentrifugation in CsCl gradients (Wendel, 1989). Methods to improve the isolation of DNA from cotton have been developed (Paterson et al., 1993; Brubaker and Wendel, 1994), but in general, DNA extraction from different *Gossypium* species gives DNA of variable and unpredictable quality. Success in DNA extraction is measured not only by yield but also by DNA quality determined by the ease with which it is digestible with restriction enzymes, replicated with polymerase, etc. To assure purity before utilizing DNA in enzymatic reactions, we incorporated a purification procedure for cotton genomic DNAs based upon the inclusion of a powerful metal chelating agent 1, 10-phenanthroline ($C_{12}H_8N_2$) (Filho and Meneghini, 1985; Halliwell and Gutteridge, 1990).

RESEARCH DESCRIPTION

Nine *Gossypium* species (Table 1) were used to determine the efficiency and broad applicability of the DNA purification protocol.

[1]Visiting Scholar, Graduate Student, Research Specialist and Professor, Department of Agronomy, University of Arkansas, Fayetteville, Arkansas.

Genomic DNA Extraction

Newly expanded leaves from each species were collected and kept in dark at room temperature overnight to metabolize the starch present in the leaves before being transferred to -80°C for storage. The leaves were ground in liquid nitrogen and then added to **extraction buffer** [100 mM Tris-HCl (pH 8.0), 20 mM EDTA, 1 M NaCl, 2% CTAB, 0.4% ß-mercaptoethanol and 2% PVP] at a ratio of 3 mL/g of tissue (approx. 5 g of tissue were used). The suspension was vortexed and mixed gently. The mixture was kept at 70°C for 1 hr and then cooled to room temperature. The suspension was extracted twice with an equal volume of 24:1 **CIA** (Chloroform : Isoamyl alcohol) to denature and separate proteins. The supernatant was transferred to a new tube and the DNA precipitated at -20°C with an equal volume of isopropanol. The DNA was spooled out with a small glass hook and washed once with **washing solution** (80% ethanol + 1 mM Ammonium Acetate) and once with 100% ethanol for 20 min each. The pellet was dried and then redissolved in 5 mL of **high salt TE solution** (10 mM Tris-pH 8.0, 1 mM EDTA-pH 8.0, and 1 M NaCl) kept at 60°C for 1-2 hrs. The DNA was again precipitated, spooled out and washed. The pellet was dried and resuspended in **low salt TE solution** (10 mM Tris, 1 mM EDTA-pH 8.0). About 2 µg of 10 mg/mL Rnase A per 100 µl of DNA solution was then added. The DNA was transferred to a 50-mL centrifuge tube, and 15 mL of **purification buffer** (2% CTAB, 0.35 M NaCl, 50 mM Tris-HCl pH 8.0, 50 mM EDTA-pH 8.0, 2 mM 1,10-phenanthroline) was added to precipitate the DNA. The tube was shaken gently for 2 hr at room temperature and then kept at -20°C for 2 hr. The tube was then shaken again for 1 hr at room temperature to dissolve CTAB. The precipitated DNA was spooled out (if difficult to spool, then centrifuge at 12,000 xg for 10 min) and washed with washing solution and 100% ethanol for 20 min each. The DNA pellet was dried and dissolved in the low-salt TE solution and treated with Rnase-A as mentioned above.

Restriction Digestion

In a total volume of 24 µL reaction mixture, 20 µL of DNA sample (0.5 µg/µL) was restricted with 1 µL of Hind III endonuclease (10 units/µL), 2.4 µL of reaction buffer type-II brought to a final volume of 24 µL with H_2O and kept at 37°C for 12 hours. The results of restriction digestion were checked on a 20 x 20 cm 0.8% agarose gel in TBE buffer. The electrophoresis was carried out at 70 volts for 4-5 hrs, and the gels were stained in ethidium bromide.

RESULTS

The DNA purification method was based upon CTAB-DNA precipitation and use of a powerful metal chelater (1,10-phenanthroline). The DNA extraction protocol was slightly modified from Brubaker and Wendel (1994). The 12 *Gossypium* species represented six of the nine genome groups. To check the efficiency of the purification protocol, the extracted genomic DNA samples were subjected to the purification protocol. The purified DNA samples were found to be easily restrictable with Hind III restriction enzyme compared to the unpurified DNAs samples. General distribution across the gel and the absence of high-molecular-weight DNA in the purified samples indicated that DNA was digested and free of contaminants. In contrast, the unpurified, digested samples showed some high-molecular-weight DNA, indicating the presence of contaminants interfering with digestion by the endonuclease. Previous studies have shown that 1,10-phenanthroline inhibits the degradation of DNA (Gutteridge, 1984) and protects DNA from damaging effects in the presence of iron ions (Filho and Meneghini, 1985). However, in living systems it induces DNA degradation in the presence of copper ions, oxygen and a suitable reducing agent (Halliwell and Gutteridge, 1990). The DNA purification protocol yields sufficient quantity of DNA for a large number of molecular applications and shows consistancy in its ability to yield high-quality DNA from a broad range of *Gossypium* species.

PRACTICAL APPLICATIONS

This DNA purification protocol consistently yielded good-quality, restrictable DNA from various *Gossypium* species among the different genome groups. The isolated DNA is suitable for molecular studies such as Random Amplified Polymorphic DNAs (RAPDs), Restriction Fragment Length Polymorphisms (RFLPs), Amplified Polymorphic DNAs (AFLPs) and Simple Sequence Repeats (SSRs).

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Table 1. *Gossypium* species used for DNA extraction, purification and endonuclease digestion.

Species	Genome
Diploids (2n=2X=26)	
G. arboreum	A_1
G. capitis-viridis	B_3
G. raimondii	D_5
G. australe	G
G. longicalyx	F_1
Tetraploids (2n=4x=52)	
G. hirsutum	AD_1
G. barbadense	AD_2
G. tomentosum	AD_3
G. mustelinum	AD_4

CHANGES IN THE COTTON BOLL WALL IN RELATION TO BOLL WEEVIL AND BOLLWORM FEEDING

M.J. Kim, D.M. Oosterhuis, N.P. Tugwell and F.M. Bourland[1]

RESEARCH PROBLEM

Bollworm and boll weevil damage to developing cotton bolls declines dramatically at approximately 350 heat units after pollination of the flower that produced the boll (Bagwell, 1995). This phenomenon can be used to time the cessation of certain insecticide applications to the cotton crop. This study evaluates the change in insect feeding habits by investigating anatomical and biochemical changes during boll wall development. The effect of plant growth regulators, PIX and PGR-IV, on the development of the boll wall was also investigated. This project should help explain the decline in attractiveness of the cotton boll with age to bollworm and boll weevils and provide additional confidence in using this phenomenon in insecticide termination.

BACKGROUND INFORMATION

Cotton bolls are the economically important component of the cotton plant. However, developing cotton bolls are prone to attack from insects, and considerable efforts are expended to protect the developing boll load. Recent research in Arkansas has shown that bollworm and boll weevil damage to a cotton boll declines dramatically at approximately 350 heat units (DD 60's) after pollination of the flower that produced the boll (Bagwell, 1995). This fact is used in the COTMAN cotton monitoring program for timing the termination of insecticide applications at 350 heat units after pollination of the last effective flower at NAWF = 5 (Cochran et al., 1995). Use of the "350 heat units after cutout decision rule" could potentially reduce input costs and save up to $50/acre in southeastern Arkansas (Cochran et al., 1994). However, the concern is that if insecticide applications are terminated too early, a decrease in yield could result.

RESEARCH DESCRIPTION

An experiment was conducted at the Arkansas Agricultural Research and Extension Center in Fayetteville, Arkansas. Cotton (*Gossypium hirsutum* L.) cv. Deltapine 20 was planted 10 May 1996 into a Captina silt loam soil. Rows were spaced 0.9

[1]Graduate Assistant, Professor of Crop Physiology, Professor of Entomology and Professor of Plant Breeding, University of Arkansas, Fayetteville, Arkansas.

m apart in a north-south direction, and plots were four rows wide and 5 m long. All plots received fertilizer and pesticide applications according to cotton production recommendations for Arkansas. The experiment was arranged in RCB design with three treatments and three replications. Treatments consisted of a control with no PGRs added, PIX™ (4 oz PIX/acre at pinhead square and 8 oz PIX/acre at first flower), and PGR-IV™ (4 oz/acre at pinhead square and first flower). Two taggings of 30 white flowers per plot were made: one at first flower and one at NAWF = 5. Thereafter, six bolls per plot were sampled from each tagging at weekly intervals and the heat units recorded. Physical, anatomical and biochemical measurements were made to record changes in boll wall development.

Physical boll wall measurements included boll size, boll wall thickness, dry weight, seeds per boll, seed weight and resistance to penetration of the boll wall (endocarp) with a modified penetrometer. Boll water content, water potential and osmotic potential were also measured. Anatomical structure of the capsule wall during fruit development was studied using light and transmission electron microscopy. Biochemical analyses included measurements of starch, sugars (glucose, sucrose and fructose) and malic acid.

RESULTS AND DISCUSSION

Preliminary results indicate that the decline in attractiveness of the cotton boll with age to bollworms and boll weevils may be due to several physical and anatomical changes in the capsule wall. The characterization of the boll growth agreed with the ontogeny described by Van Iersel and Oosterhuis (1994). Boll size and boll wall thickness reached a maximum about three weeks after anthesis. Resistance to penetration of the boll wall increased sharply between three and four weeks after white flower (Fig. 1), which corresponded with 307 to 429 heat units after white flower. This coincides with the rapid decline in damage to cotton bolls from the bollworm and boll weevil at approximately 350 heat units after white flower as reported by Bagwell (1995). Plant growth regulators, PIX and PGR-IV, did not have any noticeable effect on developmental trends of the boll wall. Anatomical and biochemical measurements indicated that the parenchymous capsule wall increased in thickness, density, tannins and epicuticular waxes with fruit age but with no dramatic change at 350 heat units. This was in contrast to the resistance to penetration of the boll wall, which increased sharply at approximately 350 heat units. The boll wall carbohydrate contents are currently being analyzed.

PRACTICAL APPLICATION

This study provides information on cotton boll wall development and changes that could explain the decline in bollworm and boll weevil damage at approximately 350 heat units after white flower. These results suggest that the changes in boll growth with time, measured as 350 heat units after anthesis, can be used to predict when resistance to penetration reduces feeding by insects. This information is important because it provides physical evidence to support termination of insecticide applications using the “350 heat units after cutout decision rule.” Decrease in yield is not likely to result from early termination of insecticide application if this rule is followed.

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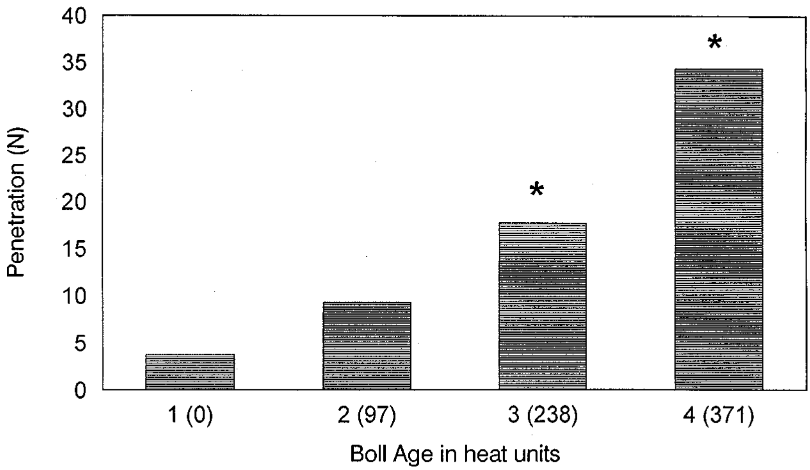

Fig. 1. Resistance of the boll wall to mechanical penetration with time in weeks and heat units after white flower. Individual flowers were tagged at nodes-above-white-flower = 5 and sampled weekly thereafter. *Dates after week 2 are significantly different (*P* = 0.05).

INSECTICIDE TRIALS WITH TARNISHED PLANT BUGS

T.G. Teague and N.P. Tugwell[1]

RESEARCH PROBLEM

The tarnished plant bug remains a threat to cotton production in the Mid-South. In the future its injurious effects may appear even greater in areas in which boll weevil is eradicated and where *Bt* transgenic cotton is widely grown. Testing new insecticides and re-evaluating standard products remains a priority area in cotton insect research.

BACKGROUND INFORMATION

Populations of plant bugs with increased tolerance to insecticides and, in some cases, insecticide resistance have been reported in Arkansas and Mississippi (Hollingsworth et al., 1997; Snodgrass and Elzen, 1996). As new insecticides become available for cotton, evaluation of effectiveness of these materials in comparison with standard insecticides is necessary to provide up-to-date chemical control recommendations for cotton farmers and their advisors.

RESEARCH DESCRIPTION

Three separate studies were conducted in 1996 at the Cotton Branch Experiment Station in Marianna. For each trial, cotton was planted on 9 May in eight-row (38-in. centers) plots 70 ft long with 10-ft alleys and separated by a 6.5-ft buffer planted in mustard, which was blooming at the time of the study. Treatments were arranged in a RCBD with three replications. Insecticides were applied using an eight-row, CO_2-charged, hi-boy sprayer calibrated to deliver 8.5 gpa at 30 psi with TJ-60 8002 nozzles on 19-in. spacing.

In the first trial, fipronil and two different formulations of Karate were evaluated using a cage bioassay. Treatments were applied 25 July. Prior to application, plant bugs were collected using sweep nets in blooming mustard then placed in 15-ml plastic vials (five insects per vial) on ice. Three organdy sleeve cages, 6 in. diameter by 18 in. long, were secured to randomly selected individual plants in the center two rows of each plot by tying the lower end of each cage around the plant ca 1 ft from the terminal with twist ties. The cages were rolled down to the tie and covered with aluminum foil, leaving plant terminals exposed. Following insecti-

[1]Associate Professor of Entomology, University of Arkansas Agricultural Experiment Station, Arkansas State University, Jonesboro, Arkansas; and Professor of Entomology, University of Arkansas, Fayetteville, Arkansas.

cide application, the foil was removed, the cage pulled up, and five plant bug nymphs (3rd to 5th instar) were placed into each cage. Cage tops were secured with twist ties. After 96 hrs following insecticide application, plants were cut below the cage and taken to the laboratory where plant bug mortality was determined. All data were analyzed with ANOVA and means separated with LSD.

The second trial included evaluation of two rates of Curacron and and a standard, Orthene. Applications were made 26 July. In addition to an assessment of plant bug control using the cage bioassay, bollworm control also was evaluated. At four days after treatment (DAT), numbers of medium and large larvae per 20 terminals were surveyed in plants in the center four rows of each plot. A group of synthetic pyrethroids, the new insect control product Tracer and the standard Orthene were evaluated in the third trial. Treatments in this trial were applied 26 July and evaluated for bollworm control four days after treatment by examining 25 terminals and 25 bolls in the center four rows of each plot. Numbers of plant bugs were estimated using 25 sweeps of an 18-in. net and six drop cloth samples on 9 ft of row (1.5-ft drops). Effects on beneficial natural enemies also were evaluated in this trial. Predaceous insects were counted in drop cloth samples. The predators were separated into groups: total predators and Hemipterian predators. The latter group consisted of *Geocoris* spp., *Nabis* spp. and *Orius* spp.

RESULTS

Trial 1 - Fipronil and Karate

Highest mortality was recorded in treatment plots receiving applications of fipronil (Table 1). No differences in mortality were observed between the different formulations of Karate.

Trial 2 - Orthene and Curacron

Plant bug mortality was greatest in treatment plots receiving applications of Orthene (Table 2). Mortality was determined to be 90% compared to 60% and 68% mortality at the high and low rates of Curacron. Bollworm numbers were not significantly affected by treatments.

Trial 3 - Synthetic Pyrethroids, Orthene and Tracer

Applications of the synthetic pyrethroids Karate, Baythroid, Decis and Capture at the high rate significantly lowered numbers of large bollworms and damaged bolls compared to the untreated control that equaled Orthene, Tracer and the lower rate of Capture (Table 3). Significantly lower numbers of plant bug were observed in drop cloth samples for all pesticides tested compared to the untreated control. Best control was observed in plots receiving Capture at 0.06 lb ai/acre and in Orthene plots. It should be noted that the drop cloth sample method was superior in allowing separation of treatment effectiveness compared to the sweep net. All treatments significantly lowered numbers of Hemipterian predators compared to the untreated control.

PRACTICAL APPLICATION

It is notable that the fields in which these trials were conducted had not been sprayed previously that season with insecticides. The relative susceptibility of the plant bug population to synthetic pyrethroids and other compounds probably was related to this lack of selection pressure. Applications of synthetic pyrethroids in early season has been shown to select for resistance within the same crop year, making control of late-season plant bugs difficult (Snodgrass and Elzen, 1996). Farmers and crop advisors are strongly encouraged to practice good rotation of insecticide classes and strictly adhere to the recommended Mid-South Insecticide Resistance Management Policy as outlined in Arkansas Cooperative Extension recommendations in order to avoid (or delay) selection for resistant populations of plant bug.

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Table 1. Mortality of tarnished plant bugs (TPB) after exposure to fipronil and Karate in cages for 3 days.

Treatment	Rate	% TPB Mortality
	lb (ai)/acre	
Fipronil 2.5 EC	0.068	68.5
Karate 1 EC	0.030	68.5
Karate 2.09 CS	0.030	85.0
Untreated		0.0
P > F (ANOV)		0.05
LSD $_{(0.05)}$		18.1

Table 2. Tarnished plant bug percentage mortality and numbers of bollworms following applications of Curacron and Orthene.

Treatment	Rate	% TPB Mortality	Mean no. bollworms/ 25 terminals
	lb (ai)/acre		
Curacron 8E	0.25	68	2.0
Curacron 8E	0.50	60	1.0
Orthene 90S	0.50	90	0.0
Untreated		0	1.7
$P > F$ (AOV)		0.05	NS*
LSD $_{(0.05)}$		32.1	

*NS = nonsignificant (P = 0.05).

Table 3. Numbers of bollworms, damaged bolls, plant bugs and beneficial natural enemies present following applications of synthetic pyrethroids, Tracer and Orthene.

Treatment & rate	Mean no. bollworms 25 terminals and 25 bolls		Mean no. bollworm and boll weevil damaged bolls/25 bolls	Mean no. plant bugs		Total generalist predators/ 9 ft row (drop cloth)	Hemipterian predators/ 9 ft row (drop cloth)
	Large	Total (L,M,S)		per 25 sweeps	per 9 ft row (drop cloth)		
lb ai/acre							
Capture 2 EC 0.04	0.50	2.75	7.75	5.25	9.75	20.75	6.50
Capture 2 EC 0.06	0.00	1.25	4.75	3.00	6.00	23.50	5.00
Karate 1 EC 0.028	0.00	1.50	4.00	5.50	7.50	24.75	4.75
Baythroid 2 EC 0.03	0.00	0.00	3.75	7.25	8.50	27.50	9.75
Decis 1.5 EC 0.023	0.00	0.50	3.25	5.00	9.75	25.75	7.75
Orthene 90S 0.5	1.25	3.25	11.50	5.75	6.00	19.00	5.75
Tracer 4 Cs 0.062	0.75	4.25	10.25	8.25	12.25	19.25	2.75
Untreated	1.75	5.75	16.50	7.75	18.50	27.75	16.75
$P > F$ (ANOV)	0.05	NS*	0.01	NS	0.05	NS	0.05
$LSD_{(0.05)}$	1.05		4.96		4.98		5.91

*NS = nonsignificant (P = 0.05).

EXTENSION-BASED SAMPLING SERVICE FOR COTTON APHID FUNGUS

D.C. Steinkraus and G.M. Lorenz III[1]

RESEARCH PROBLEM

Cotton aphid fungus, *Neozygites fresenii*, is the most important natural enemy of mid-season cotton aphids. A major objective of all IPM programs is to make use of natural enemies whenever possible. With the help of Cotton Incorporated funding, we have established a service to diagnose aphid samples from Arkansas cotton fields for fungus. This information is useful in making treatment decisions.

BACKGROUND INFORMATION

Cotton aphids are difficult to control. Aphid populations are often resistant to insecticides, and their high reproductive capacity permits them to rapidly resurge after insecticides are applied. Frequently between early July and mid-August, aphid populations are eliminated by the cotton aphid fungus, *Neozygites fresenii*. This fungus is so effective in reducing aphid populations that, frequently, pesticide studies on aphids are failures because the fungus has eliminated aphids in all plots. Our research has shown that once 15% of the aphids in a field are infected, a decline in aphid populations will occur within approximately one week, sometimes more rapidly. Field scouting for the aphid fungus is difficult because aphids are so small. Laboratory diagnosis with a phase microscope is essentially 100% accurate but requires a trained operator. Therefore, we established a service to diagnose field-collected aphids for extension agents, consultants and growers.

RESEARCH DESCRIPTION

Aphid sampling kits and instructions are distributed to participants in mid-May. Cotton fields are carefully scouted by the participants, who sample aphids and mail them to the diagnostic laboratory by express mail. Subsamples of individual aphids are diagnosed in the laboratory by examining each aphid under a microscope for presence of the beneficial fungus. The percentage of infected aphids is communicated to the agent within 24 hours by FAX or telephone. If infection levels in the aphid population are above 15%, an aphid decline is predicted, and the field may not need to be treated with insecticide.

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[1]Entomologist, Department of Entomology, University of Arkansas, Fayetteville, Arkansas; and Area Cotton Agronomist, Cooperative Extension Service, Little Rock, Arkansas.

RESULTS AND DISCUSSION

The number of counties and Extension agents participating in this service in its first four years of operation are shown in Table 1. Seventy samples were received in 1993, of which 79% contained aphids infected with *N. fresenii*. In 1994, 75 samples were received, and 62% contained infected aphids. In 1995, 125 samples were received, and 60% contained infected aphids. In 1996, 102 samples were received, and 58% contained infected aphids. These data show that *N. fresenii* is both widespread and common in Arkansas cotton fields. The dates for first occurrence of the fungus have been somewhat earlier each year. First occurrences of the fungus were 19 July, 5 July, 7 July and 25 June in 1993, 1994, 1995 and 1996, respectively. This information is useful for predicting the first epizootics and the potential control provided by this fungus. If we use the 15% prevalence rate as the demarcation of the beginning of aphid declines due to the fungus, then epizootics began in Arkansas on 15 July, 5 July, 3 July and 3 July in 1993, 1994, 1995 and 1996, respectively. This indicates that the aphid fungus will often provide control during July but not in June.

PRACTICAL APPLICATION

Control of cotton aphids is difficult and expensive, potentially contaminates the environment with pesticides, leads to increased aphid resistance and kills beneficial insects. A basic principle of IPM is to incorporate greater reliance on natural control of insect pests. Information from the diagnostic service is used by extension agents to make IPM decisions in individual fields and also to track fungal epizootic development across the state. This service is free for growers and has the potential to save them thousands of dollars when epizootics are imminent. Because insecticide applications are reduced, beneficial insects are preserved, pesticides loads on the environment are reduced, and growers save money. This program is a classic example of IPM. Cotton Incorporated has generously funded this service during 1996 and 1997. In 1997 the service has been expanded to include the states of Louisiana and Mississippi.

A summary of Extension-based sampling service for the cotton aphid fungus in Arkansas is given in Table 1. This project directly helps many Extension agents guide growers and consultants in IPM decisions regarding control of cotton aphids.

Table 1. Summary of Extension-based sampling service for cotton aphid fungus in Arkansas.

Year	# counties	# agents	# samples	# fields
1993	12	15	70	36
1994	12	11	75	37
1995	16	22	125	70
1996	15	20	102	66

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

Charles T. Allen and Blair Griffin[1]

RESEARCH PROBLEM

Cotton aphids occur each year on Arkansas cotton. They may or may not be present long enough or in high enough populations to cause economic damage to the crop. Often, cotton aphid populations quickly reach high levels and then very quickly disappear due to infections by an aphid parasitic fungus, *Neozygites fresenii*. However, populations sometimes require treatment. These rapidly reproducing insects are capable of developing resistance to insecticides very quickly (King et al., 1987; King and Phillips, 1989; Allen et al., 1990; Hardee and O'Brien, 1990; Bagwell et al., 1991; Johnson and Studebaker, 1991; Kerns and Gaylor, 1991; Reed and Grant, 1991; Leser et al., 1992). Growers need current information about the effectiveness of the available aphicides in order to effectively control cotton aphid when insecticidal control is needed

BACKGROUND INFORMATION

Much of the information in the literature about the effectiveness of the available cotton aphid insecticides in Arkansas is five years old (Bagwell et al., 1991; Johnson and Studebaker, 1991). Those papers reported poor control with many organophosphate insecticides, rapid aphid resurgence following pyrethroid treatment and aphid-induced fruit shed due to plant stress.

RESEARCH DESCRIPTION

An aphid-infested field located near Winchester in Desha County, Arkansas, was selected for this study. The field was irrigated, 'Nucotn 33B' planted in 38-in. rows on 27 April 1996. It had been fertilized with 250 lb 0-18-36 and 140 lb N/acre.

The test was initiated on 12 July 1996. A randomized complete block design with four replications of treatments was used. The plots were two rows by 25 ft in length. The treatments were applied using a two-row backpack sprayer with two T x

[1]Extension Entomologist, University of Arkansas Cooperative Extension Service, Southeast Research and Extension Center, Monticello, Arkansas; and Desha County Extension Agent, University of Arkansas Cooperative Extension Service, McGehee, Arkansas.

4 hollow cone nozzles/row. The sprays were applied at 40 PSI, with one part Kinetic® surfactant/1000, in 6.3 gal of finished spray/acre. Pre-treatment counts (7-12-96) indicated that an average of 616 aphids were present on each top leaf and 304 aphids were present on each middle canopy leaf. The average leaf in the test field on the day of treatment was infested with 460 aphids, and the aphid distribution was fairly uniform throughout the test area.

Post treatment counts were made one and three days after treatment (13 and 15 June 1996). In each plot five top leaves (4th main-stem node from the terminal and first fully expanded leaf) and five main-stem, mid-canopy leaves were randomly selected. The aphids per leaf were counted/estimated and recorded. The test was terminated after 15 June 1996 because the aphid parasitic fungus, *Neozygites fresenii*, had decimated the aphid populations in all plots. Because of the short duration of the test, yield data were not taken.

Data were processed using analysis of Variance and Duncan's Multiple Range Test. CoStat statistical software was used to conduct these tests

RESULTS AND DISCUSSION

Table 1 shows the effects of the various treatments on cotton aphids. These tables show one-day post-treatment and three-day post-treatment counts/estimates of aphids per leaf. The one-day post-treatment data probably did not provide sufficient time for slower-acting compounds to show their full effectiveness. The three-day post-treatment data were impacted strongly by the development of the fungal cotton aphid pathogen throughout the plots. Aphid counts in the untreated check cotton demonstrate the extent of the aphid population reduction that was occurring. In the untreated check plots, the average cotton aphid infestation fell from 547 aphids/leaf to 97 aphids/leaf in the two days between the one- and three-day posttreatment counts, an 82% reduction in the aphid population.

One-day post-treatment aphid control in the tops of plants was strong in the plots treated with Lannate® (0.125 and 0.25), Bidrin® (0.25 and 0.5), Provado® (0.025 and 0.047), Bidrin + Ovasyn® (0.5 + 0.125) and Furadan® (0.125 and 0.25). Dimethoate® (0.25) and Orthene® + Lorsban® (0.45 + 0.25) gave significantly poorer control but still provided significant population reduction compared with the untreated check.

Aphid counts in the middle canopy reflected the coverage problems often seen in cotton aphid control tests. In general, control was less effective in the middle canopy than in the tops of plants. The most effective compounds one day post-treatment were Bidrin (0.25), Provado (0.025 and 0.47), Bidrin + Ovasyn (0.5 + 0.125), Lannate LV (0.125 and 0.025) and Furadan (0.125 and 0.25). After three days, similar patterns were seen with fungal-related improvement in the aphid counts in most plots. The Provado plots made a strong improvement (as expected from the nature of the chemistry). Overall, mid-canopy aphid data indicated that the low rate of Bidrin (0.25) was less effective than the most effective products.

The summary data table, Table 1, showed the best aphid control products to be Bidrin, Provado, Lannate, Bidrin + Ovasyn and Furadan. Non-significant trends indicated that Furadan provided the strongest control, followed by Lannate LV (0.25) and the Bidrin-Ovasyn combination (0.5 + 0.125). Provado improved strongly between the one- and three-day observations.

PRACTICAL APPLICATION

Furadan provides excellent cotton aphid control in southeastern Arkansas. Its use has been limited by the triggered Section 18 labeling and the lengthy re-entry intervals during which protective clothing is required.

Lannate, the Bidrin-Ovasyn combination, Provado and Bidrin can be used to obtain satisfactory aphid control. These products have full Federal labeling for aphid control in cotton and much less restrictive re-entry intervals than Furadan.

ACKNOWLEDGMENTS

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Table 1. Summary table of aphids/leaf (top and middle canopy leaves)* following treatment with various insecticides. Desha County, Arkansas, 1996.

Summary of Treatment	Rate	Days Post-treatment 1	3	1 & 3
	lb ai/acre			
Check		547 a	97 a	322 a
Orthene 90S +	0.5 lb (0.45)+	293 b	84 a	188 b
Lorsban 4E	8 oz (0.25)			
Dimethoate 4E	8 oz (0.25)	230 b	56 ab	143 bc
Bidrin 8	4 oz (0.25)	108 c	53 ab	80 cd
Provado 1.6 F	2 oz. (0.025)	112 c	8 bc	60 cd
Bidrin 8	8 oz (0.5)	94 c	25 bc	60 cd
Lannate LV	6.7 oz(0.125)	65 c	20 bc	43 d
Provado 1.6 F	3.75 oz (0.047)	72 c	9 bc	40 d
Bidrin 8 +	8 oz (0.5) +	48 c	10 bc	29 d
Ovasyn 1.5	10.7 oz (0.125)			
Lannate LV	13.2 oz(0.025)	22 c	15 bc	19 d
Furadan 4F	4 oz (0.125)	18 c	1 c	10 c
Furadan 4F	8 oz (0.25)	18 c	1 c	9 d

*Means in columns followed by the same letter are not significantly different (5% level of significance).

BOLLWORM OVICIDES AND HOW THEY WORK

C.T. Allen, S. Frizzell and A.C. Riddle[1]

RESEARCH PROBLEM

Technology and U.S. Farm Policy changes are producing the most rapid and significant changes in cotton IPM systems in the past 20 years. Bt cotton, boll weevil eradication, new insecticide chemistry and large fluctuations in crop averages have set the stage for this rapid, large-scale change. The evolving new cotton production/cotton IPM systems will require a variety of system components. In some production systems, ovicides will be used for cheap, effective reductions in worm hatch while preserving beneficial arthropods and providing resistance management benefits. Ovicides may take on a larger role post-eradication and in Bt cotton to control worms and maintain insecticide susceptibility in worm populations without decimating natural enemies. They may be increasingly used in Bt cotton during the bollworm-susceptible bloom stage for low-cost worm suppression and resistance management.

Crop management specialists need to know as much as possible about how these ovicidal products work in order to use them effectively. Information on product selection, rate and timing is needed to make optimum use of these tools.

BACKGROUND INFORMATION

Little information is available about the effects of bollworm ovicide use on cotton in Arkansas. The purpose of this study was to obtain more information about the effectiveness, specific stage of the insect killed and the effects of the egg age on the activity of the ovicide.

RESEARCH DESCRIPTION

Bollworm moths were collected from light traps near McGehee, Arkansas, on 13 September 1996, 17 September 1996 and 19 September 1996. Moths were held in 1-gal cylindrical ice cream cartons and fed sugar water. The moths were kept in the containers with a 10-in. by 10-in. piece of cheesecloth, which was stretched across the opening and held in place by the lid band. The moths readily laid eggs on the cheese cloth lid. Eggs were collected on 18 September and 20 September 1996 and held until they were used on 22 September 1996.

[1]Extension Entomologist, University of Arkansas Cooperative Extension Service, Southeast Research and Extension Center, Monticello, Arkansas; Research Associate and Student Assistant, University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas.

On 26 September the cheesecloth sheets containing the eggs were cut into 0.5-in. squares containing 200-300 eggs. Three squares of 0- to 2-day-old eggs and three squares of 3- to 4-day-old eggs were placed on 8.5 x 11 in. sheets of typing paper. They were then sprayed using a hand boom, CO_2 pressurized sprayer with four nozzles on 19-in. spacings. Applications were made in 4.3-gal of total solution/acre (T x 4 nozzles and 42 psi). The applications included one part per thousand Kinetic surfactant.

When the treated cheesecloth squares were dry, they were collected and held in marked ziplock plastic bags until they could be further processed. In this way each insecticide/rate was applied to three randomly selected groups of bollworm eggs in each of two age classes.

Soon after the spray dried, the eggs were further processed by cutting up the cheese cloth squares and individually enclosing 25-30 bollworm eggs in #1 or #2 gelatin capsules. Four replications of 25-30 eggs per treatment (with 0- to 2- and 3- to 4-day-old eggs) were placed in the gelcaps. The gelcaps were held in labeled petri dishes until they could be examined to determine the fate of the eggs. The eggs were examined under 20x magnification three times at two- to three-day intervals until all had hatched or ceased development.

Each egg was categorized and recorded as hatched live, hatched dead or unhatched. Hatched live eggs were those in which the larvae hatched and emerged completely form the egg shell. These were normally alive at the time the egg was examined. Hatched dead eggs were those in which the larvae chewed through the egg shell and emerged partially from the egg, or emerged completely but died near the egg soon after emergence. Eggs from which worms never emerged were categorized as unhatched.

Data were processed using CoStat Statistical Software. ANOVA and Duncan's Multiple Range procedures were used.

RESULTS AND DISCUSSION

Comparisons in mortality egg rates between the insecticides/rates tested are provided in Tables 1-3. These comparisons are made among eggs 0- to 2-days and eggs 3- to 4-days old (at the time of treatment) and across both egg age groupings.

0- to 2-Day-Old Eggs

Karate® 0.025 lb ai/acre, Lannate LV® 0.225 lb ai/acre and Larvin® 0.4 lb ai/acre strongly reduced the percentages of hatched live larvae in the 0- to 2-day-old egg group (Table 1). Among these treatments the mortality observed was predominantly prior to egg hatch. The Larvin at 0.125 lb ai/acre (the lower rate) showed good reduction in percentage hatch of 0- to 2-day-old eggs but was not statistically as effective as the best treatments. Curacron® 0.25 lb ai/acre and Ovasyn® 0.25 lb ai/acre were still less effective but allowed lower percentage of hatching of live larvae than was observed with untreated 0- to 2-day-old bollworm eggs. Generally higher mortality was produced by the treatments during the egg stage as compared with at hatching.

3- to 4-Day-Old Eggs

Against 3- to 4-day-old eggs (Table 2), a dramatic change was seen in the activity of Ovasyn 0.25 lb ai/acre. The Ovasyn treatment was markedly more effective against 3- to 4-day-old eggs than against 0- to 2-day-old eggs. Against older eggs Ovasyn 0.25 lb ai/acre joined Karate 0.025 lb ai/acre, Lannate LV 0.225 lb ai/acre and Larvin 0.4 lb ai/acre as the most effective treatments. The low rates of Larvin and Curacron were less effective than the top treatments but still showed significant improvements in egg mortality as compared with untreated bollworm eggs. Across all treatments, mortality was higher in the egg stage than at hatching.

Cumulative Across Both Egg Ages

Karate 0.025, Lannate LV 0.225 and Larvin 0.4 gave the lowest percentages of hatched live larvae when data were combined across both egg ages (Table 3). The remaining treatments were significantly less effective. Larvin 0.125, Curacron 0.25 and Ovasyn 0.25 allowed significantly fewer live larvae to hatch than were seen among untreated eggs. Again, more mortality occurred in the egg stage than at hatching with each of the products tested.

PRACTICAL APPLICATION

Considering the cumulative data for all ages of bollworm eggs, the lowest levels of worm survival were seen in the Karate, Lannate and Larvin 0.4 lb ai/acre treatments. Karate, Lannate and the high and low rates of Larvin gave the highest levels of reductions in hatches against young eggs. Ovasyn, Karate, Lannate and the high rate of Larvin gave the highest levels of reductions in hatches of older eggs.

In general, treatment of young eggs allowed more than two-fold greater worm survival than occurred when older eggs were treated. Ovasyn and Curacron were considerably more effective against older eggs than they were against younger eggs. Conversely, Larvin and Lannate were notable in killing higher percentages of young eggs than older eggs. Treatment of older eggs produced more mortality of larvae as they emerged from the egg shell, while treatment of younger eggs produced higher percentages of eggs that failed to hatch. Lannate, Larvin and Karate were notable in their greater kill of larvae as they emerged from older eggs as compared with younger eggs.

Table 1. Effects of insecticide treatment on 0- to 2-day-old bollworm eggs.

		Egg Age 0-2 Days		
Treatment	Rate	Hatched Live Larvae	Hatched Dead Larvae	Unhatched Dead Eggs
	lb ai/acre	------	%	------
Check		56 a	1 c	43 cd
Ovasyn	0.25	43 b	3 c	53 bc
Curacron 8E	0.25	35 bc	27 a	38 d
Larvin 3.2	0.125	20 bc	17 b	63 b
Larvin 3.2	0.4	6 ed	4 c	90 a
Lannate LV	0.225	3 ed	4 c	88 a
Karate	0.025	0 ed	2 c	98 a

Table 2. Effects of insecticide treatment on 3- to 4-day-old bollworm eggs.

		Egg Age 3-4 Days		
Treatment	Rate	Hatched Live Larvae	Hatched Dead Larvae	Unhatched Dead Eggs
	lb ai/acre	------	%	------
Check		37 a	15 b	48 c
Ovasyn	0.25	2 c	3 b	95 a
Curacron 8E	0.25	15 b	38 a	46 c
Larvin 3.2	0.125	15 b	38 a	46 c
Larvin 3.2	0.4	5 c	38 a	56 bc
Lannate LV	0.225	4 c	37 a	56 bc
Karate	0.025	3 c	31 a	66 b

Table 3. Effects of insecticide treatment on all bollworm eggs aged 0-4 days.

		Egg Age 0-4 Days		
Treatment	Rate	Hatched Live Larvae	Hatched Dead Larvae	Unhatched Dead Eggs
	lb ai/acre	------	%	------
Check		47 a	8 de	45 c
Ovasyn	0.25	25 b	3 e	71 ab
Curacron 8E	0.25	25 b	32 a	42 c
Larvin 3.2	0.125	17 b	27 ab	55 bc
Larvin 3.2	0.4	5 c	21 bc	72 ab
Lannate LV	0.225	4 c	23 abc	72 ab
Karate	0.025	2 c	16 cd	82 a

PLANT BUG CONTROL TEST

C.T. Allen, S. Frizzell, K. Scott, S. Willis, A. Riddle and J. Haynes[1]

RESEARCH PROBLEM

The tarnished plant bug and other plant bug species are a major concern of Arkansas and other Mid-South cotton growers. Adult bugs move into fields from non-cotton weed host plants in the early summer, as cotton begins to square. They feed by inserting their beaks into the cotton plants, injecting saliva and then sucking the plant sap. As a result of their feeding, small squares fall from the plant, and large squares, blooms and bolls are less seriously damaged. Loss of squares causes delayed fruit set and maturity. Delayed maturity results in increased late-season pest pressure and higher control costs and lower yields. Delayed fruit set is a very important consequence of failure to control damaging levels of plant bugs in cotton. Insecticide resistance is an important concern with this pest.

BACKGROUND INFORMATION

In 1996 plant bugs caused an estimated 44,689 bales of cotton to be lost in Arkansas, a loss of about $15/acre. This was in spite of some $10.80/acre spent to control them.

Information on the effects of the available insecticides on the plant bugs, on other pests (such as boll weevil) and on the beneficial arthropod complex is needed so that a resistance/beneficial insect management plan can be developed.

RESEARCH DESCRIPTION

This study was conducted on the Southeast Research and Extension Center (SEREC) Rohwer Division Farm near Keslo, Arkansas. Standard production practices were used to produce the crop. ‘Suregrow 125’ was planted on 2 May 1996 and harvested on 18 September 1996. Mustard was planted on every fifth row on 11 April 1996 to insure strong plant bug populations in the cotton plots. Plots were four rows wide by 35 ft long. Plots were arranged in a randomized complete block design with four replications.

Pretreatment stand counts, beat sheet samples (6 row ft/plot) and node counts were taken on 30 May 1996. Plant bug immature and adult counts averaged 0.39 bugs/6 row ft (894/acre) and beneficial arthropods averaged 2.7/6 row ft (6,190/acre). The average plant had 5.1 nodes.

[1]University of Arkansas Extension Entomologist, Research Specialist and Student Workers, Southeast Research and Extension Center, Monticello.

Insecticides were applied using a highboy sprayer in 10 gal of total spray solution/acre on 30 May, 7 June and 13 June. Kinetic® surfactant at 0.5 parts/thousand was added to the Provado®, Baythroid® and Provado + Baythroid spray mixtures. Invade surfactant was used with the other treatments at 0.5 parts/thousand.

Post-treatment arthropod counts were taken using a 3-ft beat sheet. Two samples were taken in each plot, on each sampling date. Plots were sampled on 3 June, 6 June, 10 June, 13 June, 17 June and 20 June 1996.

Post-treatment fruiting counts were taken weekly during the course of the study on 6 June, 11 June, 17 June and 25 June 1996. They were processed using COTMAN.

When the test application and insect/fruiting data collection phase of the project was completed, both the cotton and the mustard were treated (Orthene 90 S 0.56 lb/acre on 21 June and 24 June 1996), and the mustard plants were shredded (21 June 1996) to limit further plant bug damage.

Lint cotton yields were determined by machine harvesting the middle two rows of the plots on 18 September 1996. Seed cotton weights were obtained by weighing the cotton harvested from each plot. The data were statistically analyzed using Costat Statistical Software.

RESULTS

The effects of the various insecticide treatments on plant bug populations is shown in Table 1. There were no significant differences between treatments in the populations of plant bug adults or nymphs analyzed across all six sampling dates in this test. However, when all plant bug life stages were analyzed across the six sampling dates, statistically significant differences were seen. All the Regent treatments, all the Orthene treatments, Provado 1.6 F, the high rate Provado 70 WG + Baythroid and Dimethoate provided significant reductions in plant bugs as compared with the check.

Percent square shed data were not statistically significant, and there are few consistent trends. Treatment effects on the beneficial insect complex are shown in Table 2. The only statistically significant differences were seen among treatments in the counts of the predaceous Hemiptera (sucking predators). Trends in the data for all predators posttreatment indicated that Dimethoate, Provado and Vydate may have been somewhat gentler on the predator complex than some of the other products.

None of the treatments produced lint yields that were significantly different from any of the other treatments. Trends in the data indicate somewhat better yields from the Vydate-treated cotton, however.

PRACTICAL APPLICATION

Regent, Orthene, Provado and Dimethoate provided suppression of plant bugs in this test. No treatment caused statistically significant reductions in the predatory arthropod complex (though meaningful trends were present). Dimethoate-, Provado- and Vydate-treated plots tended to have higher beneficial insect populations.

No significant differences in yields were seen in this test. However, a trend toward higher yields was seen in the Vydate C-LV-treated plots.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance and support of the Southeast Branch Experiment Station and Mr. Larry Earnest. Also, we wish to thank Bayer Corporation, Dow Elanco US Crop Production, Du Pont Ag Products, GemChem Inc., Rhone-Poulenc Ag Company and Valent USA Corporation for their assistance in this work. Special thanks to Alan Hopkins with Bayer Corporation for assisting with data collection.

Table 1. Plant bug numbers after treatments with various insecticides for plant bug control*, Rohwer, Arkansas, 1996.

		Plant Bugs/6 row ft†		
Treatment	Rate	Plant Bug Immatures‡	Plant Bug Adults‡	All Plant Bugs§
	lb/acre			
Check	---	2.3	0.1	2.4 a
Provado 70 WG	29 g	2.0	0.3	2.3 ab
Vydate CLV	8.5 oz	1.5	0.4	2.0 abc
Bidrin 8E	4.8 oz	1.6	0.3	1.9 abcd
Lorsban 4E	8 oz	1.6	0.2	1.8 abcd
Baythroid 2 EC	1.92 oz	1.4	0.4	1.8 abcd
Provado 70 WG +	20.9 g +			
Baythroid 2 EC	1.28 oz	1.3	0.3	1.6 abcd
Dimethoate 4 EC	8 oz	1.1	0.2	1.3 bcd
Orthene 90 S	4.48 oz	1.0	0.3	1.1 cd
Provado 1.6 F	3.6 oz	0.9	0.1	1.1 cd
Regent 2.5 EC	1.95 oz	0.8	0.1	1.0 cd
Provado 70 WG +	29 g +			
Baythroid 2 EC	1.92 oz	1.1	0.2	1.0 cd
Regent 2.5 EC	1.28 oz	0.9	0.1	1.0 cd
Regent 2.5 EC	2.56 oz	0.8	0.1	0.8 d

*Treatment dates 30 May, 7 June and 13 June.

†Sampling dates 3 June, 6 June, 10 June, 13 June, 17 June and 20 June.

‡Means not significantly different at $P \leq 0.05$.

§Means followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2. Beneficial insects per 6 row ft after plant bug insecticide treatments applied. Rohwer, Arkansas. 1996.

		Beneficial Insects/6 row ft*				
Treatment	Rate	All†‡	Lady Beetles†‡	Hemiptera†	Spiders†‡	Lacewing Larvae‡
	lb ai/acre					
Dimethoate 4 EC	8 oz	9	2.5	4.7 ab	1.8	0.2
Check	---	9	1.5	4.8 a	1.7	0.8
Provado 70 WG	29 g	8	2.3	3.8 abc	2.0	0.2
Vydate CLV	8.5 oz	8	2.0	4.2 abc	1.5	0.5
Provado 1.6 F	3.6 oz	7	2.7	2.8 abcd	1.7	0.0
Regent 2.5 EC	1.95 oz	7	2.7	3.0 abcd	1.3	0.2
Orthene 90 S	4.5 oz	7	2.0	2.8 abcd	1.8	0.2
Lorsban 4E	8 oz	6	2.8	2.0 cd	0.8	0.2
Provado 70 WG +	20.9 g					
Baythroid 2 EC	1.28 oz	6	1.3	2.3 bcd	1.5	0.6
Baythroid 2 EC	1.92 oz	6	2.3	1.8 cd	1.3	0.2
Regent 2.5 EC	2.56 oz	5	2.3	1.0 d	1.7	0.3
Bidrin 8	4.8 oz	5	1.8	2.5 abcd	0.7	0.2
Provado 70 WG +	29 g					
Baythroid 2 EC	1.92 oz	5	1.8	1.8 cd	1.3	0.0
Regent 2.5 EC	1.28 oz	5	2.3	1.8 d	1.2	0.2
Orthene 90 S	9 oz	4	1.8	0.8 d	1.5	0.0

*Summary of samples on 3 June, 6 June, 10 June, 13 June, 17 June and 20 June.

†All life stages and species.

‡Means not significantly different (P = 0.05).

CONTROL OF TWO SPOTTED SPIDER MITE WITH VARIOUS INSECTICIDES

Charles T. Allen, Steve Frizzell and Larry Earnest[1]

RESEARCH PROBLEM

Spider mites are a commonly experienced pest of many Arkansas cotton fields. Historically, they have been difficult to control. If spider mite populations are not controlled, they can cause substantial damage to cotton yields and fiber quality. Several new insecticide/miticides are now available to cotton producers. Little information is available about their efficacy. This study was done to provide Arkansas cotton producers with information about how effective the various miticides are under our growing conditions.

BACKGROUND INFORMATION

Very little published information on the efficacy of miticides on Mid-South cotton is available.

RESEARCH DESCRIPTION

This study was conducted on the Southeast Branch Station near Rohwer, Arkansas. The land was prepared for planting by disking on 1 March 1996; chiseling, disking, field cultivation and hipping up on 4 March 1996; then rehipping 9 April 1996. Thirty units of phosphorus, 60 units of potassium and 1 lb of boron per acre were applied and incorporated by field operations on 1 March 1996.

The field was planted to ‘Suregrow 125’ cotton on 2 May 1996. Row width was 38 in. Pre-emergent herbicides (per-acre rates) applied were as follows: Prowl (1.8 pints) and Zorial Rapid 80 (0.6 lb) broadcast and Cotoran 4L (0.8 pints) on a 19-in. band. At planting insecticides (per-acre rates) were Temik 15G (5.1 lb) in furrow and Orthene 90S on a 19-in. band for thrips and cutworms, respectively. Terrachlor Super-X 18G (7.1 lb/acre) fungicide was applied for seedling disease control. Post-emergence herbicides (per-acre rates) were applied as follows: Cotoran 4L (12.8 oz) + MSMA (1.5 pt) post directed on 4 June 1996 and Bladex 4L (1.6 pt) + MSMA (2.66 pt) layby on 20 June 1996. Post-emergence fertilizer applications (per-acre rates) were as follows: 50 units of N (urea) on 17 May 1996 (second true leaf), 60 units of K on 24 May 1996 (fourth true leaf), 65 units

[1]Extension Entomologist, University of Arkansas Cooperative Extension Service, Monticello, Arkansas; Research Specialist and Superintendant, University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas.

of N (32% liquid) on 4 June 1996 (first square) and three applications of Solubar (4 oz/acre) on 14 June, 21 June and 28 June 1996.

Irrigations were applied on 24 June, 2 July and 8 July 1996. The field was cultivated on 17 May, 14 June and 20 June 1996. Pix growth regulator was applied as follows: 4 June 1996 2 oz/acre, 14 June 1996 2 oz/acre and 28 June 1996 4 oz/acre. On 4 June and 12 June 1996, Guthion 2L was applied at 6.4 oz/acre for overwintered boll weevil control. Insecticides for plant bug control were applied on 30 May, 7 June, 13 June, 21 June and 24 June 1996.

Test miticides were applied on 17 July 1996. Plots were 12 rows wide x 35 ft long, and treatments were assigned to plots using a Randomized Compete Block Design with four replications. Post-treatment counts were made by collecting 10 top leaves from each plot and holding them in Ziplock plastic bags on ice until they could be examined under a microscope (the day of collection). Counts were made by examining one 20x microscopic field along the mid rib of each leaf. All live mites visible were counted. Post-treatment counts were taken two and six days after treatment (on 19 July and 23 July 1996).

Data were processed using ANOVA and Duncan's Multiple Range Tests. CoStat Statistical Software Package was used.

RESULTS AND DISCUSSION

Table 1 summarizes the results of this test. There was a notable decline in mite populations observed between the two- and six-day post treatment observations. A mite pathogenic fungus was observed reducing mite populations in all plots six days post treatment.

Two days post treatment Pirate gave statistically superior mite control compared with the other treatments. Curacron had statistically fewer mites than the check but did not differ statistically from Zephyr or Lorsban.

Six days post treatment there were no significant differences among any of the treatments. A miticidal fungus had lowered mite populations in all plots. In order, those treatments with the fewest mites were Pirate, Zephyr, Curacron, Lorsban and Check, but none of these treatments were statistically significant.

PRACTICAL APPLICATION

Probably insufficient time was allowed to observe full effects of the slow-acting insecticide, Zephyr. The quick-acting products, Pirate, Curacron and Lorsban were probably fairly evaluated.

Apparently, the naturally occurring fungus alone caused 64% mortality in mite populations in the four days between the two- and six-day post-treatment counts.

ACKNOWLEDGMENTS

The authors wish to thank American Cyamid, CIBA, Dow Elanco and Merck Chemical companies for providing insecticides and financial support for this work.

Table 1. Spider mite counts two and six days after miticides were applied, Rohwer, Arkansas, 1996.

		Mites/Microscopic Field (3.8 cm^2)	
Miticides	Rate/Acre	2-DPT	6-DPT
Check		5.3 a	1.9 a
Lorsban 4E	1.5 pt	3.6 ab	1.2 a
Zephyr	0.5 pt	3.1 ab	0.7 a
Curacron 8E	1 pt	2.1 b	0.9 a
Pirate	6.4 oz	0.4 c	0.5 a

BOLLWORM CONTROL TEST - 1996

Charles T. Allen, Steve Frizzell, Larry Earnest, Philip Tugwell, John Haynes, Sheila Willis, Amanda Riddle and Kassandra Scott[1]

RESEARCH PROBLEM

Insects continue to be an important source of yield loss in cotton production. Bollworms and tobacco budworms are among the most damaging cotton pests each year. In 1995 those pests caused losses of some 51,258 bales of cotton in Arkansas and 856,909 of cotton in the U.S. (Anonymous, 1996). This represents dollar losses of $14.8 million and $247.7 million to the Arkansas and U.S. cotton producers, respectively.

BACKGROUND INFORMATION

Growers need to know the effects of their insecticide treatments on the whole pest and predator complex and on cotton yield so that they can make wise insect management decisions.

RESEARCH DESCRIPTION

Standard production practices were used with 'DPL 5690' cotton planted on 5 May 1996 and harvested on 9 October 1996. The test design used was a randomized block design with four replications. The test treatments were applied using 10 gal of water/acre and Penetrator Plus surfactant at 0.5 pt/acre. Treatments were applied on 23 July, 9 August, 20 August and 30 August 1996.

The test field was scouted twice a week to determine pest insect infestation levels and provide information for decision making. During the test, counts were made in the plots four times (26 July, 12 August, 23 August and 30 August), three to four days after treatment. The sampling procedure used in each plot consisted of inspecting and counting the insects found on 10 plant terminals, 10 white blooms and 20 small bolls per plot. Species determination of the larva present was accomplished by observing moth traps, observing moth species in the field and microscopic inspection of the mandibles of the large larvae found. Data collected in this test were analyzed using Analysis of Variance. Duncan's Multiple Range test was used for means of separation. The 5% level of significance was used. CoStat statistical software was used to perform these analyses.

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[1]Extension Entomologist, University of Arkansas Cooperative Extension Service, Monticello, Arkansas; Research Specialist, Research Entomologist and Student Workers, Southeast Branch Experiment Station, Rowher, Arkansas.

RESULTS

Moth traps, in-field moth observations and a limited number of large larval dissections indicated that the worm population during this test was predominantly bollworm.

The results of worm and fruit damage counts three to four days post-treatment are summarized in Table 1. Bollworm egg numbers were not significantly different among treatments. Similarly, small worm numbers were not significantly different among treatments, although they tended to be lower in the check, Baythroid and Scout Xtra plots. Medium-sized larvae were significantly more numerous in the check plots but not significantly different among the various insecticide treatments. A few treatments, Karate + Larvin, Baythroid, Scout Xtra and Tracer, tended to have somewhat fewer medium-sized larva. Similarly, the data on large larva showed significantly fewer larvae in treated plots than in check plots but no significant differences among the various treatments. Treatments with lower large larva trends were Karate + Larvin, Karate, Baythroid and Karate CS. The check had significantly more total larvae than any of the treatments, but no insecticide treatment was shown to be significantly less effective than any other treatment against bollworm larvae. However, trends across the data set suggest the presence of fewer bollworms in the pyrethroid (and pyrethroid combination) plots than in their non-pyrethroid counterparts.

Damaged fruit data repeated the pattern of significant differences between check and all insecticide treatments, with no significant differences among treatments. Though not significantly different, Karate + Larvin, Scout Xtra and Karate CS showed a trend toward lower fruit damage.

The effects of the various treatments on the plant bugs is shown in Table 2. The Karate CS, Baythroid and Karate + Larvin treatments had significantly fewer plant bug adults than were found in the untreated check plots. Against plant bug nymphs, no treatments were significantly different from the check, though nymph numbers in Karate CS-treated plots were numerically (but not statistically) lower than in other plots. When plant bug adult and nymph data were combined, the lowest plant bug counts were observed in the Karate CS- and Baythroid-treated plots. Among the insecticide treatments, Pirate appeared to be least effective against plant bugs. It was consistently at or above the level of the check (numerically) in plant bug numbers.

Seedcotton yield data are provided in Table 3. Yields in the Baythroid-, Pirate- and Tracer-treated plots were significantly higher than the check. The other insecticide treatments produced yields not significantly different from those produced by the untreated check plots. Numerically, the Baythroid-treated cotton (highest yielding treatment) produced 855 lb more seed cotton than was produced by the Intrepid-treated cotton (lowest yielding treatment).

PRACTICAL APPLICATION

Bollworm populations were high enough in this test to allow for consistent differences in worm numbers and damaged fruit to be shown between the check and the other treatments. However, differences in worm numbers or worm damage between insecticide treatments were not statistically significant. Trends in the data indicated lower worm populations in pyrethroid-treated plots than in plots treated with non-pyrethroids. Damage levels and yields did a less convincing job of supporting the idea that the pyrethroids were more effective than the new non-pyrethroid chemistry in protecting fruit.

In general, pyrethroids lowered plant bug numbers (numerically, but not in all cases statistically) below levels in the untreated cotton. Tracer and Intrepid may also have lowered plant bug numbers somewhat. Pirate and Scout Xtra provided little or no plant bug control in this test.

ACKNOWLEDGMENTS

The authors wish to thank the staff at the Southeast Branch Experiment Station at Rohwer for their hard work in planting, cultivating, watering and growing the cotton for this and other cotton test plot work. Also, we wish to thank the insecticide manufacturers, AGREVO, American Cyanamid, Bayer, DowElanco, Rohm and Haas, Rhone - Poulenc and Zeneca, for their assistance in providing chemicals and financial assistance and support of this work.

LITERATURE CITED

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Table 1. Summary season-long of bollworm population and fruit damage in insecticide-treated plots*[†], Rohwer, Arkansas, 1996.

Insecticide	Rate	Bollworm eggs	Small Larvae	Medium Larvae	Large Larvae	Total Larvae	Damaged Fruit
	lb ai/acre						
Check	---	5 a	0.2 a	1.3 a	1.7 a	3.3 a	7 a
Intrepid 80W	0.35	3 a	0.4 a	0.4 b	0.7 b	1.6 b	5 b
Pirate	0.35	4 a	0.4 a	0.4 b	0.5 b	1.4 b	4 b
Tracer	0.046[‡]	3 a	0.5 a	0.2 b	0.4 b	1.1 b	4 b
Karate	0.03	3 a	0.5 a	0.3 b	0.1 b	0.9 b	5 b
Karate CS	0.03	5 a	0.4 a	0.4 b	0.2 b	0.9 b	3 b
Scout Xtra	0.023	3 a	0.2 a	0.1 b	0.4 b	0.8 b	3 b
Baythroid	0.033	3 a	0.2 a	0.1 b	0.2 b	0.6 b	4 b
Karate + Larvin	0.03 + 0.125	4 a	0.4 a	0.0 b	0.1 b	0.4 b	3 b

*Treatment dates: 23 July, 9 August, 20 August and 26 August; Sample dates: 26 July, 12 August, 23 August and 30 August.

[†]Sample = no. per 10 terminals (above the 1st position white flower), 10 white blooms and 20 small bolls/plot.

[‡]First application of Tracer was made at 0.154 lb ai/acre.

Table 2. Summary of season-long plant bug populations in plots treated for bollworm control*, Rohwer, Arkansas, 1996.

Insecticide	Rate	Plant bugs/sample† Adults	Nymphs	All
	lb ai/acre			
Pirate	0.35	3.4 ab	3.6 a	7.1 a
Check	---	3.5 a	3.3 ab	6.8 a
Scout Xtra	0.023	2.9 abc	4.3 ab	6.2 ab
Intrepid	0.35	3.2 abc	2.2 ab	5.4 abc
Tracer	0.046‡	2.4 abc	3.0 ab	5.1 abc
Karate	0.03	2.8 abc	2.2 ab	5.0 abc
Karate + Larvin	0.03 + 0.125	1.8 bc	2.6 ab	4.4 abc
Baythroid	0.033	1.8 bc	2.1 ab	3.8 bc
Karate CS	0.03	1.5 c	1.5 b	3.0 c

*Treatment dates: 23 July, 9 August, 20 August and 26 August; Sample dates: 26 July, 12 August, 23 August and 30 August.

†Sample = no. per 10 terminals (above the 1st position white flower), 10 white blooms and 20 small bolls/plot.

‡First application of Tracer was made at 0.154 lb ai/acre.

Table 3. Seedcotton yields* following treatments for bollworm control using various insecticides†, Rohwer, Arkansas, 1996.

Insecticides	Rate	Seedcotton
	lb ai/acre	lb/acre
Baythroid	0.033	3503 a
Pirate	0.35	3370 ab
Tracer	0.046‡	3284 ab
Karate CS	0.03	3271 abc
Scout Xtra	0.023	3065 bcd
Karate	0.03	3060 bcd
Check	---	2953 cde
Karate + Larvin	0.03 + 0.125	2854 de
Intrepid	0.35	2648 e

*Machine picked middle 2 rows of plots.

†Treatment dates 23 July, 9 August, 20 August and 26 August.

‡First Tracer application made at 0.154 lb ai/acre.

BIODEGRADATION PROPERTIES OF SELECTED NONWOVENS FOLLOWING SOIL BURIAL

Mary M. Warnock[1]

RESEARCH PROBLEM

This study was undertaken to determine the utilization of soil burial as a means to determine the biodegradability of nonwovens being placed into landfills. Emphasis was placed on tensile strength and elongation characteristics, colorimeter analyses and polarized light microscopy.

BACKGROUND INFORMATION

The nonwovens industry continues to flourish with rapid increases in production and product development. We know that this tremendous growth (7% per year) is not likely to slow down or decrease in the next decade; that nonwovens are widely used in disposable convenience goods such as lightweight towels, diapers, wipes, hygiene and medical products; and that these disposable goods are most often deposited into landfills for which there is less and less available location space. Therefore, biodegradability becomes an important environmental concern.

RESEARCH DESCRIPTION

The physical and morphological characteristics of six nonwoven fabrics were assessed following burial for 2, 4, 8, 16, 32 and 64 weeks in two soils of differing pH and at two locations. The nonwoven fabrics were representative of recycled melt blown PET webs of two different weights, polypropylene (PP) melt blown and spunbonded webs, and cotton/polypropylene (C/PP) thermally bonded specimens. The two soils were Red Clay having a pH of 4.8 and Calloway Silt Loam with a 7.5 pH. Rubbermaid Keepers Clear Boxes™ having mylar dividers were used for burial purposes by the Arkansas Agricultural Experiment Stations located in Fayetteville and Pine Bluff, Arkansas.

RESULTS AND DISCUSSION

According to ΔL^* data (Table 1), those fabrics buried in the more acidic Red Clay soil experienced the greatest amount of color change throughout the study. Those test specimens containing cotton experienced the greatest color change,

[1]Professor, School of Human Environmental Sciences, University of Arkansas, Fayetteville, Arkansas.

irrespective of soil type and length of burial, due to fungal growth. By the end of the study, the PP melt blown webs buried in the Calloway Silt Loam soil and the 2.0 oz/yd^2 recycled polyester melt blown web buried in the Red Clay soil exhibited the least degradation based on colorimeter values.

The PP spunbonded webs exhibited the highest breaking strength values during the study (Table 2). The disintegration of the cotton core layer with the 42/58 and 60/40 C/PP webs caused a significant loss in breaking strength after only two weeks of burial.

Photomicrographs verified the breakdown of the cotton fibers in the blended nonwovens after two weeks of burial. By the end of the 64 weeks of burial, the cotton fibers had degraded to such an extent as to be totally gone or to be in shredded components. Fibrillations and cracks were evident in the PP and recycled polyester filaments following four weeks of burial. Microscopic examination supports the loss of strength experienced by the majority of selected nonwovens used in this study.

PRACTICAL APPLICATION

Studies such as this are needed to provide “real life” landfill simulation results. This study proved that 1) the nonacidic soil contributed to faster biodegradation of disposable materials; 2) more cotton should be utilized in nonwoven fabric production to increase the rate of biodegradation.

Table 1. Mean color difference values on the CIE color scale according to soil type, fabric type and length of burial*.

		Weeks of Burial						
Soil Type	Fabric Type	0	2	4	8	16	32	64
Red Clay	42/58 C/PP	3.8	3.0	-0.5	-3.7	-14.8	-18.8	-16.8
	60/40 C/PP	3.3	1.6	-0.5	-4.8	-14.7	-14.5	-16.4
	PET/MB1	3.0	3.7	2.9	3.2	2.0	1.5	-0.7
	PET/MB2	2.6	2.2	1.8	1.7	1.7	0.9	2.3
	PPMB	4.2	4.1	4.3	3.2	3.9	2.6	2.0
	PPSB	2.8	4.3	3.6	4.5	4.1	2.6	0.6
Calloway Silt Loam	42/58 C/PP	3.8	-2.3	-16.9	-21.9	-24.3	-13.2	-11.6
	60/40 C/PP	3.3	-5.4	-10.3	-17.9	-19.1	-14.0	-14.0
	PET/MB1	3.0	2.9	3.4	3.3	2.0	2.2	0.1
	PET/MB2	2.6	1.5	2.2	1.9	1.5	1.4	1.2
	PPMB	4.2	3.8	4.0	3.9	3.8	2.5	3.3
	PPSB	2.8	3.2	4.1	6.5	4.0	2.7	1.4

*LSD ≈ 3.20.

Table 2. Mean breaking strength values (lb) of selected nonwovens buried in acidic and nonacidic soils*.

		Weeks of Burial						
Soil Type	Fabric Type	0	2	4	8	16	32	64
Red Clay	42/58 C/PP	27.1	26.7	26.3	25.6	25.0	24.9	26.0
	60/40 C/PP	25.8	25.4	25.3	25.4	25.3	24.7	24.7
	PET/MB1	24.9	25.0	24.8	24.7	25.1	25.1	24.7
	PET/MB2	27.5	27.3	27.5	27.6	27.6	27.5	27.1
	PPMB	26.2	25.7	26.1	25.8	26.0	26.1	25.5
	PPSB	34.6	34.0	33.7	34.6	35.9	34.4	34.6
Calloway Silt Loam	42/58 C/PP	27.1	26.8	26.3	25.5	26.5	26.6	25.6
	60/40 C/PP	25.8	25.5	25.3	25.4	25.3	25.1	24.7
	PET/MB1	24.9	24.8	25.1	24.8	25.1	24.9	24.4
	PET/MB2	27.5	27.4	27.6	28.1	27.9	27.7	27.1
	PPMB	26.2	26.2	26.2	26.1	26.2	25.7	25.1
	PPSB	34.6	34.9	35.2	34.2	35.3	33.9	34.0

*LSD ≈ 0.94.

COMPARISON OF NEW INSECTICIDES FOR THE CONTROL OF THE BOLLWORM AND TOBACCO BUDWORM IN ARKANSAS

D.R. Johnson, H.B. Meyers, L.M. Page and T.L. Singer[1]

RESEARCH PROBLEM

The tobacco budworm (*Heliothis virescens*) has developed resistance to the pyrethroid insecticides and every other class of insecticides developed previously. The development of new chemistry to control tobacco budworm in cotton is a continuing challenge for the new discovery research component of agricultural industries. The most recent discoveries that are being developed include Pirate (pyrrole) by American Cyanamid, Tracer® (spinosad) by Dow Elanco, Proclaim® (emamectrin benzoate) by Merck and Intrepid® (RH-2485) by Rhom & Hass. These insecticides were evaluated in field test and compared to the standard insecticide Karate® manufactured by Zeneca.

RESEARCH APPROACH

The treatments included were Karate at 0.033 lb ai/acre, Tracer at 0.067, Karate 0.033 plus Tracer 0.067, Pirate at 0.35, Karate at 0.033 plus Pirate at 0.25, Proclaim at 0.0075, Proclaim at 0.01, Intrepid at 0.25, Intrepid at 0.25 and Intrepid at 0.25 plus Larvin at 0.45. The test was arranged in a randomized complete block design, and plots were eight rows by 50 ft long. The test site was located in Jefferson County approximately 8 miles southeast of Pine Bluff, Arkansas. The treatments were applied in 10 gal total volume/acre. Treatments were applied on 24 June, 30 June, 26 July and 31 July, 1996. Larvae were collected from adjacent untreated areas and reared in diet cups to determine species composition. Data were collected by examining 50 terminals and squares at random from the center of each plot. The cotton crop was produced using standard agronomic practices and irrigated. The variety was DPL 50 planted 10 May l996. Yields were determined by harvesting the middle two rows using a John Deere cotton picker.

RESULTS AND DISCUSSION

The tobacco budworm and bollworm (*Heliocoverpa zea*) larvae occurred in cotton plots in varying frequency during 1996 (Table 1). The tobacco budworm is normally the most frequent the last week in June and around the last of July and

[1]Extension Entomologist, Extension Entomologist, Agricultural Technician - Entomology and Assistant Specialist - Entomology, Cooperative Extension Service, Lonoke, Arkansas.

first part of August. During 1996, the overall tobacco budworm population level was substantially lower than the 1995 growing season. The percent composition of the tobacco budworm population during the 1996 growing season compared to the total Heliothine population is shown in Table 1.

The larval counts from the insecticide treatments are presented in Table 2. The larval counts from the 28 June observation indicated that treatments with Karate, Karate plus Pirate, Tracer and Proclaim were significantly lower in larvae number than the untreated check. On 3 July, the untreated plot had 6.25 larvae, significantly higher than all the other treatments. The combination treatments of Karate plus Pirate, Karate plus Tracer and Intrepid plus Larvin had the lowest larvae density but significantly different from only Proclaim 0.0075.

The observation of insecticide treatments on 30 July indicated that Tracer and Proclaim had the lowest number of larvae and were significantly lower than the untreated, Karate, Pirate, Karate plus Pirate and the higher rate of Intrepid. Most treatments were significantly lower than the untreated except Pirate and Karate plus Pirate. Data collected from the 3 August observations indicated that larval numbers had declined in all plots. Treatments significantly lower in larval numbers than the untreated check included Pirate, Karate plus Pirate, Tracer, Karate plus Tracer, Proclaim low rate, all rates and combinations of Intrepid. Karate and the high rate of Proclaim were not significantly different from each other.

The varying levels of control across test date possibly indicate a selective difference in the measure of control by each insecticide toward the different species of the Heliothine complex present. The lack of control by Karate usually indicates the presence of an insecticide-resistant population of tobacco budworms. This would explain the higher numbers of larvae found in the Karate plots during the last two observation dates. The area where the test was conducted is known for the high level of resistance in the tobacco budworm population to the pyrethroid insecticides. The Tracer and Proclaim treatments both had lower larval counts in the last two observation periods, perhaps indicating a higher degree of control of the tobacco budworm. In contrast, the same treatments had slightly higher numbers of larvae during the first two observation. Field observations of separate large block tests indicated that Tracer did not adequately control the bollworm at the lower rates, and the earlier decreased control may have been bollworm survival in the plots. This hypothesis is strengthened by the fact that the combinations of Karate with Pirate or Tracer had lower larval numbers, indicating good control, and suggests that the surviving population may have been primarily bollworms.

The yields from the different treatments are shown in Table 2. The highest yield was found in the combination treatments of Karate plus Pirate and was significantly higher than all the other treatments except Karate plus Tracer and Karate alone. The treatments of Proclaim at both rates and Intrepid at all rates and combinations were not significantly different from one another. All treatments were significantly higher in yield than the untreated check.

PRACTICAL APPLICATIONS

The best results were achieved using the combinations of Karate plus either Pirate or Tracer. The results were probably due to improved control of both species of the Heliothine complex. Karate gives excellent control of the bollworm, but tobacco budworm has developed significant resistance to all pyrethroid class insecticides. The identification of the species composition is vital in making decisions on the proper selection of the insecticide to use for insect management with the new insecticides.

The newer insecticide classes are represented by Tracer and Pirate. The two different classes of insecticides have proven to be excellent against the pyrethroid-resistant tobacco budworm. However, the performance of Pirate against bollworm is weak in comparison to that of Karate. Tracer is stronger against the bollworm, but some weakness in control has been observed in large block trials when it is used at the lower rates. The newer insecticides, Intrepid and Proclaim, are excellent insecticides that will have a place in control of bollworm and tobacco budworm. Future field research should be directed toward identifying the roles of these insecticides in cotton insect management.

Table 1. Species composition in Jefferson County cotton during 1996.

Date	% Tobacco Budworm	% Cotton Bollworm
28 June	53	47
3 July	67	33
30 July	33	67
3 August	59	41

Table 2. Infestation of Heliothine species and yield in test plots using Karate, Pirate, Tracer, Proclaim and Intrepid.

	Total Larvae/50 Plant Terminal and Square				
Treatment	28 June	3 July	30 July	3 August	Yield
					lint/acre
Untreated	6.8 a*	6.2 a	12.5 a	6.2 a	376 f
Karate 0.033	1.8 b	1.2 bcd	5.5 bcd	3.8 ab	792 abc
Pirate 0.35	4.5 ab	1.5 bcd	8.8 ab	2.0 b	693 cde
Karate 0.033 + Pirate 0.25	3.0 b	0.0 d	8.5 ab	2.8 b	889 a
*Tracer 0.067-0.08	2.8 b	2.0 bcd	3.5 d	1.0 b	774 bcd
Karate 0.067 + Tracer 0.033	3.8 ab	0.2 cd	5.0 bcd	1.2 b	861 ab
Proclaim 0.0075	2.0 b	3.2 b	6.8 bcd	2.5 b	608 e
Proclaim 0.01	2.0 b	2.8 bc	3.2 d	3.8 ab	687 cde
Intrepid 0.25	3.8 ab	1.2 bcd	5.5 bcd	2.2 b	671 de
Intrepid 0.35	3.8 ab	2.5 bcd	8.2 bc	2.2 b	627 e
Intrepid 0.25 + Larvin 0.45	4.5 ab	0.2 cd	4.0 cd	2.5 b	723 cde
Intrepid 0.25 + Curacron 0.5	4.0 ab	1.0 bcd	7.2 bcd	3.0 b	706 cde

*Means followed by same letter do not significantly differ (P = 0.05, Duncan's MRT)

SURVIVAL OF *HELICOVERPA ZEA* BODDIE ON BOLLGARD COTTON

H.B. Meyers, D.R. Johnson, T.L. Singer and L.M. Page[1]

RESEARCH PROBLEM

In the first year of widespread planting of Bollgard cotton, the cotton bollworm unexpectedly became the first pest to be a problem in Bt-transgenic cotton. Field observations revealed that bollworm larvae oviposited on flowers may be able to survive on Bollgard cotton. As a result of the unexpected bollworm pressure in many Bollgard cotton fields, an experiment was designed to compare the growth potential of bollworm larvae feeding on Bollgard flowers versus larvae feeding on flowers of conventional cotton.

BACKGROUND

In the first summer of widespread use of Bollgard cotton, Arkansas producers planted roughly 160,000 acres. Plantings were primarily in southern Arkansas where about half of the state's cotton acreage is grown. Most cotton experts fully expected the tobacco budworm to be the first insect to adapt to the new technology through the development of resistance. However, in the summer of 1996, the bollworm unexpectedly became the first insect to be a problem in Bollgard cotton but not through resistance development. Bollworms have the behavioral trait in which female moths are more attracted to flowers than are other lepidoptera pests. High bollworm populations occurred in many of the fields planted with bollgard in the summer of 1996. Larval populations of bollworm in the field ranged from very low up to 40,000 larvae/acre. Fields with high populations of bollworm incurred significant damage, and often a single application of a conventional insecticide was required. Field observations quickly determined that tobacco budworm was not establishing itself in Bollgard cotton and, consequently, was not a problem. Larvae collected from Bollgard flowers were found to be nearly all bollworm.

The bollworm has traditionally been the most difficult of all lepidopteran pests to scout because the adult moth often lays eggs low on the plant. The bollworm moth has a very large host range that includes other cultivated crops, such as soybeans. In soybeans the bollworm has been documented to be more attracted to an open canopy crop where eggs are oviposited lower in the canopy. In the summer of 1996, many cotton fields in Arkansas had either delayed canopy closure or

[1]Extension Entomologist, Extension Entomologist, Agricultural Technician - Entomology and Assistant Specialist - Entomology, Cooperative Extension Service, Lonoke, Arkansas.

failed to close at all, and this may have contributed to the increased occurrence of bollworm activity in many fields.

The occurrences of the tobacco budworm populations and bollworm populations are not simultaneous in Arkansas and are usually staggered, with the bollworm populations peaking in mid July and budworm populations peaking a few weeks later near the end of July.

RESEARCH APPROACH

Field observations determined that bollworm larvae surviving on Bollgard cotton were restricted to flowers and small bolls. To compare the growth of bollworm larvae feeding on Bollgard cotton versus non-Bollgard cotton, small larvae, two day or younger, were collected from Bollgard-infested fields in Lonoke and Jefferson Counties, Arkansas. A total of 96 larvae were used in the experiment. Collected larvae were equally divided between two treatments of Bollgard cotton and non-Bt cotton. Larvae were held in the laboratory on flowers or small bolls at a constant temperature and humidity of 25°C, 70% RH, respectively. Larvae were measured for total length and weighed 24 hours after being brought into the laboratory and were measured every other day thereafter. Larvae were observed through pupation or until they died. Larvae that grew to a length of 20 mm or greater were transferred to diet cups with small bolls because of their voracious appetites.

First day flowers and small bolls were collected from Bollgard and non-Bollgard cotton in Lonoke County by cutting them at the pedicel. In the laboratory, the pedicels were inserted into water saturated floral foam (3-in. square) to keep the flowers and bolls fresh for as long as possible. The floral foam blocks were kept in a pan containing water at a depth of 1 cm. Flowers and bolls were changed approximately every three days.

RESULTS AND DISCUSSION

The larvae were not weighed before being allocated to treatments, so the first measurements taken were after the larvae had fed for 24 hours. This accounts for the divergence of weight and length early in the experiment (Fig. 1). If measurements had been taken before the larvae had fed, we would have expected there to be no differences between treatments. The weights of second-day larvae were often very small and were often less than 0.05 g. Measurements of younger, smaller larvae would have been extremely difficult without more sensitive scales.

Weight was clearly affected very early in the experiment (Fig. 1). After only 24 hours of feeding, mean weight of larvae feeding on non-Bollgard cotton was twice as great as those larvae that fed on Bollgard cotton. Mean weight of larvae feeding on non-Bollgard cotton nearly doubled every 48 hours. Although larvae feeding on Bollgard weighed less and gained weight at a slightly slower rate, growth was parallel to that of larvae feeding non-Bt cotton.

The average weight of larvae feeding on non-Bollgard cotton for 18 days was more than 0.5 g heavier than those larvae that fed on Bollgard cotton. This indicates that early stunting from feeding on Bollgard cotton cannot be made up later.

Although larvae feeding on Bollgard cotton may weigh less and be slightly smaller, they were still able to complete their development to adulthood. The experiment was conducted in an open laboratory, and environmental conditions were somewhat variable. Of the 96 larvae in the experiment, only 18 completed their development. Many larvae failed to complete pupation, most likely because of the low humidity and cooler temperatures of the laboratory. However the majority of larvae, 32 larvae in the non-Bollgard treatment and 25 larvae in the Bollgard treatment, survived more than seven days.

In the future, neonates should be substituted for day-old or older larvae. Special considerations will have to be made in order to weigh neonates because they may weigh less than 0.01 g. Measurements should start on day 0, before the larvae begin feeding. Larval growth is extremely fast and, therefore, observations should be taken every 24 hours.

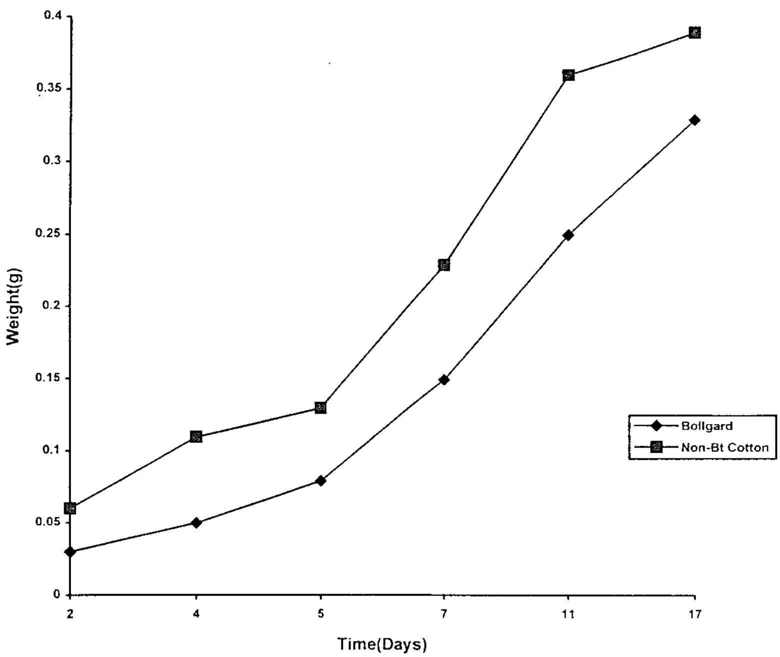

Fig. 1. Weight of *H. zea* larvae feeding on Bt and non-Bt cotton.

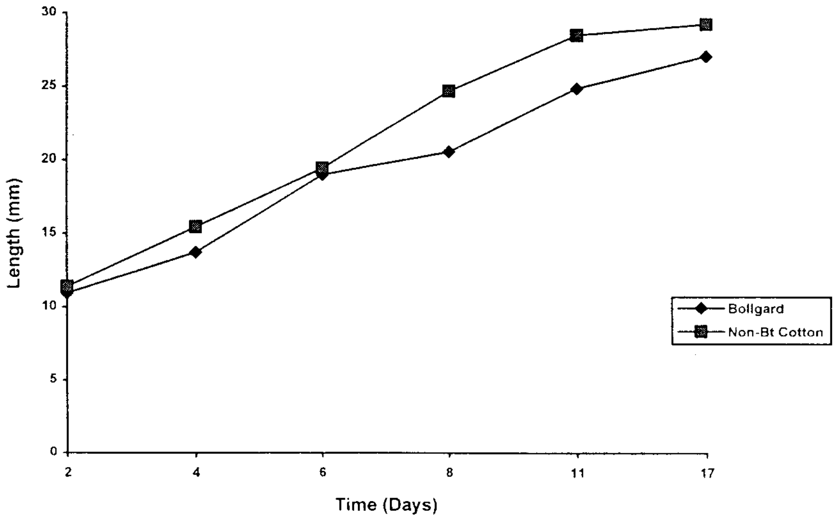

Fig. 2. Length of *H. zea* larvae feeding on Bt and non-Bt cotton.

COMPARISON OF VARIOUS INSECTICIDES IN THE CONTROL OF THE COTTON BOLL WEEVIL (*ANTHONOMUS GRANDIS*)

L.M. Page, H.B. Meyers, T.L. Singer and D.R. Johnson[1]

RESEARCH PROBLEM

Control of bollweevils requires the application of insecticides. Three classes of chemicals are available for their control. Arkansas producers need independent evaluation of the insecticides in order to make informed decisions concerning selection of a chemical for effective boll weevil control.

RESEARCH APPROACH

Tests were conducted in 1993 through 1996 in Lonoke County, Arkansas. Plots were 12 rows wide by 50 ft long and were on 38-in. centers. Tests were replicated four times. A single mowed row separated each plot to hamper migration from plot to plot. This has been observed to be an effective deterrent to migration until late-season populations swell to higher levels. Long-season varieties ‘DPL 5690’ and ‘DPL 5415’ were used to insure adequate fruit for evaluation during late-season peak weevil populations. Insecticide treatments began when damage to squares and terminals reached an average of 12-20%. Treatments were applied on a three- to five-day schedule. Evaluations for boll weevil damage occurred two days after each treatment. Twenty-five squares in each plot were inspected for feeding and oviposition damage. Insecticides were applied using a John Deere Hi-Cycle 6000 equipped with a CO_2 mounted spray system, with TSX-6 hollowcone nozzles at 30 PSI and 9.65 GPA.

RESULTS AND DISCUSSION

Boll weevil damage in 1995 exceeded the 20% damage level at which treatments are normally initiated. After five applications, the high rate of Baythroid was significantly superior to all other treatments (Table 1). Vydate C-LV and Guthion 2L allowed damage to occur and were not significantly different from the untreated check. Only Baythroid and Fury significantly reduced the number of boll weevils after the fourth application. All insecticides, with the exception of Guthion, provided good control after the last application. As in previous years, Karate at

[1]Agricultural Technician - Entomology, Extension Entomologist, Assistant Specialist, Entomology and Extension Entomologist, Cooperative Extension Service, Lonoke, Arkansas.

0.025 lb ai/acre and Asana XL at 0.03 lb ai/acre performed better than the standard treatments, but not as good as Baythroid.

In 1996, Baythroid (low and high rate) and Karate showed superior control compared to other standard treatments such as Vydate C-LV (Table 2 and 3). All treatments provided significant control compared to the untreated check.

PRACTICAL APPLICATION

Carbamate, organophosphate and pyrethroid insecticides were compared for efficacy and yield in Lonoke County, Arkansas. Baythroid at low and high rates provided superior control of boll weevils compared to Vydate C-LV at 0.25 lb ai/acre. The greater persistence by pyrethroids may be responsible for the better control.

Table 1. Efficacy of insecticides for control of boll weevils, Lonoke County, 1995.

			Damaged Squares / 25 Examined				
Treatment	Formulation	Rate	14 Aug.	22 Aug.	25 Aug.	29 Aug.	1 Sept.
		lb ai/acre					
Untreated			7.8 ab*	17.5 a	9.2 ab	5.2 a	10.5 a
Fury	1.5 EC	0.038	2.5 d	12.8 abc	7.5 abc	1.8 b	1.8 b-e
Karate	1.0 EC	0.028	3.2 cd	7.2 de	6.0 bcd	2.5 ab	0.2 e
Baythroid	2.0 EC	0.028	2.5 d	4.2 e	3.0 d	1.8 b	1.2 de
Regent	80 WG	0.050	3.5 cd	9.2 cde	6.8 abc	3.2 ab	2.2 b-e
Regent	80 WG	0.068	2.8 cd	6.5 de	7.8 abc	4.2 ab	1.5 cde
Penncap	2 E	0.250	8.2 ab	15.5 ab	9.2 ab	4.0 ab	4.2 bcd
FCR4545	1 EC	0.014	1.8 d	5.5 e	4.5 cd	3.0 ab	1.0 de
Guthion	2 L	0.250	8.8 a	16.2 ab	10.0 a	5.2 a	9.5 a
Guthion and	2 L	0.250	5.8 a-d	14.0 abc	8.8 ab	4.0 ab	5.0 bc
Orthene	90 SP	0.500					
Vydate	3.77 EC	0.250	6.8 abc	14.2 abc	8.0 ab	5.0 a	5.2 b
Vydate and	3.77 EC	0.250	4.5 bcd	11.0 bcd	6.8 abc	3.0 ab	11.0 bcd
Orthene	90 SP	0.500					

*Means in a column followed by same letter do not significantly differ (*P* = 0.05, Duncan's MRT)

Table 2. Efficacy of insecticides for control of boll weevils, Lonoke County, 1996.

Treatment	Formulation	Rate	Damaged Squares / 25 Examined					
			8 Aug.	12 Aug.	16 Aug.	21 Aug.	26 Aug.	30 Aug.
		lb ai/acre						
Untreated			4.0 ab*	9.0 a	14.3 a	18.3 a	15.5 a	19.5 a
Asana	0.66 EC	0.03	4.8 ab	6.3 ab	6.0 b	2.8 bc	5.0 c	6.8 def
Asana	0.66 EC	0.036	3.8 ab	3.5 bc	3.3 bc	0.5 c	2.5 c	4.3 ef
Asama	0.66 EC	0.042	2.3 b	0.8 c	2.8 bc	0.8 c	4.3 c	4.3 ef
Vydate	3.77 EC	0.250	1.8 b	1.0 c	0.8 c	3.5 bc	5.8 c	8.0 cde
Orthene and	90SP	0.5	2.8 ab	1.8 c	4.8 bc	4.3 bc	7.0 bc	12.0 bc
Vydate	3.77 EC	0.250						
TD 2344	0.83 EC	0.025	1.8 b	1.0 c	1.3 bc	3.0 bc	6.8 bc	4.8 ef
TD 2344	0.83 EC	0.035	5.5 a	2.5 bc	3.3 bc	1.8 bc	3.5 c	4.0 ef
Bidrin	8 EC	0.5	3.3 ab	0.8 c	4.5 bc	5.3 bc	11.8 ab	14.3 b
Baythroid	2.0 EC	0.03	4.0 ab	3.0 bc	2.5 bc	1.3 bc	2.8 c	4.5 ef
Penncap M	2.0 EC	0.35	4.0 ab	1.5 c	3.5 bc	7.5 b	8.5 bc	10.5 bcd
Baythroid	2.0 EC	0.025	3.0 ab	2.0 c	1.8 bc	5.5 bc	2.8 c	2.5 f

*Means in a column followed by same letter do not significantly differ (*P* = 0.05, Duncan's New MRT).

Table 3. Efficacy of insecticides for control of boll weevils, Lonoke County, 1995.

Treatment	Formulation	Rate	Damaged Squares / 25 Examined					
			14 Aug.	22 Aug.	25 Aug.	21 Aug.	26 Aug.	30 Aug.
		lb ai/acre						
Untreated			2.8 a*	4.0 a	5.3 a	8.8 a	16.0 a	13.8 a
Fury	1.5 EC	0.037	3.2 a	3.0 a	1.3 ab	0.0 b	4.3 b	1.8 d
Karate	1.0 EC	0.028	4.0 a	2.0 a	2.5 ab	2.0 b	3.0 b	3.0 cd
Baythroid	2.0 EC	0.028	2.2 a	1.5 a	1.0 b	0.0 b	1.5 b	0.3 d
Decis	1.3 EC	0.23	3.5 a	1.8 a	2.5 ab	1.5 b	1.0 b	2.8 cd
Decis and	1.5 EC	0.23	1.2 a	2.0 a	1.0 b	0.5 b	1.5 b	1.5 d
Phaser	3.0 EC	0.50						
FCR 4545	1.0 EC	0.014	4.0 a	0.8 a	0.0 b	0.8 b	1.0 b	1.3 d
Fipronil	2.5 EC	0.05	2.2 a	1.3 a	2.0 ab	3.0 b	2.0 b	5.5 bc
Fipronil	2.5 EC	0.068	2.2 a	1.8 a	1.3 ab	2.3 b	4.0 b	6.8 b
Fipronil	2.5 EC	0.038	1.5 a	1.5 a	2.0 ab	3.0 b	3.3 b	2.3 cd
Fipronil	80 WG	0.05	1.5 a	1.8 a	1.3 ab	3.0 b	2.0 b	2.8 cd
Karate	2.09 C	0.025	4.0 a	2.5 a	1.8 ab	1.0 b	4.0 b	3.8 bcd

*Means in a column followed by same letter do not significantly differ (*P* = 0.05, Duncan's MRT).

APPENDIX I
STUDENT THESES AND DISSERTATIONS IN PROGRESS IN 1996

Black, Colleen. Characterization of the expression and genetics of the D8 CMS/ restorer system in cotton. (M.S., advisor: Dr. Stewart).

Brannon, Dabney. Use of GIS to analyze spatial and temporal distribution of boll weevils in Northeast Arkansas. (M.S., advisor: Dr. Scott).

Candole, Byron. Characterization of suppressiveness of hairy vetch-amended soils to *Thielaviopsis basicola* and methods to asses the suppressiveness. (Ph.D., advisor: Dr. Rothrock).

Carter, Preston. Reduced volatilization of clomazone used in cotton herbicide programs. (M.S., advisor: Dr. Frans).

Chavez, Rebecca. Sunflower residue management in no-till cotton. (Ph.D., advisor: Dr. Frans).

Clements, Leigh Ann. Variation and the effects of selection associated with certain seed and seedling characteristics in cotton. (M.S., advisor: Dr. Bourland).

Coyle, Gwen. Molecular evaluation of the Asiatic Cotton Germplasm Collection. (Ph.D., advisor: Dr. Stewart).

Feaster, Michael. Control of *Helicoverpa zea* and *Pseudaletia unipuncta* (Lepidopter: Noctuidae) with soil applications of the entomogenous nematode, *Steinernema riobravis* (Rhabditida: Steinernematidae). (M.S., advisor: Dr. Steinkraus).

Janes, Lynn. Genotypic effects on foliar fertilization with potassium. (M.S., advisor: Dr. Oosterhuis).

Johnson, Joe. Characterization and associations of crop growth patterns of contrasting cotton cultivars generated by COTMAN. (M.S., advisor: Dr. Bourland).

Ke, ZhenShou. Effect of several factors on cotton callus initiation and production of embryogenic tissues. (M.S., advisor: Dr. Stewart).

Keino, James. Characterization of cotton root growth in relation to plant growth, water management and potassium kinetic uptake parameters. (Ph.D., advisor: Dr. Beyrouty).

Kim, Michelle. Changes in the development of the boll wall in relation to age and insect feeding. (M.S., advisor: Dr. Oosterhuis).

King, William, H. Sampling the cotton growth and development process: implications in Heliothine larval survival and late-season insect control costs. (M.S., advisor: Dr. Tugwell).

Khan, Altaf. Molecular map of *Gossypium arboreum* relative to *G. hirsutum*. (Ph.D., advisor: Dr. Stewart).

Lammers, Jeff. Refining the target development curve for the COTMAN system of cotton monitoring. (M.S., advisor: Dr. Bourland).

Latimer, Stephanie L. Evaluation and inheritance of resistance to Verticillium wilt in cotton. (Ph.D., advisor: Dr. Bourland).

McGowen, Robert E., Jr. Evaluation and development of resistance to tarnished plant bug in cotton. (Ph.D., advisor: Dr. Bourland).

Nepumoceno, Alex. The physiology and molecular biology of drought tolerance in cotton. (Ph.D., advisor: Dr. Oosterhuis; co-advisor: Dr. Stewart).

Rajguru, Satyendra. Genetic engineering of cotton for host plant resistance. (Ph.D., advisor: Dr. Stewart).

Rhoades, Shaun. Risk-returns of Arkansas field crops. (M.S., advisor: Dr. Parsch).

Smith, Cade. Influence of cover crop residue on weed control and cotton growth in conservation-tillage systems. (M.S., advisor: Dr. Frans).

Walker, Nathan R. The interaction between *Meloidogyne incognita* and *Thielaviopsis basicola* on cotton. (Ph.D., advisors: Drs. Kirkpatrick and Rothrock).

Zhang, Jinfa. Genetic analysis of fertility restoration in cytoplasmic male sterile lines of cotton. (Ph.D., advisor: Dr. Stewart).

Zhao, Duli. Cotton square development and response to shading and PGR-IV application. (Ph.D., advisor: Dr. Oosterhuis).

APPENDIX II
RESEARCH AND EXTENSION
1995 COTTON PUBLICATIONS

Proceedings Edited:

Oosterhuis, D.M. (ed.). 1996. Proceedings 1995 Arkansas Cotton Research Meeting and Research Summaries. Univ. of Arkansas, Ark. Agric. Exp. Stn., Special Report 178.

Refereed Publications:

Bednarz, C. and D.M. Oosterhuis. 1996. Partitioning of potassium in the cotton plant during the development of a potassium deficiency. J. Plant Nutr. 19(12):1629-1638.

Bierlen, L.D. and G. Cao. 1996. Tenant satisfaction with land leases. Rev. of Agric. Econ. 18(3):505-513.

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Bondada, B.R., D.M. Oosterhuis, R.J. Norman and W.H. Baker. 1996. Canopy photosynthesis, growth, yield, and boll ^{15}N accumulation under different soil nitrogen regimes in cotton. Crop Science 36:127-133.

Bourland, F.M. 1996. Registration of 'H1330' cotton. Crop Sci. 36:813.

Colyer, P.D., T.L. Kirkpatrick and W.D. Caldwell. 1997. Influence of nematicide application on the severity of the root-knot nematide-Fusarium wilt disease complex in cotton. Plant Disease 81:66-70.

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Steinkraus, D.C., R.G. Hollingsworth and G.O. Boys. 1996. Aerial spores of *Neozygites fresenii* (Entomophthorales: Neozygitaceae): Density, periodicity, and potential role in cotton aphid (Homoptera: Aphididae) epizootics. Environ. Entomol. 25:48-57.

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Virginia. Beltwide Cotton Production Research Conferences. Nashville, TN. p. 1429-1430.

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Barham, J.D., T.L. Kirkpatrick and R.J. Bateman. 1996. Evaluation of in-furrow fungicides for control of seedling disease in cotton, 1995. Fungicide and Nematicide Reports 51:236.

Barham, J.D., T.L. Kirkpatrick and R.J. Bateman. 1996. Evaluation of Start and Rovral + Ridomil for control of seedling disease in cotton, 1995. Fungicide and Nematicide Reports 51:237.

Bednarz, C.W. and D.M. Oosterhuis. 1996. Partitioning of potassium in field-grown cotton plants under various levels of available potassium. Arkansas Fertility Bulletin Studies 1995. Research Series 450:75-77.

Bednarz, C.W. and D.M. Oosterhuis. 1996. Physiological aspects of potassium deficiency in cotton. Proc. 1996 Arkansas Cotton Research Meeting and Summaries of Research. Univ. Arkansas Agri. Exp. Stn. Special Report 178:133-139.

Bondada, B.R. and D.M. Oosterhuis. 1996. Physiological responses of cotton to late-season foliar nitrogen fertilization. Proc. 1996 Arkansas Cotton Research Meeting and Summaries of Research. Univ. of Arkansas Agri. Exp. Stn. Special Report 178:128-132.

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Bourland, F.M., G.M. Palmer, J.M. Hornbeck and B.S. Frizzell. 1996. Arkansas cotton variety and strain tests, 1995. Univ. of Arkansas Agric. Exp. Stn. Research Series 451.

Boys, G.O., D.C. Steinkraus, and R.G. Hollingsworth. 1996. Multistate sampling for *Neozygites fresenii* in cotton. *In* Proceedings 1996 Beltwide Cotton Research Conferences, Nashville, TN. pp. 735-738.

Cochran, M.J., F.M. Bourland, N.P. Tugwell and D.M. Oosterhuis. 1996. Overview, update and future. Proc. 1996 Arkansas Cotton Research Meeting and Summaries of Research. Univ. of Arkansas Agri. Exp. Stn. Special Report 178:36-38.

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Cochran, M.J., N.P. Tugwell, F.M. Bourland and D.M. Oosterhuis. 1996. COTMAN Users Guide, Version 2.1. Univ. of Arkansas, Dept. of Agri. Econ. and Rurual Soc. Miscellaneous Publication.

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Keino, J.K., C.A. Beyrouty, E.E. Gbur and D.M. Oosterhuis. 1996. Effect of foliar-applied potassium on kinetic uptake parameters of cotton. Proc. 1996 Arkansas Cotton Research Meeting and Summaries of Research. Univ. of Arkansas Agri. Exp. Stn. Special Report 178:158-161.

Keino, J.K., C.A. Beyrouty, E.E. Gbur and D.M. Oosterhuis. 1996. Effect of foliar potassium on kinetic uptake parameters of cotton. Arkansas Soil Fertility Studies 1995. Univ. of Arkansas Agri. Exp. Stn. Research Series 450:72-74.

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Oosterhuis, D.M., C. Bednarz and L.D. Janes. 1996. Improving potassium predictions for foliar feeding in cotton by understanding plant needs. Fluid Fertilizer Foundation Proceedings. pp. 74-77.

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Robertson, B., P. Ballantyne, K. Williams, S. Rodery, J. Vestal, A. Fisher, M. Crow, A. Vangilder and D. Wiley. 1996. 1996 County yield demonstration result. AG 485-4-97.

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