WHAT'S HAPPENING IN THE REAL WORLD?

David Wildy[1]

In order to cover the subject that I have been given, I decided to look at some agricultural trends in the state of Arkansas and across the North Mississippi Delta. The number of farms has remained about constant across the state while the number of north delta farms has decreased about 15% in the last five years. However, when you look at farm size and irrigated farms, there is a 20% increase in the North Delta. When you look at irrigated acres across the state, there has been a 40% increase, while the irrigated acres have increased 70% in the North Delta region. Cotton acreage has done about the same with a 17% increase in the north delta with little change recorded in the rest of the state. Also, when you look at where the cotton acreage is located in Arkansas, one will see that approximately 60% of the cotton is grown in only 6 counties in the northeast corner of the state (Fig. 1). As one looks at the trends in agriculture, I think it is important for researchers to understand where the biggest changes are taking place and where a large percentage of the cotton is grown in the state.

I don't think anyone would argue that the cotton industry is struggling. The big questions are, "what are the problems and what can be done to correct them?" Certainly economics play a big role in cotton profitability. High input costs and low prices have played major roles. Cotton yields and yield stability have also played major roles in decreasing the profitability of cotton production.

If you look at a graph of the average yield in Arkansas across the last 10 years, it is somewhat like a roller coaster. Certainly yield variability is seen as a problem, but I think the important thing to realize is that the average yield over this ten-year period has actually decreased (Fig. 2). In ten years we have made no progress. Also for this same time period the average price has remained about the same – flat.

Cotton acreage in Arkansas has also remained fairly constant over the last few years while total value of the crop has declined from over 575 million dollars to under 350 million dollars. As production costs continue to rise and the price of cotton decreases, the producer is caught in the middle. Our only alternative is to try to increase yields to stay in business.

On my farm, with the exception of 1993, from 1987 through 1994 yields were on the increase. But from that point forward we have seen a definite downward trend (Fig. 3). It is obvious when looking at my yield data that in the good years, there is less

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difference in irrigated versus dry-land yields. As one looks at these graphs, it isn't hard to conclude that something must be done quickly to increase and stabilize yields to save the cotton industry in Arkansas.

I have shown that little progress has been made in the last ten years if you look at average yields across the state. Some have asked, "Where do genetically modified organisms (GMOs) fit into the equation?" Can biotechnology help to stabilize yields and improve production? Up to this point it has not. I agree that there are some very exciting things on the horizon involving biotechnology. However, under the current economic situation of our industry, will we be able to afford these technologies and will they be cost effective? Another concern is public acceptance of genetically modified crops. Fiber quality is also a big issue, but until premiums are paid for improved quality, producers are more likely to focus only on increasing the yield.

Where do we go from here? Better prices would greatly help to increase gross revenue but input costs seem to be outpacing any price increases. Also, producers have little control over price or costs. We also have no control over climatic conditions, which many times become the scapegoat for poor yields. I think it is fairly obvious that a producer is going to focus on yield and yield stability in his quest for survival. We have looked at yield trends and variability from year to year, but what about stability within a given year? If we look at variability across fields, we see a large range of yields. To take it one step further, we also can see tremendous variability within a given field. With cotton yield monitors, we can show that even in a bad year certain areas within a field will have exceptionally high yields. With the technology available to us today, I think much could be learned by monitoring these areas of high and low yields. Fertility, soil type, soil characteristics, water availability, growth patterns, plant maps, and fruit retention should be researched as quickly as possible. Tillage practices and methods, fertility, and irrigation methods (initiation, frequency, and termination) are of utmost importance.

Center-pivot versus furrow irrigation has been a topic of conversation with many producers and researchers. The general consensus seems to be that furrow irrigation might be better in extremely dry years. However, over the last fourteen years on my farm, furrow has out-yielded center pivots only two of those years. Is this the norm or the exception?

Researchers must also begin to look at new systems. A big move is on toward limiting tillage. Reduced till, ridge-till, and no-till are receiving much attention and use. Evaluation of these systems must be made to steer producers in the right direction as they strive to increase production while maintaining efficiency.

The question is "What must happen for the cotton industry to survive?" Very simply, a better price for our product and stable or lower production costs would go a long way toward improving the economy of the cotton industry. But we as producers will have limited effect on these factors. Yield stability and yield improvement must quickly be addressed. The trends must be changed.

I sincerely hope that, through a team approach across all production disciplines and practices, ten years from now I will be able to say the yield trend is up.

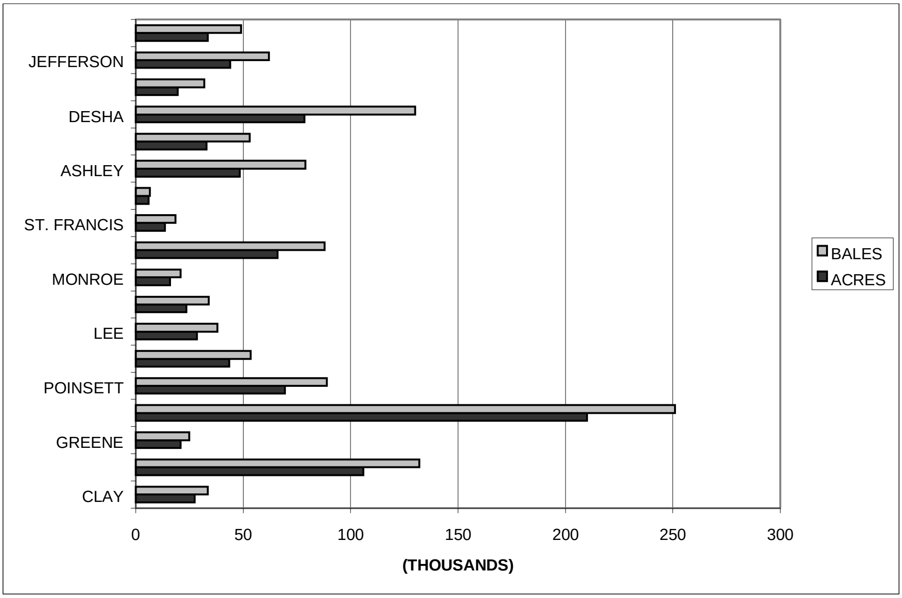

Fig. 1. Arkansas cotton production by county.

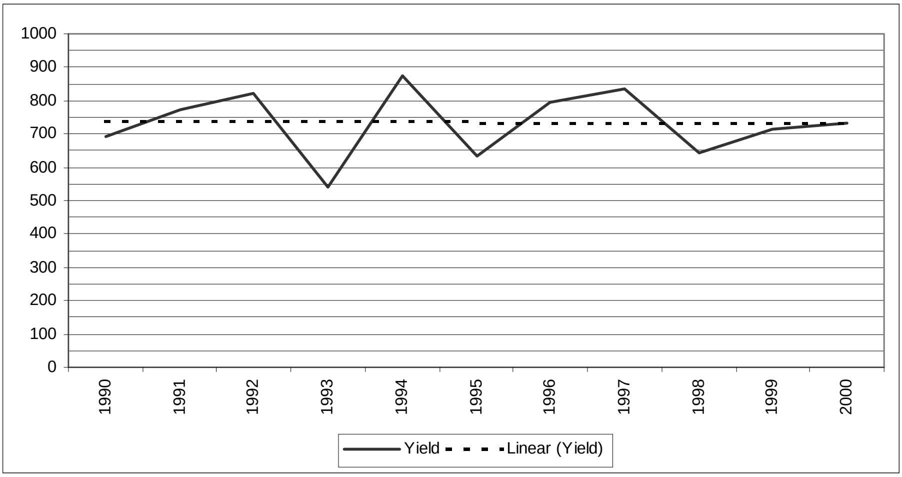

Fig. 2. Arkansas cotton yield trends.

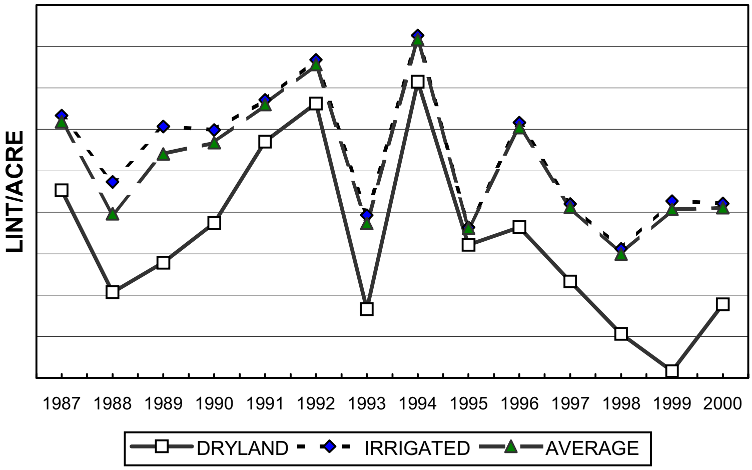

Fig. 3. Yield across years at the Wildy Farms in northeast Arkansas.

YIELD VARIABILITY PROBLEM

William C. Robertson[1]

The problem associated with yield variability is one that impacts all producers. Yield variability is most easily identified by differences from year to year (Fig. 1). However, yield variability is also a function of variability from field-to-field and plant-to-plant within a field. Arkansas cotton producers experienced a tremendous amount of variability from field-to-field and within fields in 2000. The documentation of variability within a field with the advent of yield monitors and other tools will reveal much about the levels of variability that exist and hopefully will offer clues to a solution.

Sources of yield variability can be divided into two broad categories: environment and genetics. The environment is composed of not only the weather, pests, and other related factors, but also includes management. How the management of a crop is altered in response to these factors can lessen or enhance its effect on yield. Oftentimes the weather, particularly temperatures, will override management, but management is still important. High nighttime and day temperatures impact yield. Heat units incurred during the month of August generally have an effect on the state-average yield. As August heat units increase, yields generally decline (Fig. 1). Record yields were observed in 1992 and 1994, years with relatively lower heat unit accumulations. However, record heat-unit accumulation was observed in August 2000 while the state yield actually increased slightly from the previous year. The lack of rainfall during the summer and much of the harvest season resulted in reduced incidence of boll rot and harvest losses, which may have contributed to this phenomenon.

The University of Arkansas Official Variety Trials (OVT) clearly indicate the level of variability associated with genetics. A level of consistency exists both at the top and the bottom of the rankings. The best varieties generally do well at multiple locations in both dryland and irrigated sites. The same can generally be said for the varieties at the bottom of the list. The problem lies with many of the varieties in the middle and with their genetic traits. In the 2000 OVT, 7 to 8 of the top 10 varieties were non-transgenic, yet less than 25% of the acreage statewide was planted to conventional varieties. Yield rankings of varieties in irrigated versus dryland testing sites may give insight into the ability of a particular variety to tolerate stress. Some varieties yielded

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well in the highly-managed irrigated sites while falling in rank significantly compared to other varieties in the stressed dryland sites.

Short-term solutions to managing yield variability include selecting varieties that fit each producer's situation. Some varieties, while not the high yielding "Race Horse" varieties, compared to others are relatively forgiving with respect to stress tolerance. On the other hand, "Race Horse" varieties, which respond very well to management, can sometimes fall victim to poor timing of inputs or extreme environmental conditions. Improvement in management strategies, particularly with regard to irrigation initiation and frequency, will yield significant positive results, especially in a dry year such as 2000.

Long-term keys to managing yield variability must come from improved genetics. Producers are in dire need of high-yielding varieties with the fiber-quality characteristics that meet mill demands. We are beginning to see conventional varieties with improved yield and quality traits. Yet improved varieties with the transgenic traits producers desire to fit into current production strategies are lacking. Inserting new genes into old varieties will not necessarily result in an improved new variety.

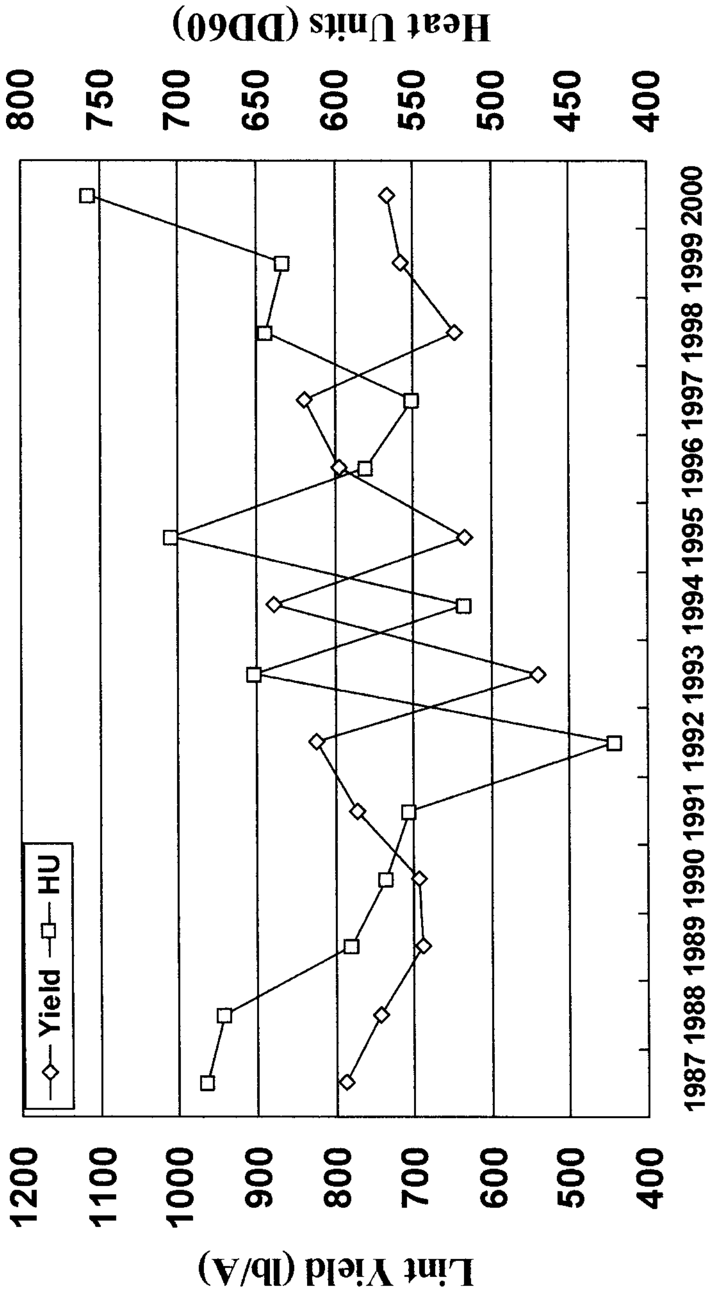

Fig. 1. Relationship of the statewide lint yield average and total heat unit (DD60) accumulation for the month of August in Central Arkansas.

ADDRESSING YIELD VARIABILITY THROUGH RESEARCH

Fred M. Bourland and Derrick M. Oosterhuis[1]

INTRODUCTION

To some extent, highly variable cotton yields pose a greater economic threat to producers than do consistently low yields. When yields are consistently low, the producer is forced to change production practices to lower input costs or change to other crops. In a highly variable yield situation, expectations of good yields prompt high investments each year. Today's low commodity prices and increasing production costs require high yields to simply break even. Thus, the effects of disappointing yields have become more harsh.

Although yearly fluctuations in yields have always occurred, these perturbations have been exacerbated in recent years and have greatly increased attention to yield variability. This paper will review yield variability from a historical perspective, and then will summarize indirect and direct approaches being employed by the University of Arkansas Cotton Research Group to address the problem.

HISTORICAL PERSPECTIVE

Yield variability before ca. 1960

Prior to about 1960, most cotton in Arkansas was planted with fuzzy seed. Resulting stands were hand-thinned, hand-weeded, and hand-harvested. Very little of the crop was irrigated. A wide variation in varietal types was grown. Yields were relatively low, but had increased dramatically since the mid-1940s (Lewis and Richmond, 1968).

In this labor intensive situation, breeding emphasis was placed on wilt (Verticillium and Fusarium) resistance, ease of hand-picking and high gin turnout. The latter two were specifically aimed at reducing harvesting costs. Other major research areas included pest control (mainly focused on single diseases and insects); fertility (mainly nitrogen); and the introduction of chemical weed control, defoliation, and mechanical harvest.

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Yield variability - ca. 1960 to 1980

Cotton production changed rapidly with efforts to reduce labor requirements. The introduction of mechanically-delinted seed made it possible to treat seed and to meter (to some extent) seeding rates. Replacement of mechanically-delinted seed with acid-delinted seed enabled the grading, treating, and precise metering of seed. Precise metering of seed eliminated the use of hand-thinning, but variable stand densities became much more common. Chemical weed control reduced the amount of hand-weeding, but also introduced some degree of lateral root pruning and plant injury. The spindle picker quickly eliminated hand-picking. Two relatively late-maturing varieties, 'Stoneville 213' and 'Deltapine 16', dominated acreage during much of this period. These work-horse varieties were widely adapted, and seemed to produce relatively similar yields regardless of how they were treated. Irrigation use increased, but appreciably more in south than north Arkansas. Yield variability was, to some extent, related to length of the growing season. Yields steadily increased, but then flattened (Lewis and Sasser, 1999). The subject of declining yields was addressed in special sessions at the Beltwide Cotton Production Conferences in 1977 ("What's happening to cotton yield?") and in 1982 ("The cotton yield problem").

Breeding emphasis was focused on developing earlier-maturing varieties and improving host plant resistance. Several morphological traits were examined to specifically improve resistance to insect pests. Research in the pest control area began to recognize and emphasize interactions of multiple diseases and insects. A host of new chemistry of pesticides, fertilizers, and defoliants was examined. With the use of mechanized harvest, the effects of production practices could be more closely examined (Tugwell and Waddle, 1964).

Yield variability - ca. 1980 to 1990

Irrigation became more commonly used throughout Arkansas cotton-growing regions during this period. The increase was sparked by the drought experienced in 1980 and the high costs of insect control, and was partly facilitated by the development of early-maturing varieties. The era of short-season cottons was ushered in by the release of 'DES 56' and 'DES 24' in 1978, with the subsequent releases of 'Stoneville 506' and 'Deltapine 41'. The release of 'Deltapine 50' in 1984 provided a widely-adapted short-season smooth-leaf variety that was quickly accepted. Improved herbicides (less crop injury); increased fertility; new insecticides (particularly the pyrethroids); and increased irrigation along with the new varieties caused high yields to be expected. However, costs of production also increased.

Research emphasis during this time included integrated pest management whereby plant interactions with various pests and chemicals were examined. Plant growth and development were studied and evaluated using newly developed mapping techniques and modeling efforts. Research on new chemicals included work on plant growth regulators.

Yield variability - ca. 1990 to 2000

To a large extent, the production systems of the 1980s continued in the 1990s. Inputs continued to increase, but cotton prices generally declined. In the mid-1990s, transgenic varieties were introduced. These varieties were derived by backcrossing Bt and/or Roundup Ready genes into formerly released varieties. Variety stagnation began to be questioned. During this time, record high yields were attained, but yields were highly variable. The level of variability was higher than previously experienced, and ignited questions regarding yield variability (see Bryant and Parsch, pp. 20-24 in this volume).

Research emphases were focused on keeping up with the changes. Warm winters increased overwintering of insects and nematodes and brought new problems to be addressed. The hot, dry summers brought attention to physiological and irrigation issues. Work with reduced tillage systems was enhanced by the introduction of Roundup Ready cottons. The COTMAN management system was developed and released, and has become a focus for integrated research.

ADDRESSING YIELD VARIABILITY - INDIRECTLY

Most experiments are repeated over time (multiple years) and/or space (multiple locations). Furthermore, evaluation of data from such tests considers yield variability. Current, ongoing research projects in the following disciplines indirectly are addressing yield variability:

- Variety Testing: Varieties are routinely evaluated at multiple locations each year, and variety by location interactions are examined. Multiple year means of varieties that are re-submitted to the tests are determined.
- Breeding: In early generations, scarcity of seed prevents evaluation at multiple locations. As lines are selected and progress to higher generations, they are evaluated at multiple locations for host plant resistance and adaptation. To remain in the program, a line must perform well each year.
- Genetics: Interspecific and intraspecific sources of germplasm are being evaluated for enhanced pest resistance and drought tolerance, and to expand the genetic base of cultivated cotton.
- Physiology: Basic physiological functions of the plant as affected by nutrition, water, light, and growth regulators, as well as their interactions, are being evaluated. Much of this work involves the effects of environmental stress on plant growth and yield development.
- Plant Pathology: Work is in progress to quantify the effects of weather on seedling disease and root-knot nematodes. Since the effects of diseases are exacerbated by weather stress, quantifying these effects will help to improve control and stabilize production.
- Entomology: Currently, research projects are focusing on the control of thrips, aphids, and plant bugs. The use and effects of Bt cotton and boll weevil eradica-

tion on cotton production systems are being examined. Also, interactions of weather and plant stress on insects continue to be studied.
- Weed science: Emphasis has been placed on the developing weed control systems for transgenic cottons and comparisons to conventional systems.
- Fertility: Fertility needs and the effects of deficiencies are being examined in current and new production systems.
- Multidisciplinary: Work is continuing to validate and expand the use of the COTMAN management system. Testing has been initiated to develop and evaluate newly prescribed cotton production systems.

ADDRESSING YIELD VARIABILITY - DIRECT

Yield components

Lewis *et al.* (2000) suggested a novel approach to the analysis of cotton yield. They explained yield by two basic components: number of seed per acre and weight of fiber per seed. Typically, cotton yield has been defined in terms of (1) lint percentage, (2) boll size, (3) bolls/plant, and (4) plants/acre. Compensation among these components is expressed by multiple interactions, which essentially negate their value as selection criteria. For example, since bolls/plant can be increased by simply decreasing plants/acre or by decreasing boll size, selection for increased bolls/plant has little or no impact on yield. With fewer possible interactions, the yield components of Lewis *et al.* (2000) should provide a more direct opportunity to improve yield.

Improvement of lint weight per seed should also provide more stable yields. Lewis *et al.* (2000) indicated that yields in most recently developed varieties rely more heavily on increased seed/acre than on increased lint weight/seed. Reliance on increased seed/acre component of yield causes varieties to be more likely to fluctuate in yield because more weight (1.6 pound of seed to produce a pound of lint) and energy (oil compared to cellulose production) are required to produce seed than lint.

To a large extent, variability in yield is related to response of plants to stress. Three projects are underway in the general area of stress physiology that will contribute to our understanding of yield development, susceptibility to environmental stress and management options. These include: (1) evaluation of genotype and environmental stress on partitioning at seed, boll, and whole-plant level to better understand stress tolerance (includes evaluation of yield components); (2) understanding and measuring the effects of environmental stress on the development of boll weight; and (3) development of a mathematical model to predict boll weight with incorporation of dynamic with environmental thresholds.

Crop management focused on realized and projected stress relationships is a multidisciplinary project that has been initiated. This work seeks to integrate (and add to) the plant monitoring techniques established in COTMAN with concepts derived from the stress physiology work. The goal is to not only monitor plant stress, as is now possible with COTMAN, but to also project and establish means of dealing with plant stress.

PROMISING CHANGES

Hopefully, the present problem with highly variable yields will disappear in the same fashion as the yield decline problem in the early 1980s. At least six factors provide optimism that yields may become less erratic.

1) The more typical weather experienced so far this winter should lessen overwintering of some insect pests and nematodes, and allow the season to start with substantial soil-water reserves.
2) Improved varieties are now becoming available (Benson *et al.*, 2001). Unfortunately, the best of the new varieties do not carry the transgenes for Roundup Ready or Bt. However, improvement in transgenic varieties is occurring, and the genetic lag associated with transition to transgenic varieties should gradually decline.
3) Boll weevil eradication should greatly reduce insect losses, and lessen variability in yields.
4) Systems to reduce seedling injury are being developed. By establishing more uniform, healthy seedlings, plants should develop faster and more uniformly. Optimal application timing of management practices are then facilitated.
5) Increased use of farm-tested crop monitoring (COTMAN) techniques should greatly facilitate crop management for more timely and economical inputs.
6) Finally, simply acknowledging and increasing attention to yield variability will improve the chances of better understanding and thus lessening the problem.

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MANAGEMENT TO REDUCE STRESS

Derrick M. Oosterhuis and Fred M. Bourland[1]

INTRODUCTION

Year-to-year variation in yields of the cotton crop in Arkansas has become a major concern of cotton producers. Much of this variability has been attributed to the occurrence of periods of drought and high temperature during boll development (Oosterhuis, 1995, 1996, 1997, 1999). This paper will describe the uniqueness of cotton in relation to its sensitivity to the environment and its capacity to withstand stressful conditions and compensate through additional growth, fruit set, and yield. In order to understand the ability of the cotton plant to withstand stress, it is necessary to briefly review the unique growth pattern of the cotton crop, central to which is the flowering and fruiting habit. Stress can take many forms, and therefore a definition of stress will be presented and the major biotic and abiotic components of stress will be listed. Lastly, using these descriptions of plant development and plant response to stress, management to reduce stress will be discussed. Obviously there is no magic formula to reduce stress and ensure high yields, but with an understanding of crop growth and behavior to stress, a series of management options can be considered and adopted where appropriate. In this way crop managers should be able to strive to get the most out of their cotton crop in any given set of environmental conditions and achieve some yield stability.

COTTON IS UNIQUE, SENSITIVE, AND FORGIVING

The cotton plant is reputed to have the most complex growth habit of all major row crops. This is because it is a perennial, it has an indeterminate growth habit, a sympodial fruiting habit, and complex flowering pattern. Furthermore, the cotton plant is very sensitive to changes in the environment and also from management inputs. Changes in vegetative growth (e.g. rank growth) and also in fruiting characteristics (e.g. shedding) are common in response to perturbations in the weather, inadequate insect control, or bad management. However, in our favor, the cotton plant is fairly resistant to stress and can slow down growth in response to undesirable environmen-

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tal conditions, and can compensate with additional square set and boll growth with little or no effect on yield, provided the season is sufficiently long and favorable.

PLANT DEVELOPMENT

To implement sound management programs and to be able to react to changes in the environment, e.g. adverse weather, it is essential to understand the growth pattern and changing requirements of the cotton crop. Cotton follows a fairly predictable and well documented developmental pattern (Fig. 1) although this can be influenced by adverse weather – temperature and drought in particular – and also by management inputs such as irrigation and nitrogen fertilizer. The cotton plant proceeds through a number of stages, which for practical purposes can be divided into germination and emergence, seedling development, leaf area and canopy development, squaring development, boll development, and boll maturation (Oosterhuis, 1990). Knowing the particular requirements and sensitivities of each stage of development of the crop permits producers to act on a timely basis to ensure that shortages of any particular resource do not occur at any stage, and stress is thus avoided before it can occur, thereby protecting the yield potential of the developing crop and maximizing yields. It is important to manage according to crop requirements and yield potential.

FRUITING HABIT AND SHEDDING

Reproductive growth is first visible to the naked eye about four weeks after planting with the appearance of squares (pinhead squares) in the terminal (although microscopic squares are already present in the terminal a few weeks after planting). The cotton plant, due to its indeterminate growth habit, continues some vegetative growth at the same time as reproductive development throughout the remainder of the season. Good management implies maintaining this balance with judicious use of fertilizers and water and correcting imbalances with plant growth regulators. An imbalance, e.g. too much vegetative growth, can lead to rank cotton, excess shading in the canopy, and excessive fruit shedding. The cotton plant has a distinctive and predictable flowering pattern that starts with the appearance of the first white flower at main-stem nodes 5 to 7 about 60 days after planting. About three days elapse between the opening of a flower at a given position and the opening of a flower at the same relative position on the next higher fruiting branch. On the other hand, the time interval for the development of two successive flowers on the same branch is about six days. The order is thus spirally upward and outward.

Cotton producers and researchers have long been interested in square and boll shedding. Some regard the process of fruit shedding as a physiological disorder, which, if corrected, would greatly increase crop productivity. Others, more correctly, regard boll shedding as a natural process by which the plant adjusts its fruit load to match the supply of inorganic and organic nutrients available to the plant - such that a certain amount of fruit shedding is essential for good yields. Square and boll development are very sensitive to environmental conditions and fruit retention is a season-long job for cotton growers. No area of the Cotton Belt escapes all the factors that cause fruit shedding – if it is not insects or disease causing shedding, then it's weather or plant factors. Shedding is regulated largely by nutrient, carbohydrate, and water supply and mediated through plant hormones and anatomical changes in the boll. Cotton has the ability to compensate for shedding from insects or bad weather but recovery will depend on conditions during the remainder of the season.

Various management options exist to regulate fruit growth and to prevent excessive shedding. Crop monitoring provides an accurate means of following fruit retention and detecting stress such that management options can be used on a timely basis before yield losses occur. Management practices to reduce shedding involve good pest control of especially insects, but also weed and disease control. Crop and environmental conditions that promote shedding should be avoided. This includes rank growth, inadequate fertility, water stress, and high plant density. Judicious use of irrigation and water conservation is critical. Plant growth regulators provide a means of controlling plant growth and improving fruit retention. Consideration of appropriate varieties is essential to tailor a crop to the existing management regime.

DEFINITION OF STRESS

Stress can be defined simply as anything that adversely affects growth and yield. Of course, this encompasses a myriad of factors including adverse weather (e.g., drought, high temperatures, etc.) and poor management (e.g. inadequate fertilizer, inadequate insect control, delayed irrigation, rank growth, etc). Stress is often divided into biotic and abiotic stresses. Abiotic factors include water stress, extreme temperatures, low light, inadequate nutrition, and chemicals. Biotic factors include insects, disease, weeds, water in open flowers, incorrect plant spacing, extreme plant populations, and plant competition.

It is important to realize that there are "good stresses" as well as "bad stresses." A *bad stress,* as already stated, is something that adversely affects growth and yield. On the other hand, a *good stress* is a relatively new term for a stress that results from some desirable growth attribute such as the stress the developing boll load imposes on the vegetative parts of the plant, the terminal in particular. This *good stress* is manifested by the slowing down of the terminal part of the plant as resources are preferentially diverted to the developing bolls, a fact made use of in the COTMAN crop monitoring program to determine cutout, on which end-of season management decisions are based.

MANAGEMENT TO REDUCE STRESS

Stress: we have to live with it! We can never completely avoid the negative impact of adverse weather, but we can moderate the effects of stress. The following provides a general discussion of appropriate existing measures to combat environmental stress and protect the developing boll load. Obviously, it is important to follow current recommendations for producing irrigated or dryland cotton. This includes the choice of appropriate tillage practices including conservation tillage, selection of the best-suited varieties, careful seedbed preparation for good germination and seedling vigor, precise weed control, attention to plant population and uniformity, judicious use of fertilizer and growth regulators, and crop rotations where possible. More research focus is needed on various aspects of precision farming that may be of benefit for moderating the detrimental effects of stress. As already mentioned, it is essential to know the developmental pattern of the cotton crop and the particular requirements of each stage in order to be able to act on a timely basis to ensure that shortages of any particular resource do not occur and thereby avoid stress as much as possible.

Drought Stress

Water shortages are the most limiting factor for crop production worldwide and the same applies to cotton production. Although the cotton plant originates from arid areas, it does nor grow well without adequate water. The cotton plant exhibits some drought tolerance compared to other crops (Fig. 2) but this characteristic has become limited in current U.S. commercial varieties. Crop monitoring with COTMAN clearly shows the effects of any water shortage on growth (e.g., deviations from the target development curve, shedding, and height and node development irregularities). The negative impact of water deficit can never be completely avoided, but we can try to moderate the effects of the stress. Remedies include use of drought-tolerant varieties; irrigation; judicious use of fertilizer, nitrogen in particular; water conservation tillage; and appropriate crop rotations.

Temperature Extremes

Cotton originates in hot areas but does not grow best at high temperatures. The optimal temperature range for cotton is 68-86°F. Although growth still occurs at temperatures higher or lower than this range, the growth rate drops off rapidly as temperatures deviate more widely from the optimal range. The ability of the cotton crop to photosynthesize and grow at high temperatures depends on the availability of water. This is because water is needed for growth and also to cool the leaves as evaporation occurs from the leaf during transpiration. That is why leaves of a well-watered crop feel cool to the touch on a hot day. Evaporative cooling from the leaf can cool the leaves by as much as 6°F below air temperature. Thus the detrimental effect of high temperature can be compounded by drought. Both high *day* temperatures and high *night* temperatures will adversely affect growth and reduce yield potential. High day temperature can result in decreased photosynthesis and increased respiration, thereby decreasing the available carbohydrates needed for boll growth and yield. Elevated night temperatures increase respiration and further decrease the carbohydrate pool available for boll growth. The remedies for combating high-temperature stress include the selection of tolerant varieties (i.e., incorporate new germplasm); early planting and early maturity (COTMAN); and irrigation (for cooling).

Crop Monitoring

The current crop monitoring program (COTMAN) allows us to closely follow crop development and detect stresses. COTMAN therefore provides cues for management inputs on a timely basis to alleviate or moderate deficiencies and stresses to protect the developing yield potential. Current research efforts are concentrating on a new stress index, using the data already collected in COTMAN, to further increase our ability to detect undesirable growth and act on a timely basis to help ensure stable and acceptable yields.

CONCLUSIONS

Cotton is very responsive to changes in the environment and to management. It is essential that producers understand the developmental pattern of the crop and the stage-dependent requirements in order to avoid possible problems and protect yield. There is no magical formula to prevent stress. However, by paying attention to recommended practices, especially those designed to reduce stress, yield potential can largely be protected. Unfortunately, there is limited drought and temperature tolerance in our current varieties. This is being addressed in current research efforts. Crop monitoring provides a precise means to follow crop growth and pinpoint problems for timely action. Current research efforts are focusing on a stress index to provide additional means of detecting and reacting to stress in order to stabilize yield variation.

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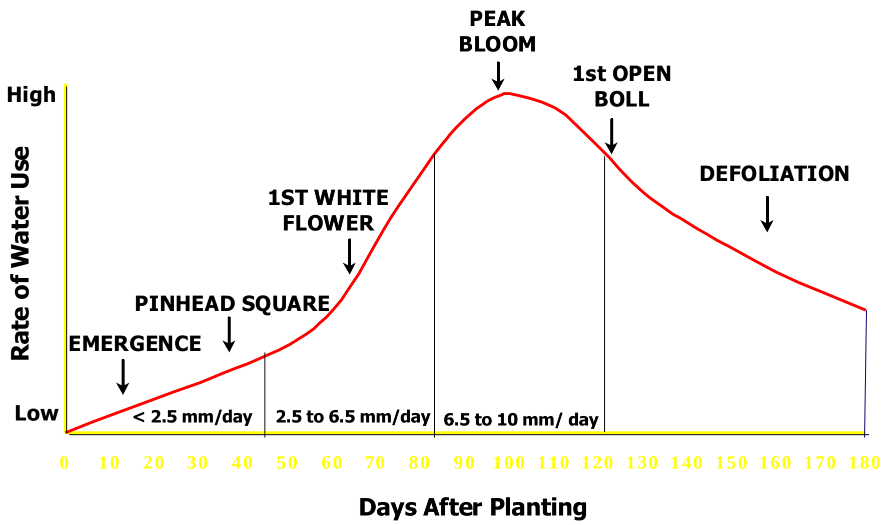

Fig. 1. Seasonal pattern of water and energy requirements by the cotton crop.

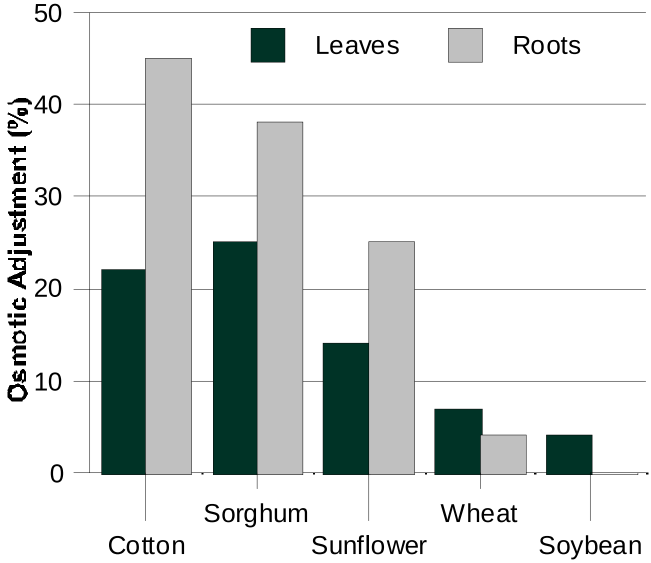

Fig. 2. Drought tolerance (osmotic adjustment) of cotton compared to other major row crops (Oosterhuis, 1989).

MAINTAINING PROFITABILITY DESPITE VARIABLE YIELDS

Kelly J. Bryant and Lucas D. Parsch[1]

RESEARCH PROBLEM

Implementation of the 1996 Farm Bill has exposed cotton farmers to increased price risk and has magnified existing yield risk. Low prices in recent years have made Arkansas cotton farmers increasingly aware of yield variability in cotton.

STUDIES REVIEWED

Since 1996, studies have been conducted in the University of Arkansas Department of Agricultural Economics and Agribusiness that document trends in cotton yields and their variability over time (Parsch and Rhoades, 1998; Parsch and Becerra, 1999; Malo *et al.*, 2000). Kay and Edwards (1999) suggest certain risk-management strategies farmers can use to reduce whole-farm risk.

RESULTS

Malo *et al.* (2000) examined state average cotton yields in Arkansas from 1965 to 1999. The authors fit linear trend lines to the 35-year data series and to "a series of six 10-year sub-samples with five-year overlaps (1965-1974, 1970-1979, 1974-1979, 1980-1989, 1984-1995, 1990-1999)." They also reported the Root Mean Squared Error (RMSE) associated with each trend line. The RMSE was used as an absolute measure of risk. Their results are contained in Fig. 1 and Table 1.

Notice that cotton yields increased over the 35 year period by 11 lb/acre/year, on average (Table 1). However, 1975-84 and 1980-89 experienced tremendous growth in yield/acre/year, whereas 1990-99 experienced no statistically significant growth in yield/acre/year. Absolute cotton yield variability (RMSE) rose by 75% in Arkansas between the 1970-79 time period and the 1990-99 time period (Table 1). The authors conclude

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that "in the past decade, stagnant Arkansas state-level yield has been accompanied by increased yield risk."

Parsch and Rhoades (1998) examined statewide yield data for dryland and irrigated cotton in Arkansas from 1981 to 1995. They fit linear trend lines to the 15-year data series and reported the associated RMSE. Their results are contained in Table 2. The authors concluded that "the yield risk under irrigated production (99 lb/acre) was 90% of the risk level for dryland cotton (110 lb/acre)."

Parsch and Becerra (1999) built on the 1998 study. They developed 15-year trend lines for each major cotton producing county in Arkansas. They then plotted the trend line-predicted yield against the RMSE for both dryland and irrigated production in each county. Their results are contained in Fig. 2. Notice that the irrigated yields surpassed the dryland yields in most counties, and that risk decreased with irrigation. However, the amount by which yield increased and risk decreased varied from one county to another.

Kay and Edwards (1999) list possible strategies farmers can take to manage risk. These include irrigation; a share-lease arrangement; diversification, using proven practices; and formal crop insurance. Of these alternatives, the two that seem to have significant potential for helping to alleviate the current risk associated with cotton yields and cotton revenue are irrigation (as shown in Fig. 2) and crop insurance. Recent increases in government subsidization of crop insurance premiums have made crop insurance for cotton much more attractive as a risk management tool.

CONCLUSIONS

Analysis of historical data indicates that cotton production is more risky now than ever because stagnant yields in Arkansas are accompanied by increased variability of yields. Also, cotton production is more risky in some counties than in others.

While informal insurance (such as irrigation, share-lease arrangements, and proven production practices) is important for managing cotton production risk, formal crop insurance also promises to be of value to cotton farmers in Arkansas at the current level of subsidization. Ultimately, identifying the cause of the variability in cotton yields is critical to managing that risk.

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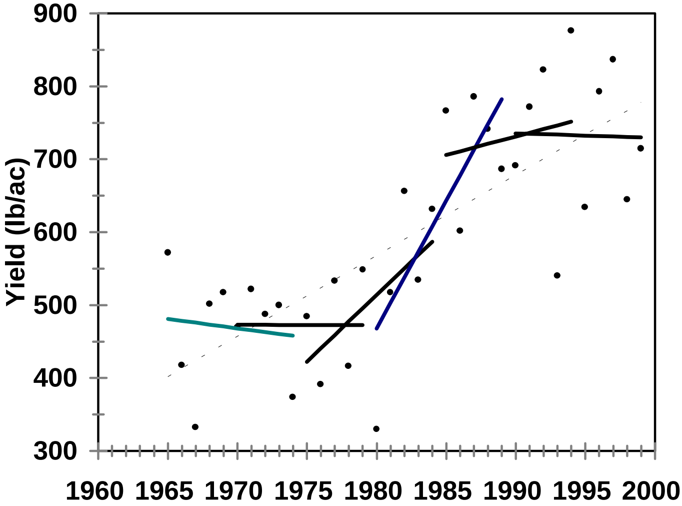

Fig. 1. Actual yield versus linear trendlines, "All" Cotton, Arkansas, 1965-1999. (Source: Malo *et al.*, 2000)

Table 1. Trend line regression statistics for Arkansas cotton yield (Source: Malo *et al*., 2000)

Period	Slope coefficient (Yield trend)	RMSE[z] (Absolute yield risk)	Trendline CV (Relative yield risk)
	lb/acre/yr	lb/acre	%
1965-99	11.05***[y]	100.34	12.89
1) 1965-74	-2.55	77.31	16.87
2) 1970-79	-0.04	63.74	13.48
3) 1975-84	18.32*	91.46	15.57
4) 1980-89	34.92***	94.33	12.05
5) 1985-94	5.11	106.00	14.10
6) 1990-99	-0.59	112.34	15.38

[z] RMSE characterizes the random variability around each linear trendline regression after the systematic variability has been removed.

[y] Single, double, or triple asterisks represent statistical significance at the 0.10, 0.05, or 0.01 levels, respectively.

Table 2. Arkansas statewide cotton lint yield, 1981-1995. (Source: Parsch and Rhoades, 1998).

	Yield statistic	Dryland	Irrigated
Summary statistics			
	15-yr mean (lb/acre)	612	818
	High-low range (lb/acre)	352	328
Trend line analysis			
	Predicted yield (lb/acre)	651	868
	Slope (lb/yr)	5.55[z]	7.12[z]
	RMSE (lb/acre)	110	99
	CV (%)	16.9	11.4

[z] Significant at the 0.41 (dryland) and 0.25 (irrigated) levels.

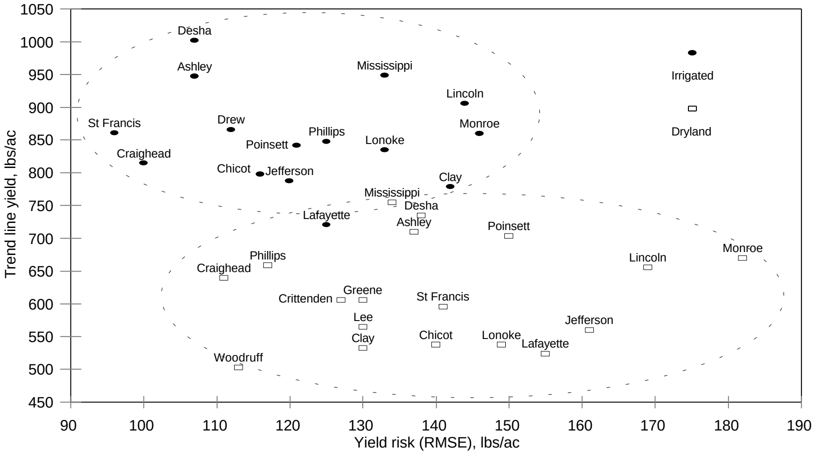

Fig. 2. Trend line yield and yield risk (RMSE) for major cotton-producing counties in Arkansas. (Source: Parsch and Becerra, 1999).

2000 OUTSTANDING GRADUATE STUDENT IN COTTON RESEARCH IN ARKANSAS

Sponsored by Cotton Incorporated

Since much of the cotton research is conducted by graduate students, this award recognizes a student each year whose research is judged to be the most notable from among all the student projects within the state being conducted for the award year (see list in this publication). Submission of graduate student research projects for this competition carries the added benefit of providing a compilation of some of the current cotton research in the state that often is overlooked and not readily available to other members of the Arkansas cotton fraternity. Graduate students are the future workers and leaders in our cotton industry, therefore, recognition of outstanding research accomplishment by a yearly award is appropriate.

SATYENDRA N. RAJGURU

The selection committee consisted of representatives from the Arkansas Cotton Support Committee; University of Arkansas Departments of Entomology and Agricultural & Extension Education; University of Arkansas Cooperative Extension Service; USDA-ARS (Stoneville, MS); and private Industry (Paymaster Seed Company, Lubbock, TX). Fourteen graduate student projects were evaluated, each consisting of a two-page summary of the research. The 2000 winner was Satyendra (Raj) Rajguru, advised by Dr. Mac Stewart, for his research, “Transgenic expression and evaluation of plants transformed with a synthetic analog of magainin.” Based on the amino acid sequence of the antimicrobial peptide, Raj constructed a gene that was able to direct the synthesis of the peptide and cause it to be sequestered in cell vacuoles of genetically engineered plants. He tested the effect of the sap of transformed vs. non-transformed plants on bacterial blight, Verticillium, Rhizoctonia, and Thielaviopsis pathogens and found a distinct inhibition of these by the sap from the transformed plants compared to plants not genetically engineered to produce the peptide. Raj received a certificate and an award of $500 for his research.

2001 SUMMARIES OF
COTTON RESEARCH IN PROGRESS

UNIVERSITY OF ARKANSAS COTTON BREEDING PROGRAM - 2000 PROGRESS REPORT

F.M. Bourland[1]

RESEARCH PROBLEM

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

BACKGROUND INFORMATION

Cotton breeding programs have existed at the University of Arkansas since the 1920s (Bourland and Waddle, 1988). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and possess good host plant resistance traits. Overviews and updates of the current program have been published (Bourland, 1988; 1995a; 1995b; 1996; 1997; 1998; 1999; 2000).

RESEARCH DESCRIPTION

Each year, breeding lines and strains are tested in the University of Arkansas Cotton Breeding Program. The breeding lines are developed and evaluated in non-replicated tests, which include initial crossing of parents, individual plant selections from segregating populations, and evaluation of the progeny grown from seed of the individual plants. Once the segregating populations are established, each sequential test provides screening of genotypes to identify ones with specific host plant resistance and agronomic performance capabilities. Selected progeny are carried forward and evaluated in replicated strain tests at multiple Arkansas locations to determine their yield, quality, and adaptative properties. Superior strains are subsequently evalu-

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ated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or released as germplasm or cultivars.

RESULTS

Breeding Procedures

Some modifications in the selection procedures used in the University of Arkansas Cotton Breeding Program were made in 2000 and will be implemented in 2001 (Table 1). The major difference is the role of first-cycle selections, i.e. individual plants selected in the F_2 generation. Previously, first-cycle selections were evaluated in the Preliminary Progeny Test, and superior ones were progressively evaluated in the Advanced Progeny, Preliminary Strain, and the New Strain Tests. Second-cycle selections were made only from those lines that progressed to new strain status. The second-cycle selections were again evaluated as progeny rows and preliminary strains, and then compared to first-cycle selections. The major problem with this scheme has been the time required to establish and evaluate second-cycle selections. Two cycles of selection are usually needed to improve homozygosity of lines. In 2001, second-cycle selections will be made from the best-performing advanced progeny. Thus, first-cycle selections will not be evaluated in replicated tests. This strategic change shifts emphasis from strain (replicated) testing to progeny testing. Plant material should progress through the program at a faster rate. This change has partly been facilitated by the capacity to machine-harvest progeny for yield.

Selection Criteria

In 2000, basic work to establish selection criteria was intensified in four specific areas: Root-knot nematode resistance, thrips resistance, yield components, and bract trichomes.

Root-knot Nematode (RKN) Resistance

When evaluated for resistance to RKN, no resistant plants were found in over 50 lines that had been developed in the program using RKN-resistant parents. This observation suggests that RKN resistance genes are selectively eliminated by the selection criteria in this program. The strategy for development of adapted RKN-resistant lines must be to screen for RKN resistance in an early generation prior to other selection. This selection should be followed by identification of the best agronomic ones among the resistant genotypes. In 1999, six F_2 populations with RKN-resistant parentage were screened by Dr. Terry Kirkpatrick. Seed from 29 RKN-resistant plants were planted in progeny rows in 2000. Of the 29 progeny, 20 were harvested and will be evaluated as advanced progeny in RKN-infested plots in 2001. Also, selected RKN-resistant progeny were used as parents in 2000, and F_1 seeds have been sent to winter increase. Resulting F_2 progeny will be screened in the RKN-infested plots in 2001.

Thrips Resistance

New and advanced strains were evaluated for yield in adjacent plots having thrips control (in-furrow insecticide) and no thrips control in 1999 and 2000. Strains having relatively high yields in both control and no thrips control are considered to have high agronomic and resistance characteristics. Consistency has been found over years. These data will be used in describing lines for release.

Yield Components

Work was initiated to characterize genotypes regarding relative influence of basic yield components of seed per acre (SPA) and lint weight per seed (LPS). Selection based on LPS should provide genotypes that have improved yield stability. However, LPS was found to be highly correlated with seed size, i.e. the larger the seed, the more lint per seed. Therefore, selection based on these components must also consider seed size. Genotypes selected as parents for several crosses made in 2000 and for strain advancement included high yielding ones that possessed relatively low SPA, relatively high LPS, and relatively small seed size. Resulting lines will be used in a new Cotton Incorporated project initiated in 2001.

Bract Trichomes

Although trichomes, leaves, and stems have received considerable attention by cotton breeders, trichomes on margins of bracts have essentially been ignored. Considering that bract tissue is a major component of leaf trash in seedcotton and that leaf trichomes have been related to leaf grade, this absence of investigation is remarkable. Our preliminary work has established that genetic variability exists for a number of marginal bract trichomes, and has initiated examination of the relationship of bract size and marginal trichome number (Hornbeck *et al.*, 2001). Bract trichomes occur on both glabrous and hairy cotton lines, but are relatively less dense in the glabrous lines. Variation in bract trichomes among glabrous and among hairy cultivars suggests that bract trichomes might be reduced independently of leaf and stem trichomes. Intuitively, reduction in marginal bract trichomes should enhance the cleanability of cotton fiber and reduce trash problems. Since cotton fibers are anatomically trichomes arising from seed coats, association of bract trichomes with lint per seed may be extremely important.

Strain Evaluation

Poor stands in the 2000 Preliminary Strain Tests prevented critical evaluation of the 54 preliminary strains. Consequently, individual plant selections were made from first-cycle selections and seed increase was obtained from second-cycle selections. New and advanced strains were compared to two standard cultivars (Sure-Grow 747 and Stoneville 474) in tests at four locations in 2000. Over all locations, 11 and 25 of 36 strains yielded more than the highest and lowest yielding standard cultivar, respectively. These superior strains exhibited a wide range of lint percentages, leaf pubescence, maturity, and fiber quality.

Release of Material

Two germplasm lines (Arkot A314 and Arkot A306) were released in 2000. Data are being summarized for the following strains to be released in 2001:

8304 lines

Specific lines have shown rapid true leaf development, seedlings have enlarged epicotyls at emergence. This trait may be important for improvement of seedling vigor. Additional selections have been made to improve these lines prior to release.

Tufted lines

Lines have tufted seed (no linters except on micropylar end of seed), which may be a valuable seed trait. Improved progeny were evaluated in 2000. Lines to be released in 2001 or 2002.

8606-50

Evaluated for 6 years in strain tests; selections have not shown improvements. Very early maturing, good fiber strength, hairy leaf, bacterial blight resistant, moderate resistance to *Fusarium* and *Verticillium* wilt, and good yielding ability (particularly with respect to its early maturity).

Ark 8712

Advanced line that has been evaluated for 8 years in strain and variety tests. Smooth leaf, early maturing, excellent fiber quality, and good yield (13th out of 37 in the 1999 Arkansas 1st year Cotton Variety Test). In 2000, yield was 8th out of 29 varieties in north Arkansas locations and 19th out of 32 in south Arkansas locations. This will be released as variety or germplasm in 2001.

8710-45-17

A semi-smooth, early maturing line that has good resistance characteristics, yields are high but not consistent, fiber quality is good but strength is weak. Will be released as germplasm line in 2001.

8717-17-20

A semi-smooth, early maturing line with good resistance and excellent fiber quality characteristics. Yields are high, but not consistent. Will be released as germplasm line in 2001.

8727-21-10

A semi-smooth line with good resistance and excellent fiber quality characteristics. This line possesses gossypol glands in the calyx cap. Will be released as a germplasm line in 2001.

PRACTICAL APPLICATION

Genotypes with improved host plant resistance that are adaptable to Arkansas environments and possess good fiber quality are being developed. These genotypes should be valuable as breeding material to commercial breeders or released as cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions. Also, new approaches to breed and improve cotton lines are being investigated.

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Table 1. Revised work plan of the University of Arkansas Cotton Breeding Program, 2000.

Test Designation[z]	Generation	Description	Selection	Approx. no. selected
B0	P/P	Crosses	None	34
B1	F_1	Mexico	None	20
B2	F_2	Segregating population	Individual plants	523
B3	F_3	1st cycle progeny rows	Rows	172
B4	F_4	Sel. 1st cycle progeny	Individual plants	807
B5	F_5	2nd cycle progeny rows	Rows	68
S1,2,3	F_6	Preliminary strain test	Strain	54
S5	F_7	New strain test	Strain	18
S6	F_{8+}	Advanced strain test	Strain	5

[z] B tests are non-replicated evaluations of early-generation lines. S tests are replicated strain tests of advanced lines.

ULTRASTRUCTURAL CHANGES INDUCED BY *ROTYLENCHULUS RENIFORMIS* IN RESISTANT AND SUSCEPTIBLE COTTON

Paula Agudelo, K.S. Kim, Robert T. Robbins, and James M. Stewart[1]

RESEARCH PROBLEM

The reniform nematode, *Rotylenchulus reniformis*, has become a serious threat to cotton crops in Arkansas, and it is important that resistant varieties are soon available. When resistance genes to other plant parasitic nematodes have been identified and used successfully, a wealth of information has been available to describe parasitism events in great detail. In the case of the reniform nematode, several studies have been published (Birchfield, 1962; Jones and Doprkin, 1975; Khan *et al.*, 1985; Razak and Evans, 1976; Rebois, 1980; Rebois *et al.*, 1975), but information is still limited. The key to understanding resistance to reniform nematode is to expand our knowledge of the nature and function of the changes induced by the nematode in the plant. The objective of this work is to describe histological and ultrastructural modifications induced by *Rotylenchulus reniformis* in resistant and susceptible cotton (*Gossypium hirsutum*).

BACKGROUND INFORMATION

In the presence of host roots, immature females penetrate the root cortex, establish a permanent feeding site in the stele and become sedentary. The trophic site consists of a stelar syncitium. Products of the esophageal glands secreted through the stylet induce profound morphological, physiological, and molecular changes in the recipient host cells to enable them to function as a continuous source of nutrients for the nematode. General characteristics of syncitia formed by *R. reniformis,* and other sedentary nematodes, are thickened cell walls remodeled to form elaborate ingrowths, dense granular cytoplasm, and an increased number of organelles and small vacuoles (Khan *et al.*, 1985; Rebois, 1980).

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1 Graduate Assistant, University Professor, and Professor, Department of Plant Pathology, Fayetteville; and Professor, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

Seeds of susceptible (Deltapine50) and a partially resistant near-cotton genotype (measured as reduced nematode reproduction) were germinated in moist paper towels, then uniform seedlings planted in 500-cc pots. One week after transplanting, each pot was inoculated with 3000 vermiform nematodes. After 15 days, roots were washed and prepared for observation. Tissues were fixed in Karnovsky's fixative and post-fixed in 1% osmium tetroxide. They were pre-stained in 0.5% uranyl acetate, dehydrated, and embedded in Spurr's epoxy resin. Ultra-thin sections were prepared and stained with lead citrate for observation under the electron transmission microscope. Additionally, thick sections (0.5-1.0µ) were prepared and stained with toluidine blue for observation under light microscope.

RESULT DISCUSSION

Both susceptible and resistant plants formed syncitia with cell wall perforations, dense cytoplasm, increased endoplasmic reticulum, and increased size of nucleus. Dissolution of cell walls occurred as the response stimulus from the feeding nematode spread from the site of initial penetration to adjacent root pericycle cells (Figs. 1 and 2). Changes that appeared to be induced in plants with a higher level of resistance include a layer of necrotic cells surrounding the syncitia and prominent cell-wall appositions in syncitium component cells near the necrotic layer. These manifestations were absent in the susceptible plants.

PRACTICAL APPLICATION

Events that determine the degree of susceptibility of cotton plants to reniform nematode occur at the feeding site. Therefore, further understanding of how the plant responds in the induction and formation of syncitia in response to stimulus from the nematode is an essential component for the identification and characterization of resistance genes that could be used in developing resistant cotton cultivars.

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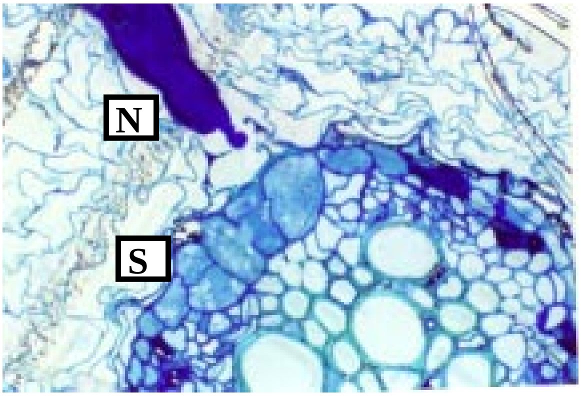

Fig. 1. Thick section stained with toluidine blue showing N, feeding nematode and S, stelar syncitium (200X).

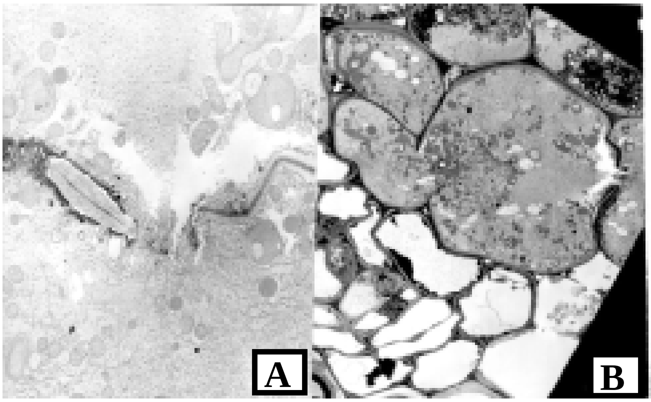

Fig. 2. Transmission electron micrographs. A. Detail of cell wall rupturing (3,300X). B. Syncitial cells with dense cytoplasm (1,000X).

EFFECT OF SOIL AND FOLIAR POTASSIUM FERTILIZATION ON YIELD OF WATER-DEFICIT STRESSED COTTON

Dennis Coker, Derrick M. Oosterhuis, and Robert S. Brown[1]

RESEARCH PROBLEM

The importance of potassium (K) for cotton fiber development and quality is well recognized. However, widespread K deficiencies have been reported in Arkansas during cotton flowering and peak boll development stages when K needs are greatest. Currently, information is lacking about the most efficient ways to manage K fertilizer inputs in terms of maximum production profitability with limited water resources. Therefore, the objective of this study was to evaluate the effect of water-deficit stress and K deficiency on the dry matter partitioning and final yield components of field-grown cotton.

BACKGROUND INFORMATION

Total K requirements of modern cotton cultivars have not decreased and the K uptake window to satisfy those requirements has been compressed (Varco, 2000). Factors that interfere with the strong source-sink relationship of K in cotton will directly influence the efficiency of K use and the potential for high lint yields (Oosterhuis, 1995). Although K may be taken up in luxury amounts by the cotton plant prior to peak demand, K deficiencies still occur late in the growing season when the large developing boll load becomes the dominant sink for available K. Foliar fertilization with K has been proposed and used to satisfy plant K needs. Mitchell (1994) reported that cotton yield response to foliar-applied K may be influenced by a variety of factors not consistent with time and location. Efforts to find an explanation for these phenomena have recently been underway. Our objective was to study the impact of water-deficit stress on K partitioning and the efficiency of foliar K uptake during the peak boll development stage.

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[1] Research Specialist, Distinguished Professor, and Graduate Assistant, Department of Crop, Soil, and Environmental Sciences, Fayetteville.

RESEARCH DESCRIPTION

Cotton growth and K partitioning under limited water and K inputs were studied in 1999 in a field environment at Rohwer (Coker and Oosterhuis, 1999; Coker and Oosterhuis, 2000). The following information reflects the same study continued in 2000 at Rohwer and Clarkedale. Eight treatment combinations of well-watered (W) or dry-land (D) conditions; high soil-K (H) or low soil-K (L); and with foliar-applied K (F) or without foliar K (N) were arranged in a split-split plot design with five (Rohwer) or six replications. Each plot consisted of four rows 40 feet long (50 feet at Clarkedale), spaced 38 inches apart. At Rohwer, cultivar Suregrow 125 was planted in a moderately well-drained Hebert silt loam on 19 May 2000. At Clarkedale, cultivar Suregrow 747 was planted in a well-drained Calloway silt loam on 16 May 2000. Granular KCl fertilizer was hand broadcast to designated plots prior to planting according to recommendations (Sabbe, 1998). Foliar KNO_3 was applied four times at weekly intervals starting one week after first flower with a CO_2 backpack sprayer. The water status of the soil in each plot was monitored using screen-cage thermocouple psychrometers buried to a 24 cm depth. Plant water status was monitored using end-window thermocouple psychrometers and infrared thermometry starting at pinhead square (PS). Growth, dry matter, photosynthesis, and K concentration were measured at key phenological stages [PS, first flower (FF); first flower + 3 weeks (FF+3); and first flower + 5 weeks (FF+5)]. Final lint yield and components of yield were determined by mechanically harvesting the two center rows of each plot and by hand-picking a 1-m length of each of the two center rows, and counting and weighing the bolls.

RESULTS

Harvest Components at Rohwer

The number of open bolls, gin turnout, and lint yield did not change significantly ($P \le 0.05$) in response to foliar K under any combination of water and soil K level (data not shown). However, foliar K significantly ($P \le 0.05$) increased the weight of open bolls under well-watered, high soil- K conditions by an average of 6.3%. The same response to foliar K was not observed for the well-watered, low soil-K condition. In contrast with the previous season (Coker and Oosterhuis, 1999), foliar K did not have any significant ($P \le 0.05$) effect on open boll number and lint yield when averaged over the water, soil K, or water and soil K treatments (Table 1). Foliar K significantly ($P \le 0.05$) increased boll weight when averaged over water and soil K levels; however, the change did not translate to a substantial increase in lint yield. Likely, the extended hot and dry conditions during the boll filling period served to minimize increases in lint yield from foliar K feeding during the boll filling period.

Consistent with the 1999 season, a significant water-by-soil K interaction ($P \le 0.05$) was observed for lint yield (Table 2). Lint yield averaged over foliar K under the well-watered condition increased significantly ($P \le 0.05$) in response to soil-applied K but under the dryland condition decreased by 6.7% in response to soil-applied K. When averaged over foliar K, the addition of soil-applied K increased boll weights substantially under the well-watered condition only and was largely responsible for the lint yield increase from the well-watered treatment. The number of open bolls changed negligibly in response to soil-applied K under either level of water when averaged over foliar K or water and foliar K. We continued to observe relatively high soil K levels at planting as with the previous season (i.e. 300 lb/acre), which likely had some bearing on the small lint yield responses.

Harvest Components at Clarkedale

Observations of final yield components from the Clarkedale location showed other differences between treatments compared to those from the Rohwer location during 2000. Firstly, we observed a lower soil-K level prior to planting (i.e., 250 lb/acre) compared to the soil-K level at Rohwer. Foliar K had no significant ($P \leq 0.05$) effect on the number of open bolls or boll weight under either level of soil K and well-watered or dryland conditions (data not shown). Under well-watered, high or low soil-K conditions, there was a trend of increased gin turnout and lint yield due to foliar K application. Under dryland conditions, foliar K significantly ($P \leq 0.05$) increased gin turnout and lint yield where soil-applied K was not added. When averaged over water, we observed a significant ($P \leq 0.05$) lint yield increase in response to foliar K under the low soil-K but not the high soil-K level (Table 3). Apparently, this was the result of a modest boll weight and gin turnout increase caused by foliar K under the well-watered and dryland, low soil-K condition. The number of open bolls, boll weight, gin turnout, and lint yield did not change significantly ($P \leq 0.05$) due to foliar K feeding when averaged over soil K or water and soil K. Gin turnout showed a significant ($P \leq 0.05$) water x foliar K interaction that lacked explanation as trends from the other yield components were considered.

When averaged over foliar K, boll weight increased by over 9%, gin turnout by 1.2%, and lint yield by over 6% in response to added soil K under dryland conditions (Table 4). Boll weight, gin turnout, and lint yield responded less to added soil K under well-watered conditions. Where soil K was added, boll weight, gin turnout, and lint yield tended to increase when averaged over the water and foliar K treatments.

PRACTICAL APPLICATION

Extreme hot and dry conditions throughout the peak boll filling stage appeared to limit gains in lint yield from foliar K feeding under well-watered or dryland conditions for the 2000 season. At Rohwer, where upper-medium to high soil-K levels were observed at planting, lint yield did not respond to foliar K under either water regime. At Clarkedale, soil-K resources fell into the marginal to medium range of existing recommendations and foliar K added to lint yield under dryland or well-watered conditions, particularly in plots where no K was applied to the soil.

Thus far, our studies have shown that (1) the soil-K status should be strongly considered when making decisions about foliar K inputs, and (2) yield response to foliar K feeding will likely differ little between irrigated and dryland cotton. Lint yield responded significantly to added soil K at Rohwer under well-watered conditions; however, under dryland conditions the yield response to soil-applied K was not consistently positive. Therefore, soil-applied K appears to be more important for maximum lint yield under irrigated as compared to dryland conditions in the Mississippi Delta region of Arkansas. Weather conditions during the growing season appeared to have a direct impact on how quickly and efficiently foliar-applied K was used to correct K deficiencies.

ACKNOWLEDGMENTS

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Table 1. Yield response of field-grown cultivar Suregrow 125 to foliar-applied K averaged over the water and soil K treatments, Rohwer, 2000.

	Components of yield		
Treatment	Open boll	Boll weight	Lint
	# m^{-2}	g $boll^{-1}$	kg ha^{-1}
Averaged over water			
High soil K, no foliar K	71.3	3.74	1123
High soil K, with foliar K	69.7	3.98[z]	1116
Low soil K, no foliar K	70.5	3.67	1088
Low soil K, with foliar K	71.4	3.84	1074
Averaged over soil K			
Well-watered, no foliar K	82.7	4.12	1452
Well-watered, with foliar	83.8	4.37[z]	1448
Dryland, no foliar K	59.2	3.29	758
Dryland, with foliar K	57.3	3.45	742
Averaged over water and soil K			
No foliar K	70.9	3.71	1105
With foliar K	70.5	3.91[y]	1095

[z] Significant at $0.05 < P \leq 0.1$ for the paired treatments.
[y] Significant at $P \leq 0.05$ for the paired treatments.

Table 2. Yield response of field-grown cultivar Suregrow 125 to soil-applied K averaged over the water and foliar K treatments. Rowher, 2000.

	Components of yield		
Treatment	Open boll	Boll weight	Lint
	# m^{-2}	g $boll^{-1}$	kg ha^{-1}
Averaged over foliar K			
Dryland, high soil K	57.8	3.34	724
Dryland, low soil K	58.7	3.40	776
Well-watered, high soil K	83.2	4.38	1514
Well-watered, low soil K	83.3	4.11[z]	1386 [y]
Water x soil K	–[x]	–[x]	–[w]
Avg. over water and foliar K			
High soil K	70.5	3.86	1119
Low soil K	71.0	3.76	1081

[z] Significant at $0.05< P\leq 0.1$ for the paired treatments.
[y] Significant at $P \leq 0.05$ for the paired treatments.
[x] Significant at $P \leq 0.05$ for treatment interaction.
[w] No interaction.

Table 3. Yield response of field-grown cultivar Suregrow 747 to foliar-applied K averaged over the water and soil K treatments. Clarkedale, 2000.

Treatment	Components of yield			
	Open boll	Boll weight	Gin turnout	Lint
	(no./m^{-2})	(g/boll)	(%)	(lb/acre)
Averaged over water				
High soil K, no foliar K	53.3	4.07	41.2	948
High soil K, with foliar K	56.5	3.94	41.1	956
Low soil K, no foliar K	53.8	3.82	40.1	887
Low soil K, with foliar K	53.4	3.89	40.3	985 [z]
Averaged over soil K				
Well-watered, no foliar K	69.5	4.37	42.0	1241
Well-watered, with foliar K	69.5	4.19	41.1	1292
Dryland, no foliar K	37.6	3.52	39.3	593
Dryland, with foliar K	40.4	3.63	40.3	649
Water x foliar K	—[y]	—[y]	—[x]	—[y]
Avg. over water and soil K				
No foliar K	53.6	3.94	40.7	917
With foliar K	55.0	3.91	40.7	971

[z] Significant at P ≤0.05 for the paired treatments.
[y] Significant at P ≤0.05 for treatment interaction.
[x] No interaction).

Table 4. Yield response of field-grown cultivar Suregrow 747 to soil-applied K averaged over the water and foliar K treatments. Clarkedale, 2000.

Treatment	Components of yield			
	Open boll	Boll weight	Gin turnout	Lint
	(no./m^{-2})	(g/boll)	(%)	(lb/acre)
Averaged over foliar K				
Dryland, high soil K	39.0	3.73	40.4	640
Dryland, low soil K	39.0	3.42[z]	39.2[z]	602
Well-watered, high soil K	70.8	4.27	41.9	1264
Well-watered, low soil K	68.2	4.28	41.2	1269
Averaged over water and foliar K				
High soil K	54.9	4.00	41.1	952
Low soil K	53.6	3.85	40.2[z]	936

[z] Significant at 0.05< P 0.1 for the paired treatments.

VARIETAL RESPONSES OF COTTON TO NITROGEN FERTILIZATION[1]

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

RESEARCH PROBLEM

Growth and yield response of cotton (*Gossypium hirsutum* L.) varieties to nitrogen (N) fertilization is an ongoing concern of cotton producers in Arkansas (Maples and Frizzell, 1985). New varieties, both genetically engineered and traditional, are continually introduced into Delta production systems. Advantages of these new varieties include enhanced pest resistance, superior lint quality, faster maturity, and other new characteristics. Research that provides information on production parameters for the most recently released varieties is scant. The objectives of this study are to gain ongoing experience with new cotton varieties and to determine the responses of new varieties to N fertilization.

BACKGROUND INFORMATION

Development and release of new cotton cultivars has increased the diversity of cotton in the Delta. Varieties now available for use in the Delta may possess genetically engineered traits for pest resistance as well as superior yield and maturity and fiber properties that are attractive to textile mills. The genetic variability of the currently available varieties indicates that crop growing practices such as fertilization might differ to achieve optimal yields. Optimizing N fertilization for individual cotton varieties is a possible way of tailoring production practices for individual cultivars to achieve optimal economic returns.

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RESEARCH DESCRIPTION

Testing of the responses of cotton varieties to N fertilization was originally begun at the Southeast Branch Experiment Station in 1989 (McConnell *et al.,* 1993). Varieties routinely change as new varieties are introduced into the Delta region. Three years of data, 1997 through 1999, were available from the current test. Varieties currently under evaluation are Deltapine 20, Deltapine 5415, Stoneville 474, and Nucot 32B. Fertilizer treatments range from 0 to 150 lb urea-N/acre in 50 lb N/acre increments. The N fertilizer was split-applied with 50 lb urea-N/acre after emergence, around the two true-leaf stage, and the balance applied at first square. The entire test was furrow irrigated.

The measurements taken on the cotton varieties included seedcotton yield, lint fraction, plant height, and plant population. All data were analyzed using SAS. The experimental design used was a randomized complete block. F-tests and least significant differences (LSDs) were calculated at the α=0.05 level of probability.

RESULTS

The N fertilization rate that seemed optimal for all four varieties was the 100 lb N/acre treatment (Table 1). The results of the study correlate well for Deltapine 20 and Stoneville 474. The N fertilization rate necessary to produce maximum yield was 100 lb N/acre for Deltapine 20 and Stoneville 474. Although a trend of higher yield was observed with greater N rates, the differences were not significant from the 100 lb N/acre treatment. In 1998, Stoneville 474 yields declined when N was increased from 100 to 150 lb N/acre. Yield trends with Deltapine 5415 and Nucot 32B differed slightly from the two faster maturing varieties. In 1997, both Deltapine 5415 and Nucot 32B achieved maximum yields with only 50 lb N/acre. A trend of increasing yield with more N was observed for Deltapine 5415 and Nucot 32B, but the differences were not significant compared to the 100 lb N/acre treatment.

PRACTICAL APPLICATION

The results from this test are preliminary. Final conclusions should not be drawn from these data. The yield response of all cultivars seemed to maximize near 100 lb N/acre. Generally, yields were not found to significantly increase with N rates above 100 lb N/acre. Yield responses of Deltapine 5415 and Nucot 32B tended not to be as great as those of Deltapine 20 and Stoneville 474. This indicates that the slower maturing varieties may require a little less N fertilizer than the faster maturing varieties.

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Table 1. Lint yields of four cotton varieties – [Deltapine 20 (DP20), Stoneville 474 (ST474), Deltapine 5415 (DP5415), and Nucot 32B (NU32B)] – grown with nitrogen (N) rates of 0, 50, 100, and 150 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, Arkansas, during 1997, 1998, and 1999.

	Varieties			
N-Rate	DP20	ST474	DP5415	NU32B
lb N/acre	(lb lint/acre)			
1997				
150	1309	1416	1179	1226
100	1082	1350	1084	1172
50	937	1181	1003	1020
0	619	620	448	545
$LSD_{(0.05)}$ = 165				
1998				
150	1218	1247	1159	1217
100	1097	1321	1241	1216
50	992	1130	1049	1084
0	687	691	548	615
$LSD_{(0.05)}$ = 104				
1999				
150	1207	1393	1213	1298
100	1145	1255	1156	1246
50	1021	1022	1000	1026
0	726	686	609	614
$LSD_{(0.05)}$ = 118				

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

J. Scott McConnell, Robert C. Kirst, Jr., Robert E. Glover, and Ray Benson[2]

RESEARCH PROBLEM

Recent developments in cotton (*Gossypium hirsutum* L.) production technology in the Delta include drill-planting cotton. Ultra-narrow-row (UNR) cotton is a low-input production system designed to maximize economic returns. Research that provides information on production parameters is scant. Optimal nitrogen (N) fertilization rates are unknown. The objective of these studies was to determine how UNR cotton would respond to N fertilization.

BACKGROUND INFORMATION

Technology development for UNR cotton production has increased recently. It has long been known that plants grown in very narrow rows intercept and utilize sunlight more efficiently. Potential benefits of UNR cotton production include reduced production costs, utilization of poorer soils, decreased soil erosion, and utilization of the same equipment for cotton, soybeans, and cereal crops. Potential drawbacks of UNR cotton include increased weed pressure in low-stand areas; different equipment requirements from conventionally row-spaced cotton (precision drill planter, finger stripper harvester); and possible lint quality declines. Variety differences, fertility requirements, effect of planting date, and other parameters for optimal growth and yield of UNR cotton are unknown.

RESEARCH DESCRIPTION

A pilot study of responses to N fertilization was conducted in 1997. Fertilizer treatments of 100 lb urea-N/acre, 100 lb Meister-N/acre, 50 lb urea-N/acre, and 0 lb N/acre were strip applied with a fertilizer buggy just prior to squaring.

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The test was expanded in 1998 to include N-rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre. The test design was randomized complete block. Nitrogen treatments were applied as the crop reached the two-true-leaf stage. The test was further expanded in 1999 to include a second study site at the Northeast Research and Extension Center (NEREC) near Keiser.

Measurements taken on the UNR cotton included seed cotton yield, plant height, plant population, boll load, and boll weight. All data were analyzed using the SAS. The F-tests and least significant differences (LSDs) were calculated at the $\alpha=0.05$ level of probability.

RESULTS

The pilot study of UNR cotton response to N fertilization was conducted in 1997. Ultra-narrow-row cotton fertilized with either 50 or 100 lb N/acre, regardless of N source, did not differ in yield (Table 1). Cotton receiving no N fertilizer was significantly lower yielding than cotton that received N fertilizer. Boll load and boll weight were both greatest and not significantly different for the UNR cotton that received N fertilizer, and lowest for the untreated cotton.

The results of the first year of the expanded study correlated well with the pilot study. The N fertilization rate necessary to produce maximum yield, boll load, and boll weight was 50 lb N/acre (Table 2). Although trends of higher values were observed with greater N rates, the differences were not significant from the 50-lb N/acre treatment. Plant height increased with increasing N fertilization up to 100 lb N/acre.

Results from NEREC were similar to the first year at SEBES. Maximum yields were achieved with only 25 lb N/acre (Table 3). Plant height was found to significantly increase up to 75 lb N/acre. No significant differences were observed in either the plant populations or boll loads at NEREC.

Most recent results from SEBES indicated that severe drought conditions masked the impact of N fertilization of cotton (Table 4.). Nitrogen fertilization of conventionally row-spaced cotton has been shown to be ineffective under severe water deficit (McConnell *et al.*, 1998). The N treatments were not found to significantly affect any of the measured parameters.

PRACTICAL APPLICATION

The preliminary responses of UNR cotton to N fertilization treatments indicate that the N required for maximum yield will be less than for cotton grown in conventionally spaced rows. Yields were not found to increase with N rates above 50 lb N/acre. Additionally, the 50-lb N/acre treatment was found to maximize both the boll load and boll weight at SEBES. The parameters measured in these studies indicate that the N fertilization management of UNR cotton may be substantially different from conventionally grown cotton.

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ACKNOWLEDGMENT

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Table 1. Seedcotton yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with nitrogen (N) rates of 0, 50, and 100 lb urea-N/acre and with 100 lb Meister (M)-N/acre at the Southeast Branch Experiment Station near Rohwer, Arkansas in 1997.

N Rate	Seedcotton yield	Plant height	Plant population	Boll load	Boll weight
lb N/acre	lb/acre	inches	plt/acre	bolls/acre	g/boll
100 (M)	2,938	24.9	115,360	393,675	3.36
100	3,008	31.3	140,368	392,869	3.44
50	3,333	29.9	108,099	416,263	3.58
0	1,529	20.4	118,587	242,820	2.87
$LSD_{(0.05)}$	1,099	6.1	NS[z]	119,875	0.38

[z] NS = non significant.

Table 2. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with nitrogen (N) rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, Arkansas in 1998.

N Rate	Lint yield	Plant height	Plant population	Boll load	Boll weight
lb N/acre	lb/acre	inches	plt/acre	bolls/acre	g/boll
125	1060	27.5	153,074	349,710	3.31
100	1033	30.5	168,199	327,928	3.39
75	1034	26.3	160,334	341,844	3.30
50	899	24.4	175,460	321,273	3.12
25	745	20.4	177,275	278,921	2.93
0	468	19.9	171,225	191,796	2.84
$LSD_{(0.05)}$	153	4.2	NS[z]	48,066	0.28

[z] NS = non significant.

Table 3. Lint yield, plant height, plant population, and boll load of cotton grown in ultra-narrow rows with nitrogen (N) rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre at the Northeast Research and Extension Center near Keiser, Arkansas in 1999.

N Rate	Lint yield	Plant height	Plant population	Boll load
lb N/acre	lb/acre	inches	plt/acre	bolls/acre
125	989	20.7	212,488	341,499
100	1,004	20.4	261,816	333,910
75	958	23.7	239,049	314,938
50	965	20.4	292,171	417,387
25	883	17.5	250,432	394,621
0	608	16.7	250,432	318,732
$LSD_{(0.05)}$	267	2.7	NS[z]	NS

[z] NS = non significant.

Table 4. Lint yield, plant height, plant population, boll load, and boll weight of cotton grown in ultra-narrow rows with nitrogen (N) rates of 0, 25, 50, 75, 100, and 125 lb urea-N/acre at the Southeast Branch Experiment Station near Rohwer, Arkansas in 1999.

N Rate	Lint yield	Plant height	Plant population	Boll load	Boll weight
lb N/acre	lb/acre	inches	plt/acre	bolls/acre	g/boll
125	700	10.6	130,687	264,400	2.70
100	638	11.4	139,763	253,077	2.55
75	598	12.8	157,914	223,863	2.76
50	548	24.4	175,460	321,273	3.12
25	547	50.4	177,275	278,921	2.93
0	474	19.9	171,225	191,796	2.84
$LSD_{(0.05)}$	NS[z]	4.2	NS	48,066	0.28

[z] NS = non significant.

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

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

RESEARCH PROBLEM

Nitrogen (N) and irrigation management are two very important aspects of successful cotton (*Gossypium hirsutum* L.) production. The interactions of N fertilizer and irrigation under the humid production conditions of southeast Arkansas are not well documented (McConnell *et al.*, 1988).

Objectives of these studies were to evaluate the growth, 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 optimal 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

Studies were conducted at the Southeast Branch Experiment Station on an Hebert silt loam soil. The experimental design was a split block with irrigation methods as the main blocks. Five irrigation methods were used from 1988 to 1993 (Table 1), but only three since 1993. Ten total N treatments were tested within each irrigation method. Six

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N rates (0, 30, 60, 90, 120, and 150 lb urea-N/acre) were tested, with varying application timings used for the higher (90 to 150 lb N/acre) N rates.

RESULTS

In the last 5 years, irrigation increased cotton yields four of the total years. The only exception was the year when early season rainfall resulted in standing water that delayed the irrigated plants; or when verticillium wilt was prevalent (Table 2). The method of irrigation to maximize lint yield varied year-to-year, and therefore, appeared to be less important than irrigation usage.

Generally, lint yield was found to increase with increasing N fertilization (Table 3). The N treatments that usually resulted in the greatest lint yields were applications of 60 to 150 lb N/acre, depending upon the irrigation treatment and year. Exceptions were found for the 150-lb N/acre treatment (75 lb N/acre PP and 75 lb N/acre FS), which was found to decrease lint yield in some irrigation blocks. The yields of the high-frequency block during some 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 standing water or verticillium wilt affected the crop. Fertilizer N requirements of cotton for maximal 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.

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ACKNOWLEDGMENT

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

Irrigation methods	Duration	Tensiometer Threshold	Tensiometer Depth	Water applied
		--------- cbar --------		inches
High frequency center pivot	Planting to P.B.[z]	35	6	0.75
High frequency center pivot	P.B. to Aug. 15	35	6	1.00
Furrow flow	Until Aug. 15	55	12	Not precise
Dryland	Not irrigated	–	–	–

[z] P.B. = Peak bloom.

Table 2. Lint yield response of cotton to three irrigation methods from 1995 to 1999.

Method	1995	1996	1997	1998	1999
	-----------------------------	---------	lb/acre	---------	-----------------------------
High frequency center pivot	1113	1344	1400	1211	1401
Furrow flow	1217	1463	1458	1341	1288
Dryland	892	1057	1521	750	728
$LSD_{(0.05)}$	59	108	99	129	120

Table 3. Lint yield response of cotton to 10 nitrogen (N) fertilization rates and splits under three irrigation methods from 1995 to 1999.

N Rate PP[z]	N Rate FS	N Rate FF	HF[y]	FI	DL
----------	lb N/acre	----------	---------------------	lb lint/acre	---------------------
1995					
75	75	0	1127 a	1393 a	954 a-c
50	50	50	1166 a	1373 ab	1039 a
30	60	60	1193 a	1369 ab	971 ab
60	60	0	1162 a	1376 ab	879 b-d
40	40	40	1213 a	1360 ab	1032 a
45	45	0	1107 a	1236 bc	946 a-c
30	30	30	1149 a	1280 ab	947 a-c
30	30	0	1198 a	1098 cd	852 cd
15	15	0	964 b	980 d	781 d
0	0	0	838 c	704 e	532 e
$LSD_{(0.05)}$			106	146	114

continued

Table 3. Continued.

N Rate					
PP[z]	FS	FF	HF[y]	FI	DL
---------- lb N/acre ----------			--------------------- lb lint/acre ---------------------		
1996					
75	75	0	1315 c	1630 a	1067 a
50	50	50	1411 a-c	1543 a	1116 a
30	60	60	1331 bc	1572 a	1078 a
60	60	0	1383 a-c	1522 a	1035 a
40	40	40	1431 ab	1576 a	1174 a
45	45	0	1382 a-c	1495 a	1050 a
30	30	30	1440 ab	1527 a	1059 a
30	30	0	1461 a	1633 a	1059 a
15	15	0	1309 c	1167 d	1048 a
0	0	0	979 d	868 c	752 b
$LSD_{(0.05)}$			114	251	155
1997					
75	75	0	1491 a	1739 a	1682 ab
50	50	50	1491 a	1679 a	1777 ab
30	60	60	1384 a	1576 ab	1867 a
60	60	0	1528 a	1547 a-c	1629 b
40	40	40	1491 a	1751 a	1799 ab
45	45	0	1507 a	1582 ab	1615 b
30	30	30	1420 a	1368 c	1754 ab
30	30	0	1477 a	1457 bc	1338 c
15	15	0	1157 a	1102 d	1067 d
0	0	0	1086 b	764 e	683 e
$LSD_{(0.05)}$			159 b	207	217
1998					
75	75	0	1230 bc	1519 a	767 ab
50	50	50	1154 bc	1495 ab	721 a-c
30	60	60	1096 c	1520 a	777 ab
60	60	0	1185 bc	1281 bc	641 bc
40	40	40	1237 bc	1490 ab	816 a
45	45	0	1259 ab	1410 ab	837 a
30	30	30	1413 a	1437 ab	883 a
30	30	0	1226 bc	1331 ab	779 ab
15	15	0	1195 bc	1107 c	712 a-c
0	0	0	1116 bc	817 d	589 c
$LSD_{(0.05)}$			161	220	171

continued

Table 3. Continued.

N Rate					
PP[z]	FS	FF	HF[y]	FI	DL
---------- lb N/acre ----------			--------------------- lb lint/acre ---------------------		
1999					
75	75	0	1595 a	1533 a	656
50	50	50	1468 ab	1431 a-c	788
30	60	60	1467 ab	1463 ab	706
60	60	0	1552 ab	1405 a-c	636
40	40	40	1545 ab	1587 a	783
45	45	0	1445 ab	1454 a-c	756
30	30	30	1406 b	1203 c	740
30	30	0	1446 ab	1280 bc	791
15	15	0	1105 c	847 d	799
0	0	0	1057 c	677 d	605
$LSD_{(0.05)}$			169	257	NS

[z] Preplant (PP); first square (FS); and first flower (FF).
[y] High frequency (HF); furrow irrigated (FI); dryland (DL).

EVALUATION OF SOIL AND FOLIAR FERTILIZATION WITH BORON IN ARKANSAS

Derrick M. Oosterhuis, William C. Robertson, J. Scott McConnell, and Duli Zhao[1]

RESEARCH PROBLEM

Boron (B) is routinely applied in commercial cotton production as soil- and foliar-applications irrespective of soil B status. However, this recommendation was based largely on research conducted 30 years ago, and there has been no recent work to substantiate this with modern cultivars and production practices. Furthermore, there is only a limited understanding of B use by the cotton plant and the effect on the physiology of the cotton plant has not clearly been documented. The objective of this study was to evaluate yield response of soil- and foliar-applied boron at low- and high-soil nitrogen levels. In a companion study the effect of boron deficiency on the growth of the cotton plant was characterized (Oosterhuis and Zhao, 2001).

BACKGROUND INFORMATION

Boron (B) is an essential element required by cotton for optimal growth and development. Current production recommendations in Arkansas call for initial preplant soil applications of 1.0 lb to 2.0 lb B/acre or two up to six foliar applications of 0.1 lb to 0.2 lb B/acre. This is based largely on research conducted over 30 years ago (Miley, 1966; Baker *et al.*, 1956; Maples and Keogh, 1963). More recently, reports of yield response to soil- or foliar-applications of boron have been inconsistent. Howard and Gwathmey (1998), Abaye *et al.* (1998), and Heitholt (1992) reported no yield response to boron-utilizing non-buffered spray solutions. However, Howard and Gwathmey (1998) did observe that buffering boron spray solutions to pH 4.0 increased yields relative to buffering to pH 6.0.

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RESEARCH DESCRIPTION

The study has been conducted for two years at three locations across the state (northeast, central, and southeast Arkansas). The locations, cultivars used, planting dates, and initial soil B level (SBL) are presented in Table 1.

Fayetteville and Rohwer locations were on University Experiment Stations and trials were conducted utilizing small-plot studies. Nitrogen rates for the low and high N treatments were 50 and 100 units, respectively. County locations were conducted utilizing large plots/strips in producer fields. Treatments were replicated at all locations.

Soil-applied B consisted of 1.0 lb B/acre and foliar B applications consisted of three 0.2-lb B/acre applications 1, 2, and 4 weeks after first flower. 'Buffer Xtra Strength' manufactured by Helena Chemical was used to buffer spray solution to a pH of 4.0 to 5.0.

RESULTS

In general, soil- or foliar-B treatments had only small non-significant effects on lint yields, and in only one out of eight field trials was a significant yield advantage recorded (Table 2). In Fayetteville the soil-applied B treatment numerically increased yield compared to the control in 2000 while the opposite was observed in 1999. In Desha/Jefferson Counties, the B-treated plots numerically increased yields in 1999 while inexplicably decreasing yields in 2000. In St. Francis County, the soil-applied B increased yields compared to foliar sprays in 1999 and 2000. In Rohwer, significant differences were observed in the irrigated study with B increasing yields in the low-N plots. No significant differences were observed in the dryland study and the high-N plots of the irrigated study. Buffered foliar applications did not significantly affect lint yield (Table 3).

PRACTICAL APPLICATION

Results in 1999 and 2000 indicate that soil- or foliar-applied fertilizer B may not have been necessary for obtaining high cotton yields. There were no positive responses to applied soil-B or foliar-B in the high-N level soil in any of the locations. There was only one situation where the low-N treatments responded to applied B. No positive responses were observed to buffered spray solutions of B at either of the two locations. These results should be interpreted in relation to initial soil-B status. This study indicates that the application of additional B as a routine procedure may not be necessary.

ACKNOWLEDGMENTS

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Table 1. The locations, cultivars used, planting dates (PD), and initial soil-B levels (SBL).

	1999			2000		
Location	Cultivar	PD	SBL	Cultivar	PD	SBL
Fayetteville	SG 125	4 June	0.5 lb	ST 747	12 May	0.5 lb
Desha Co.	ST BXN47	14 May	---	---	---	---
St. Francis Co.	PM 1560BG	11 May	---	PM 1218BG/RR	21 May	0.6 lb
Rohwer	ST 474	14 May	0.1 lb	---	---	---
Jefferson Co.	---	---	---	DP 451B/RR	9 May	1.6 lb

Table 2. Effect of soil- and foliar-B application on cotton yields for test locations in Arkansas in 1999 and 2000.

	Lint yield									
	Fayetteville irrigated		Desha Co. irrigated	Jefferson Co. irrigated	St. Francis Co. irrigated		Rohwer			
							Irrigated		Dryland	
Treatment	1999	2000	1999	2000	1999[z]	2000	1999	2000	1999	2000
	(lb/acre)									
High N-control	1173	1348	1187	1063	986	---[y]	1432	1240	883	922
High N-soil-B	1149	1462	1196	1041	955	1291	1466	1339	942	784
High N-foliar-B	1181	1302	1209	1041	944	1250	1420	1330	945	754
Low N-control	1236	1296	---	---	---	---	721	769	896	717
Low N-soil-B	1072	1352	---	---	---	---	1024	845	963	778
Low N-foliar-B	1044	1392	---	---	---	---	1037	815	929	754
$LSD_{(0.05)}$	NS[x]	NS	NS	NS	NS	NS	184	NS	NS	NS

[z] Field oversprayed with 1 lb B/acre three weeks after the first flower.
[y] Treatment not included.
[x] NS = not significant (P = 0.05).

Table 3. Effect of buffered (pH 4.0 to 5.0) foliar-applied boron solutions on cotton yields for two locations in Arkansas in 2000.

Treatment	Lint yield	
	Jefferson Co. irrigated	St. Francis Co. irrigated
	---------- (lb/acre) ----------	
Control	1063	1229
Foliar	1041	1253
Foliar-buffered	1054	1221
$LSD_{(0.05)}$	NS[z]	NS

[z] NS = Not significant (P = 0.05).

EFFECT OF INSECTICIDE TERMINATION AT VARYING HEAT UNITS AFTER CUTOUT ON YIELD, BOLL WEIGHT, AND CARBON MOVEMENT

Derrick M. Oosterhuis and Robert S. Brown[1]

RESEARCH PROBLEM

COTMAN, a crop monitoring program for cotton, uses the concept of 350 heat units after anthesis of the last effective flower population at NAWF=5 for termination of insecticide applications. After this time insects can feed on fruit above NAWF=5 without decreasing yields. This allows growers to save money by eliminating costly end-of-season insecticide applications without the fear of decreased yields. This study was designed to confirm the hypothesis that insect damage to upper-canopy (above NAWF=5) squares results in improved partitioning of carbon to lower developing bolls, which may increase yields.

BACKGROUND INFORMATION

Since cotton (*Gossypium hirsutum* L.) is a perennial with an indeterminate growth habit, it will continue to produce fruit as long as the season persists. However, these late-season bolls are often small in size, low in fiber quality, costly to protect from increasing insect pressure, and also provide a food source for insects. In most crop monitoring programs, such as COTMAN (Danforth and O'Leary, 1998), a major aim is to identify the last effective boll population and project a date for insecticide termination. Bagwell (1995) showed that bollworm *Helicoverpa zea* (Boddie) and boll weevil *Anthonomus grandis* (Boheman) damage to cotton bolls decreases dramatically at about 350 heat units after anthesis. This finding was supported by Kim (1998), who showed increased resistance of the boll wall to penetration at NAWF=5 plus about 350 heat units. This phenomenon is made use of in COTMAN for decisions about late-season termination of insecticide applications at 350 heat units after NAWF=5. Research and field observations have indicated that terminating insecticide use at 350 heat units after physiological cutout defined as NAWF=5 (Oosterhuis *et al.*, 1999) results in a higher yield than when terminating earlier or later than 350 heat units;

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however more research is needed to confirm this. The ongoing objective of this four-year study was to investigate the effect of different times of upper-canopy square removal after NAWF=5 on subsequent first position boll weights at the NAWF=5 main-stem node and on lint yields.

RESEARCH DESCRIPTION

Six field studies and two ^{14}C labeling studies were conducted to test the hypothesis that removing upper-canopy square above NAWF=5 will increase cotton yields from improved carbon partitioning to lower developing bolls. Field experiments were conducted in Fayetteville in 1996, Rohwer in southeastern Arkansas in 1998 and 1999, and Clarkedale in northeastern Arkansas in 1998, 1999, and 2000. Cotton cultivar Deltapine 20 was hand planted in early May at Fayetteville and cultivar Suregrow 125 was mechanically planted in early May for the 1998, 1999, and 2000 seasons at Rohwer and Clarkedale. The field experiments were arranged in a randomized complete block design with four treatments and three replications in 1996, four replications in 1998 and 1999, and six replications in 2000. All plots consisted of four rows fifty feet in length and were furrow irrigated as needed. Treatments consisted of a control with no fruit removal and a simulated upper-canopy fruit damage (hand removal) of all upper-canopy squares above NAWF=5 at approximately 250, 350, and 450 heat units after the NAWF=5 stage. Taggings of 20-30 flowers per plot were made at the first fruiting position of the main-stem node at NAWF=5, and treatments were initiated as the appropriate heat units were accumulated. At harvest, 10 mature tagged bolls were hand harvested to determine first position boll weight of NAWF=5 bolls and seedcotton yields were determined from mechanical harvest.

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

RESULTS

Field Studies

Results from Fayetteville in 1996 indicated that removing upper-canopy squares at (NAWF=5+350 H.U.) resulted in the highest numerical first-position boll weights at NAWF=5. These boll weights were not significantly different than the control where no fruit above NAWF=5 was removed, but were greater ($P \leq 0.05$) than the weights of bolls where squares were removed at 250 or 450 heat units after NAWF=5 (Table 1). Results from the 1998, 1999, and 2000 field studies indicated no treatment differences with respect to increasing first-position boll weight at the NAWF=5 main-stem node, however, boll weight was numerically higher for the (NAWF=5+350 H.U.) treatment at both locations and years with the exception of Clarkedale in 1999 (Table 1). Overall, first-position boll weight at NAWF=5 was generally increased when upper-canopy fruit was removed at NAWF=5+350 H.U. These results support the COTMAN concept of insecticide termination at 350 heat units after NAWF=5.

Yield results in 1998, 1999, and 2000 at Clarkedale indicated no significant differences between treatments. In 1998, all square removal treatments resulted in numerically higher yields than the control (Table 2). However, in 1999 the control treatment yielded the highest with the NAWF=5 + 350 H.U. treatment representing the lowest yields (Table 2). Favorable late-season growing conditions may explain why the control treatment resulted in the highest yields. These favorable conditions allowed the upper-canopy squares not removed in the control to mature and contribute to yield. In 2000, the highest numerical yields were observed when fruit was removed at NAWF=5 + 250 H.U. It was speculated that if termination occurred too early, yields might be reduced. However, due to low insect populations in the field with the weevil eradication in progress, these not yet protected bolls were able to mature and gained additional assimilates from early removal of upper fruit. For the most part, it appears that removing late-season cotton fruit may aid in increasing boll weight; however at times yield was reduced, necessitating additional field evaluations to insure the adequacy of fruit removal.

^{14}C Growthhroom Study

At 351 heat units after NAWF=5 there was a greater amount of ^{14}C translocated to the upper developing boll from the ^{14}C-labeled main-stem leaf than in the 240 or 467 heat unit treatments (Table 3). These results support those of the field study in 1996 and 1998 and the hypothesis that available carbohydrates from upper-canopy source leaves were translocated to alternative sinks, such as bolls developing below the area of square removal. Boll weight at the NAWF=5 main-stem node was again highest in the 310 heat unit treatment (Table 3). A duplicate ^{14}C study was performed in field grown cotton in Fayetteville in 2000. This study will further test the hypothesis that there is an increased differential movement of assimilates to bolls lower in the canopy when fruit is removed at NAWF=5 + 350 H.U. versus lower or higher heat unit values (data still being analyzed).

PRACTICAL APPLICATION

Results from the 1996 and 1998 seasons indicated that the weight of lower developing bolls could be enhanced from the removal of upper-canopy squares at 350 heat units after the NAWF=5 stage. Yield results from Clarkedale in 1998 also supported the hypothesis that removing late-season squares could enhance cotton yields. Improvements in boll weight and seedcotton yield are related to translocation of carbohydrates from upper-canopy leaves with squares removed to alternative sinks, such as the boll developing below the area of square removal. The 1996 and 1998 data support the COTMAN concept of insecticide termination at 350 heat units after NAWF=5, however the 1999 data suggest that removing this fruit did not enhance lower boll weights or cotton yield. This research will be continued.

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Table 1. Mean boll weight of first position bolls at NAWF=5 for the control treatment and the square removal treatments at approximately 250, 350, and 450 heat units past NAWF=5.

	Average boll weight			
Treatment	1996[z]	1998	1999	2000[y]
	---------- (g) ----------			
Control	4.39 ab[x]	3.52 a[w] / 3.75 a[y]	3.83 a[w] / 5.29 a[y]	3.7 a
NAWF=5 + 250 H.U.	3.95 bc	3.82 a / 3.62 a	4.06 a / 5.07 a	4.1 a
NAWF=5 + 350 H.U.	5.25 a	4.03 a / 4.34 a	4.06 a / 4.99 a	4.1 a
NAWF=5 + 450 H.U.	2.99 c	3.76 a / 3.98 a	6.84 a / 5.41 a	4.1 a

[z] Represent boll weights from the Fayetteville location.
[y] Represent boll weights from the Clarkedale location.
[x] Means within a column followed by the same letter are not significantly different ($P \leq 0.05$).
[w] Represent boll weights from the Rohwer location.

Table 2. Means for total seedcotton yield, after square removal above NAWF=5, for the 250, 350, and 450 heat unit and control treatments, Clarkedale, Arkansas, 1998, 1999, and 2000.

	Seedcotton yields		
Treatment	1998	1999	2000
	------------------------------- (kg/ha) -------------------------------		
Control	2485 a[z]	3112 a	4226 a
NAWF=5 + 250 H.U.[y]	2880 a	3072 a	4351 a
NAWF=5 + 350 H.U.	2656 a	2912 a	4190 a
NAWF=5 + 450 H.U.	2844 a	3000 a	4174 a

[z] Means within a column followed by the same letter are not significantly different ($P \leq 0.05$).
[y] Represents approximate heat unit values at which squares were removed.

Table 3. Effect of upper-canopy square removal on boll weight and translocation of ^{14}C from the labeled upper-canopy main-stem leaf to the boll at the first fruiting position at NAWF=5. Growth chamber 1998, Fayetteville, Arkansas.

Treatment	Boll dry weight	^{14}C translocated[z]
	(g)	(%)
240 Heat Units[y]	3.3	1.8
351 Heat Units	3.8	75.4
467 Heat Units	2.8	44.4
$LSD_{(0.05)}$	0.9	63.2

[z] Calculated from leaf percent of ^{14}C that moved to the boll.
[y] Squares removed by hand at 240 heat units after NAWF=5.

REMOVAL OF COTTON FRUIT BY CHEMICAL AND PHYSICAL MEANS AT INSECTICIDE TERMINATION TO IMPROVE YIELDS

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

RESEARCH PROBLEM

With the increasing cost associated with raising cotton (*Gossypium hirsutum* L.) and low fiber prices, producers are in need of higher yields and lower input costs to remain profitable. COTMAN, a cotton management program developed at the University of Arkansas, has gained much attention over the past few years as a means of reducing end-of-season costs through the elimination of costly insecticide applications. Several research reports have indicated enhanced cotton yields following the termination of insecticide applications at five nodes above white flower plus 350 heat units (NAWF=5 + 350 H.U.). It is speculated that yields are increased following insecticide termination because insects are allowed to feed on upper fruit leading to increased partitioning of assimilates to the lower (economical) boll population. Based on these findings, field studies were conducted to determine if chemical or mechanical fruit removal at the time of insecticide termination would further enhance lint yields. This research project also has implications for better control of boll weevils by removing their late-season food sources. This may be especially important in areas that have not yet adopted the eradication program.

BACKGROUND INFORMATION

Cotton is a perennial with an indeterminate growth habit and will continue to produce fruit as long as the season persists. However, these late-season bolls are often small in size, low in fiber quality, costly to protect from increasing insect pressure, and also provide a food source for insects. Nodes above white flower (NAWF) is an integral concept used in the COTMAN crop monitoring program for basing end-of-season decisions (Bourland *et al.*, 1992). In COTMAN, a major aim is to identify the last effective boll population and project a date for insecticide termination. Bagwell (1995)

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showed that bollworm *Helicoverpa zea* (Boddie) and boll weevil *Anthonomus grandis* (Boheman) damage to cotton bolls decreases dramatically at about 350 heat units after anthesis. This finding was supported by Kim (1998), who showed increased resistance of the boll wall to penetration at NAWF=5 plus about 350 heat units. Oosterhuis *et al.* (1999) reported that terminating insecticides at 350 heat units after physiological cut-out (NAWF=5) results in a higher yield than when terminating before or after this time. This improvement in yield following fruit removal at 350 heat units may be explained by the differential movement of carbohydrates from upper-canopy leaves with squares removed to bolls developing below the area of fruit removal (Kim and Oosterhuis, 1998). The first objective of this study was to evaluate the efficiency of various chemicals for removing fruit above NAWF=5 following insecticide termination. The second objective was to determine if removing this upper-canopy fruit would increase the weight and quality of first-position bolls at NAWF=5 (last harvestable boll population) and total lint yields.

RESEARCH DESCRIPTION

Field studies were conducted from 1997 to 1999 at two locations in Arkansas to determine how various fruit removal techniques late in the cotton season affected lint yield and quality. Results from these studies showed conflicting results in terms of chemical efficacy at removing fruit and no clear yield trends (Brown *et al.*, 2000). In 2000 a more extensive field study was conducted at Marianna in Arkansas to further test the effects of late-season, upper-canopy fruit removal. This study evaluated some of the same chemicals and rates tested the previous years with additional rates and chemical combinations. Cotton cultivar Deltapine DP20B was planted on 11 May 2000 in a Randomized Complete Block design with 14 treatments (listed below) and 6 replications. Rows were spaced 0.9 m apart and plots were 4 rows wide with a plant density of 10 plants per meter. All plots received fertilizer and pesticide applications following the cotton production recommendations for Arkansas and were furrow irrigated as needed.

Treatments

- Control with no chemical or physical square removal
- Square removal by hand (all squares above NAWF=5)
- Mechanical topping (all plant material above NAWF=5)
- Chlormequat (CCC) @ 0.58L/ha + PHCA @ 0.58L/ha
- Chlormequat (CCC) @ 0.58L/ha
- Chlormequat (CCC) @ 0.58L/ha **+** Roundup Ultra @ 0.55kg a.i./ha
- Chlormequat (CCC) @ 1.6L/ha + PHCA @ 0.58L/ha
- Chlormequat (CCC) @ 1.16L/ha
- Ethephon (Prep) @ 0.22 kg a.i./ha

- Ethephon (Prep) @ 0.45 kg a.i./ha
- Cyclanilide (Finish) @ 0.06 kg a.i./ha
- Cyclanilide (Finish) @ 0.11 kg a.i./ha
- Methyl jasmonate @ 300 ppm
- Methyl jasmonate @ 600 ppm

At the NAWF=5 stage, 20-30 first-position white flowers were tagged on the center two rows of each 4-row plot. Daily heat units [(max + min temp/2) – 60° F] were accumulated from first white flower until 350 heat units were reached. At this time (NAWF=5+350 H.U.), the square removal treatments were applied. One week after treatment application, first-position square shed was determined for the 5 nodes above and below the tagged NAWF=5 position, as well as at the tagged position itself. At final harvest, 10 tagged bolls at NAWF=5 were collected in order to determine boll weight and fiber quality. Lint yields were determined from mechanical harvest assuming a standard gin turnout of 38%.

RESULTS

Efficiency of Chemicals for Removing Fruit

No chemical treatment or chemical treatment combinations evaluated in 2000 were able to remove as much fruit as the physical removal treatments, which of course removed 100 percent of the upper-canopy fruit (Table 1). When comparing the efficacy of the 11 chemicals tested, the 0.58 L/ha rate of Chlormequat combined with Roundup Ultra at 0.55 kg a.i./ha was the most successful chemical combination for removing upper-canopy fruit, removing 70% of the first-position fruit above NAWF=5 (Table 1). However, this treatment combination was not significantly different from the control. Chlormequat applied at 1.16L/ha in combination with PHCA at 0.58L/ha represented the least effective treatment for removing upper-canopy fruit and removed only 55.6% of first-position squares and small bolls (Table 1). Unfortunately, the Chlormequt/Roundup combination, which effectively removed the most upper-canopy fruit, also removed a significantly greater percentage of first-position bolls at the NAWF=5 position than the control did. Prep applied at the 0.22 kg a.i./ha rate was the most detrimental chemical for adversely removing bolls at the NAWF=5 position (Table 1). No statistical differences occurred between treatments for adversely removing the harvestable bolls below NAWF=5.

Lint Yields

The highest numerical lint yields from the 2000 field study were observed in the control plots where no upper-canopy fruit was removed (Table 2). This indicated that the upper-canopy fruit did develop and contribute to overall lint yields. In most years, upper-canopy fruit above NAWF=5 did not reach maturity due to high insect pressure, increased shed percentages, and lack of heat units for fiber development. However, given the favorable late-season weather pattern in 2000 and extra insecticide use with boll weevil eradication in progress, the upper-canopy fruit was able to reach maturity and contribute to lint yields. The mechanical topping and hand-square-removal treatments, in which 100% of the upper-canopy fruit was removed, significantly reduced lint yields when compared to the control (Table 2). Jasmonate applied at 300 ppm and Finish applied at 0.11 kg a.i./ha resulted in the highest lint yields of the chemicals tested, however they were among the worst for removing upper-canopy fruit (Tables 2 and 1).

Boll Weights at NAWF=5

It was hypothesized that removal of upper-canopy fruit would increase boll weight of lower bolls from the improved partitioning of carbohydrates from the upper source leaves to lower sink bolls. Results from the 2000 field study failed to confirm this hypothesis. Instead, it was determined that the hand-square-removal treatment, where all upper-canopy fruit was removed, resulted in some of the lowest boll weights (Table 2). The only logical explanation for this might be that the late-season regrowth noticed in these plots acted as a sink, thereby decreasing the amount of carbohydrate partitioned to lower developing bolls (data not shown). The largest bolls occurred where Chlormequat was applied at 0.58L/ha, however this was not significantly different from the control (Table 2).

Fiber Quality

Bolls occurring above the NAWF=5 main-stem nodal position are generally known for providing below-average fiber quality. It was hypothesized that removing this fruit would improve the fiber quality of lower, harvestable bolls. Unfortunately, late-season removal of upper-canopy fruit did not result in any significant differences among treatments in comparison to the control for improving length or strength of cotton fiber (Table 3). However, Prep applied at 0.45 kg a.i./ha significantly reduced fiber uniformity compared to the control and represented the lowest numerical fiber length (Table 3). The control treatment provided the highest micronaire values, which were significantly greater than mechanical topping, Prep at 0.22 kg and 0.45 kg a.i./ha rates, and Chlormequat at the 1.16 L/ha rate (Table 3).

PRACTICAL APPLICATION

The primary objective of this study was to evaluate various chemicals to determine which chemicals were the most effective at removing unwanted upper-canopy fruit late in the growing season. Secondly, we wanted to determine if this removal of fruit affected the weight and quality of first position NAWF=5 bolls and subsequent lint yields. Generally, the results of the chemical fruit removal were variable, unpredictable, and disappointing. There was evidence that some chemicals could be helpful in achieving this goal but more research is needed to confirm this.

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Table 1. First-position fruit shed percentages at the tagged NAWF=5 position, as well as above and below the tag one week after treatment applications. Marianna, Arkansas, 2000.

Treatment	Fruit shed		
	NAWF=5	Above	Below
	(%)		
Control	3.1 c[z]	61.4 bcd	17.4 a
Hand square removal	19.9 abc	100.0 a	19.9 a
Mechanical topping	7.4 bc	100.0 a	21.9 a
CCC (0.58L/ha) + PHCA (0.58L/ha)	6.3 bc	68.1 bc	21.4 a
CCC (0.58L/ha)	19.9 abc	58.3 cd	24.4 a
CCC (0.58L/ha) + Roundup Ultra (0.55kg/ha)	27.0 ab	70.1 b	18.0 a
CCC (1.16L/ha) + PHCA (0.58L/ha)	18.8 abc	55.6 d	20.5 a
CCC (1.16L/ha)	15.6 abc	60.6 bcd	19.6 a
Prep (0.22kg a.i./ha)	30.1 a	68.1 bc	17.4 a
Prep (0.45kg a.i./ha	13.6 abc	66.8 bcd	21.8 a
Finish (0.06kg a.i./ha)	20.8 abc	61.8 bcd	17.6 a
Finish (0.11kg a.i./ha)	13.6 abc	57.6 cd	16.8 a
Jasmonate (300ppm)	17.6 abc	60.6 bcd	16.3 a
Jasmonate (600ppm)	11.4 abc	62.0 bcd	18.1 a

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

Table 2. Effect of late-season fruit removal on the weight of the first-position NAWF=5 bolls and total lint yields. Marianna, Arkansas, 2000.

Treatment	Boll weight	Lint yield
	(g/boll)	(kg/ha)
Control	5.6 ab[z]	1452 a
Hand square removal	5.4 ab	1258 c
Mechanical topping	5.5 ab	1275 bc
CCC (0.58L/ha) + PHCA (0.58L/ha)	5.6 ab	1422 abc
CCC (0.58L/ha)	5.8 a	1403 abc
CCC (0.58L/ha) + Roundup Ultra (0.55kg)	5.5 ab	1328 abc
CCC (1.16L/ha) + PHCA (0.58L/ha)	5.5 ab	1344 abc
CCC (1.16L/ha)	5.6 ab	1353 abc
Prep (0.22kg a.i./ha)	5.3 ab	1377 abc
Prep (0.45kg a.i./ha)	5.6 ab	1386 abc
Finish (0.06kg a.i./ha)	5.6 ab	1396 abc
Finish (0.11kg a.i./ha)	5.2 b	1429 ab
Jasmonate (300ppm)	5.5 ab	1369 abc
Jasmonate (600ppm)	5.5 ab	1443 ab

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

Table 3. Effect of late-season fruit removal on length, uniformity, strength, and micronaire of first position NAWF=5 bolls. Marianna, Arkansas, 2000.

Treatment	Length	Uniformity	Strength	Micronaire
	(in.)	(%)	(g/tex)	
Control	1.09 ab[z]	84.9 ab	27.1 ab	5.45 a
Hand square removal	1.09 ab	84.6 ab	27.1 ab	5.45 a
Mechanical topping	1.09 ab	84.2 bc	26.7 ab	5.12 e
CCC (0.58L/ha) + PHCA (0.58L/ha)	1.09 ab	85.0 ab	26.9 ab	5.33 abcd
CCC (0.58L/ha)	1.09 ab	85.0 a	27.0 ab	5.37 abcd
CCC (0.58L/ha) + Roundup Ultra (0.55kg)	1.08 ab	85.0 a	26.9 ab	5.40 abc
CCC (1.16L/ha) + PHCA (0.58L/ha)	1.09 ab	85.2 a	27.0 ab	5.30 abcd
CCC (1.16L/ha)	1.09 ab	85.1 a	27.2 a	5.27 bcde
Prep (0.22kg a.i./ha)	1.10 ab	84.7 ab	27.2 a	5.25 cde
Prep (0.45kg a.i./ha)	1.07 b	83.8 c	27.1 ab	5.23 de
Finish (0.06kg a.i./ha)	1.08 ab	84.8 ab	26.6 ab	5.40 abc
Finish (0.11kg a.i./ha)	1.08 ab	84.9 ab	26.2 b	5.42 ab
Jasmonate (300ppm)	1.10 a	84.8 ab	26.9 ab	5.30 abcd
Jasmonate (600ppm)	1.09 ab	85.1 a	27.4 a	5.40 abc

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

VALIDATION OF COTMAN SYSTEM FOR INSECTICIDE TERMINATION IN SOUTHEAST ARKANSAS

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

RESEARCH PROBLEM

Insecticides are needed for the economical production of cotton (*Gossypium hirsutum* L.) in southeast Arkansas. However, they are an expensive input and add to the cost of producing the crop. Thus, terminating insecticide applications at the most "ideal" time in the season help growers get the most out of their crop. The COTMAN system (Danforth and O'Leary, 1998)has been developed in Arkansas in order to help cotton growers decide when to safely terminate insecticidal treatments. Field studies are needed in order to further validate the COTMAN program.

BACKGROUND INFORMATION

Cotton growers are faced every year with making the critical decision of when to terminate sprays for insect pests. If farmers terminate insect control sprays too early, the crop is rendered vulnerable to damage by insects which destroy cotton fruit that would have contributed to higher yields and greater profitability. Conversely, if they spray too long they will be protecting cotton fruit that will not contribute to higher yields. Such additional sprays are thus unnecessary, create environmental concerns, increase production costs, reduce profitability, and increase selection pressure on insects leading to the development of resistance to insecticides. Until recently, there has not been a reliable system to help farmers terminate insecticide use as early as possible without sacrificing yield. Researchers have worked for years to define the "right" time in the cotton growing season at which insecticidal sprays can be terminated for optimum returns. The COTMAN, (COTton MANagement) crop monitoring program provides an uncomplicated system to assist growers, county agents, and consultants in making insecticide termination decisions. The system provides a technique for monitoring cotton growth and fruit development during the season and assisting with end-of-season management decisions (Oosterhuis *et al.*, 1996).

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COTMAN uses Nodes Above White Flower (NAWF) as the basis to determine crop maturity. Research has shown NAWF is closely related with variations in canopy photosynthesis (Oosterhuis *et al.*, 1992) and that fruiting forms produced on main-stem nodes above the NAWF=5 stage did not contribute significantly to total yield (Bourland *et al.*, 1992; Lammers, 1996). The date that a crop attains NAWF=5 is the flowering date of the last effective boll population (Oosterhuis *et al.*, 1996). Beyond that point, the number of heat units accumulated forms the basis on which to predict the date on which the last effective boll population will be safe from insect injury and insecticide applications can be safely terminated. Research has shown that cotton bolls that have accumulated 350 heat units (DD 60's) or more since first flower are safe from significant loss by bollworm/budworm or boll weevil damage. Therefore, COTMAN recommends insecticide termination at NAWF=5 + 350 heat units, unless beet armyworm or fall armyworm infestations are present. However, growers in fear of late-season damage to bolls often continue insecticide applications beyond the COTMAN termination date. The available research indicates there is no economic advantage to using insecticides after the COTMAN termination date, but few studies have been conducted in south Arkansas. This study was conducted to examine the effect of insecticide termination date on yield and economic returns.

RESEARCH DESCRIPTION

The insecticide termination test was conducted in 2000 on Stevens Farms in Desha County, Arkansas. The field consisted of 37 acres of irrigated Stoneville BXN 47 planted on 20 April 2000 and maintained using standard production practices. The test was conducted using a Randomized Complete Block Design with four replications. Plots were four rows wide and ran across the field (average length 1321 ft). A twenty-four row border area separated adjacent plots. Two insecticide termination regimes were compared: NAWF=5 + 350 heat units (early termination) and NAWF=5 + 598 heat units (the standard termination regime recommended by the consultant). The field in which the test was conducted received treatments of Temik 15G (3.5 lb/acre) at planting, then foliar applications of Bidrin (3.20 oz/acre) on 15 May and 26 May 2000; Larvin (21.33 oz/acre) on 16 June 2000; Karate Z (1.83 oz/acre) + Tracer (1.28 oz/acre) on 18 July 2000; Curacron (16 oz/acre) on 22 July 2000; and Baythroid (2.13 oz/acre) + Orthene (8 oz/acre) on 4 August 2000. NAWF=5 occurred on 25 July and NAWF=5 + 350 heat units occurred on 10 August 2000. After 10 August, standard termination plots were treated by air with Tracer (1.83 oz/acre) on 15 August and 22 August 2000. Complete plant mapping was done on 29 September 2000 by thoroughly examining10 plants in each plot and recording fruit presence/absence on each fruiting site. Height of 10 plants per plot (measured from the cotyledon leaves to the tip of plant) was also taken at the time of mapping. Lint yield was determined by machine harvesting all four rows of the plots on 12 October 2000. Data collected were analyzed using ANOVA and LSD

(0.05) Test. Variables analyzed were amount of lint per boll, lint per fruiting node, percent turn out, boll count and retention rate, lint yield, and net return. For economic comparisons, $0.60 per pound was applied to the lint yields.

RESULTS AND DISCUSSION

Boll Weight, Count, and Retention Rate

All fruiting sites analyzed produced statistically similar amounts of lint per boll in both the early and standard insecticide termination systems (Table 1). Turn out rates for those same fruiting sites were also similar between the two termination systems (Table 1). Even when data were analyzed across all fruiting sites per node, no significant differences were found between the two insecticide termination systems in terms of lint produced per node for nodes 5 through 24 (Table 2). Fruit count per node was also statistically similar between the two insecticide termination systems for nodes 5 through 24 (Table 2). There was, however, a slight numerical increase in fruit count under the standard termination system. Boll retention rates were also similar between the early and standard termination systems for all nodes (Table 2) including the uppermost nodes, which are the main target of the extra insecticide sprays made in the standard termination system. However, there was a tendency for retention rates on the six uppermost nodes to be numerically higher under the standard than under the early termination system.

Lint Yield

Plots in the standard insecticide termination regime produced similar lint yield to those under the early termination system recommended by COTMAN (Table 3). There was a numerical increase in yield of about 64 lb/acre under the standard termination system in comparison with the early termination system. The fact that boll weight and boll retention rates in the two insecticide termination regimes were similar explains the insignificant differences found in lint yields. Although there was a noticeable numerical increase in the amount of lint collected per boll for node/fruiting site 20-1 (Table 1), fruit on such nodes high on the main stem does not contribute much to crop yield.

Economic Assessments

The economic returns after treatment costs were similar between the two insecticide termination systems (Table 3). Prolonging crop protection time under the standard termination regime did not translate into higher yields or more profits compared with the early termination regime recommended by COTMAN. Such results are particularly interesting having been obtained from southeast Arkansas, an area currently undergoing boll weevil eradication. Heavy worm infestations occurred late in the 2000 growing season which, in our test, required that two insecticide applications be made to plots in the standard termination system to keep worm counts below the economic threshold. That added an additional expense of about $25.00 per acre in production costs incurred by our cooperator. Yet there were no economic benefits, statistically noted, for extending the period of crop protection beyond COTMAN recommendations.

PRACTICAL APPLICATION

Insecticide termination rules recommended by COTMAN have been validated in this study. There were no economic advantages for extending protection period of crop from insect damage any further than that recommended by COTMAN. Plots in which insecticide applications were terminated early (at NAWF=5 + 350 heat units) were similar in boll counts and retention rates, lint yields, and economic returns to plots in which insecticides were terminated at a later time (NAWF=5 + 598 heat units).

ACKNOWLEDGMENTS

The authors wish to thank our cooperator, Mr. Steve Stevens, for allowing us to conduct the insecticide termination study on his farm.

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Table 1. The effect of early insecticide termination system (COTMAN) versus standard system on amount of lint collected per boll and gin turnout. Desha County, Arkansas. 2000.

Node /	Lint		Gin turnout	
Fruiting site[z]	Early[y]	Standard[x]	Early[y]	Standard[x]
	(g/boll)		(%)	
6-1	1.40 a[w]	1.25 a	37.3 a	36.0 a
7-1	1.47 a	1.69 a	39.0 a	38.3 a
7-2	1.56 a	1.25 a	36.8 a	37.8 a
8-1	1.85 a	1.71 a	39.0 a	38.3 a
8-2	1.62 a	1.68 a	38.0 a	38.3 a
8-4	1.63 a	1.39 a	40.0 a	38.3 a
9-1	1.81 a	1.88 a	39.8 a	40.8 a
9-2	1.66 a	1.81 a	39.0 a	39.3 a
9-4	1.41 a	1.30 a	39.8 a	39.3 a
10-1	1.95 a	1.91 a	39.5 a	40.8 a
10-2	1.80 a	1.76 a	39.0 a	38.8 a
10-3	1.48 a	1.71 a	40.8 a	42.3 a
11-1	1.94 a	1.98 a	41.0 a	40.8 a
11-2	1.59 a	1.74 a	40.3 a	39.0 a
11-3	1.52 a	1.62 a	41.8 a	41.0 a
12-1	1.99 a	2.08 a	40.5 a	41.3 a
12-2	1.42 a	1.75 a	41.3 a	40.5 a
12-3	1.69 a	1.72 a	41.0 a	42.0 a
13-1	1.90 a	1.97 a	40.5 a	40.0 a
13-2	1.83 a	1.81 a	43.3 a	42.0 a
13-3	1.54 a	1.40 a	41.8 a	42.0 a
14-1	1.88 a	1.90 a	42.5 a	41.5 a
14-2	1.53 a	1.92 a	42.8 a	43.0 a
15-1	1.72 a	1.74 a	42.8 a	44.3 a
15-2	1.53 a	1.47 a	41.3 a	41.8 a
16-1	1.82 a	1.91 a	42.3 a	43.0 a
16-2	1.42 a	1.66 a	40.8 a	42.7 a
17-1	1.69 a	1.85 a	42.8 a	42.8 a
17-2	1.43 a	1.38 a	40.3 a	40.8 a
18-1	1.60 a	1.60 a	41.5 a	41.0 a
19-1	1.46 a	1.51 a	40.5 a	41.7 a
20-1	1.08 a	1.94 a	44.8 a	43.0 a

[z] From bottom of plant.
[y] NAWF=5 + 350 DD60 heat units.
[x] NAWF=5 + 598 DD60 heat units.
[w] Means within rows followed by the same letter are not significantly different (P = 0.05).

Table 2. The effect of early insecticide termination system (COTMAN) versus standard system on the amount of lint collected per node, number of bolls per node, and boll retention. Desha County, Arkansas. 2000.

Node number[x]	Lint collected[z] Early[y]	Lint collected[z] Standard[w]	Number of bolls[z] Early[v]	Number of bolls[z] Standard[w]	Boll retention[y] Early[v]	Boll retention[y] Standard[w]
	----------- (g) ----------		---- (bolls/node) ---		---------- (%) --------	
5	0.06 a[u]	0.04 a	0.05 a	0.03 a	2.5 a	1.3 a
6	0.36 a	0.17 a	0.25 a	0.15 a	11.3 a	5.0 a
7	1.44 a	1.70 a	0.95 a	1.20 a	42.5 a	55.3 a
8	2.40 a	2.05 a	1.40 a	1.30 a	56.3 a	55.6 a
9	2.28 a	2.12 a	1.35 a	1.23 a	48.8 a	54.3 a
10	2.77 a	2.77 a	1.55 a	1.60 a	57.5 a	57.9 a
11	2.66 a	2.88 a	1.55 a	1.65 a	51.3 a	59.2 a
12	2.33 a	2.65 a	1.35 a	1.45 a	53.8 a	50.4 a
13	2.27 a	2.41 a	1.25 a	1.43 a	50.0 a	55.3 a
14	1.84 a	1.73 a	1.08 a	1.00 a	46.3 a	46.4 a
15	1.70 a	1.78 a	1.03 a	1.13 a	48.8 a	51.4 a
16	1.25 a	1.51 a	0.75 a	0.87 a	35.0 a	42.2 a
17	1.03 a	1.41 a	0.65 a	0.88 a	30.0 a	40.2 a
18	0.80 a	0.92 a	0.48 a	0.40 a	22.5 a	31.3 a
19	0.38 a	0.57 a	0.25 a	0.39 a	11.3 a	17.0 a
20	0.30 a	0.29 a	0.25 a	0.19 a	12.5 a	9.5 a
21	0.07 a	0.13 a	0.05 a	0.10 a	2.5 a	5.2 a
22	0.16 a	0.21 a	0.13 a	0.15 a	5.0 a	7.7 a
23	0.08 a	0.05 a	0.05 a	0.03 a	2.5 a	1.3 a
24	0.00 a	0.04 a	0.00 a	0.03 a	0.0 a	1.4 a
Veg. branch	1.49 a	1.02 a	1.03 a	0.71 a	-	-

[z] Total per node/10 (plants/sample), across all fruiting positions.
[y] NAWF=5 + 350 DD60 heat units.
[x] From bottom of plant.
[w] NAWF=5 + 598 DD60 heat units.
[v] Total boll count per node/10 (plants/sample) x 100, first and second fruiting positions only.
[u] Means within rows followed by the same letter are not significantly different (P = 0.05).

Table 3. Effect of insecticide termination system on lint yield and net return in southeast Arkansas. Desha County, Arkansas. 2000.

Insecticide termination system	Lint yield	Gross revenue[z]	Cost of extra protection	Net return
	(lb/acre)	--------------------------	($/acre)	-------------------------
Early termination[y]	1011.8 a[x]	607.10 a	-	607.10 a
Standard termination[w]	1075.4 a	645.23 a	25.00	620.23 a

[z] $0.60 per pound applied to lint yield.
[y] NAWF=5 + 350 DD60 heat units.
[x] Means within columns followed by the same letter are not significantly different (P = 0.05).
[w] NAWF=5 + 598 DD60 heat units.

EFFECTS OF MESSENGER™ ON COTTON GROWN IN THE FIELD AND UNDER CONTROLLED CONDITIONS

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

RESEARCH PROBLEM

Over the last few decades, concern for the protection of the environment has escalated. This has inspired agricultural researchers to develop non-toxic crop protectants, often borrowing from nature itself. One such product is Messenger™ (Eden Bioscience, Seattle, WA), which contains the protein harpin isolated from bacterial plant pathogens. The protein is involved in the induction of a plant's natural defense mechanism. Preliminary studies have shown that Messenger may improve yields in a variety of crops including cotton (Wright *et al.*, 2000). The objectives of these studies were to evaluate the effects of seed treatment and foliar applications of Messenger on cotton yield and physiology in the field and under controlled conditions.

BACKGROUND INFORMATION

Messenger is the first of a new class of crop protectants that contain the active ingredient harpin. Harpin, an extracellular protein isolated from bacterial plant pathogens, activates a plant's natural defense mechanisms by inducing systemic acquired resistance (SAR), thus providing resistance to a broad range of diseases and pests. Messenger has shown success in a variety of crops, including tomato (*Lypersicon esculentum* L.), wheat (*Triticum aestivum* L.), and cotton (*Gossypium hirsutum* L.) in regard to pest management and yield enhancement.

RESEARCH DESCRIPTION

The field study was conducted at the Delta Branch Station in northeast Arkansas. Six replications of Suregrow 747 were planted into a randomized complete block design on 16 May 2000. Pest control, irrigation, and fertilizer management were according to Arkansas cotton production recommendations. Plots consisted of 4 rows, 50 ft in length spaced 36 in. apart. Foliar sprays using deionized water were applied with a

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CO_2 backpack sprayer calibrated to deliver 10 gal of solution/acre. The treatments were as follows: 1) untreated control; 2) seed treatment: 2 oz/100 lb seed at planting; 3) foliar treatment: 2.23 oz/acre at first true leaf (TL), pinhead square (PHS), first-flower (FF), and FF + 2 weeks; and 4) seed and foliar treatment (treatments 2 and 3). Leaf nutrient concentrations of N, P, K, Ca, Fe, Mg, and Zn were determined at FF, FF + 2 weeks, and FF + 6 weeks from fifteen leaves per plot collected between 9 and 10 a.m. Photosynthesis and stomatal conductance were measured at FF + 2 weeks with a LI-COR 6200 portable photosynthesis system. Yield was determined from the inside two rows of each plot with a mechanical picker. Boll numbers, boll weights, and fiber quality were assessed by hand-harvesting 2 m^2 of row per plot.

A growth chamber study was conducted at the Altheimer Laboratory in Fayetteville in the spring of 2000 to determine the effects of Messenger on the physiology of cotton. Suregrow 125 was planted in 2 L pots containing Sunshine mix, a soilless horticultural blend, and arranged in a completely randomized design. All pots were watered with half-strength Hoagland's nutrient solution to maintain a well-watered status. Treatments consisted of 2 rates, 2 timings, and an untreated control sprayed with deionized water only. Rates were 2.23 and 4.46 oz/acre, and sprays began at the second true leaf, or at PHS, and continued weekly through PHS + 2 weeks. At FF, the following measurements were taken: leaf photosynthetic rate; chlorophyll content (SPAD index); membrane integrity; and the dry weight of above-ground biomass.

RESULTS

In the field study, no significant differences were encountered between treatments in yield components (Table 1) or physiological data (Table 2). Leaf nutrient analyses (data not shown) revealed potassium deficiencies throughout flowering and boll development in the field study that may have influenced the plant response to Messenger. The mean potassium tissue concentration was 0.92%. Zinc concentrations fell to 15.9 ppm at FF + 2 weeks, with 15 to 20 ppm being the marginal range for zinc at this stage of cotton development. All other measured nutrients were in adequate concentrations throughout the sampling period.

In the growth chamber, no significant differences between treatments existed in physiological data (Table 3). While no significant differences existed between treated and untreated plants in regard to plant height, plants treated with 4.46 oz/acre beginning at PHS appeared to have more main-stem nodes compared to the untreated control plants (Table 4). Significant differences were evident in the number of squares, as both treatments receiving 4.46 oz/acre of Messenger had significantly more squares compared to the untreated control plants.

PRACTICAL APPLICATION

The Messenger trials described in this paper did not result in significant yield or physiological differences. Both potassium and zinc are important in cotton fruit set and development, and it is possible that these deficiencies in the field study, along with the extreme heat and drought conditions, masked any potential yield differences. The significant differences in number of nodes and squares in the growth chamber were a good indication that Messenger can enhance cotton growth and yield potential. Because many factors determine final yield, the evaluation of an agricultural product should include results from several field seasons. Research will be continued to determine if Messenger can influence plant growth and enhance cotton yields.

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Table 1. Yield components at time of harvest in the field study in northeast Arkansas.

Treatment	Lint	Turnout	Open bolls	Boll weight
	(kg/ha)	(%)	(#/m^2)	(g/boll)
Untreated control	1658	40.5	82	5.0
Seed treatment	1671	40.1	81	5.1
Foliar treatment	1690	40.8	86	4.8
Seed + foliar treatment	1744	42.9	86	4.8
$LSD_{(P=0.05)}$	NS[z]	NS	NS	NS

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

Table 2. Physiological data at FF + 2 weeks in the field study in northeast Arkansas.

Treatment	Photosynthesis	Stomatal conductance
	(mol/cm^2/sec)	(mol/m^2/sec)
Untreated control	32.3	4.04
Seed treatment	33.8	4.07
Foliar treatment	29.2	4.16
Seed + foliar treatment	32.1	4.35
$LSD_{(P=0.05)}$	NS[z]	NS

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

Table 3. Effect of Messenger on photosynthesis and chlorophyll at first flower in the growth chamber study.

Treatment	Photosynthesis	Chlorophyll
	($mol/cm^2/sec$)	(SPAD Index)
Untreated control	18.2	41.7
2.23 oz/acre 2nd TL	20.2	41.2
2.23 oz/acre PHS	18.1	42.4
4.46 oz/acre 2nd TL	19.7	41.3
4.46 oz/acre PHS	20.8	41.4
$LSD_{(P=0.05)}$	NS[z]	NS

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

Table 4. Effect of Messenger on cotton growth at first flower in the growth chamber study.

Treatment	Height	Nodes	Squares
	(cm)	---------------(#/plant)	-------------
Untreated control	77.5	12.6	6.3
2.23 oz/acre 2nd TL	75.2	12.4	5.6
2.23 oz/acre PHS	78.8	13.2	8.8
4.46 oz/acre 2nd TL	78.8	13.4	10.8
4.46 oz/acre PHS	79.6	13.6	10.4
$LSD_{(P=0.05)}$	5.7	0.9	3.48

DEFINING THE COTMAN™ TARGET DEVELOPMENT CURVE FOR ULTRA-NARROW-ROW COTTON ON CLAY SOIL

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

RESEARCH PROBLEM

Identification of the last effective boll population allows informed decisions for termination of insecticide and application of harvest aids. However, the current COTMAN cutout reference, i.e. NAWF=5 (Oosterhuis *et al.*, 1998), may need to be changed for ultra-narrow-row (UNR) cotton. The objective of this study was to determine the main-stem node number of the last effective boll population in UNR cotton grown on clay.

BACKGROUND INFORMATION

A great deal of research has gone into COTMAN, the COTton MANagement system developed at the University of Arkansas (Danforth and O'Leary, 1990). Comparison with a target development curve (TDC) indicates when the crop is under stress. Identification of the last effective boll population allows informed decisions for termination of insecticide and application of harvest aids. Although previous observations of growth curves for conventional cotton on clay (unpublished data) suggest that a different development curve from the COTMAN TDC may be warranted, the relatively small amount of cotton produced on such soils has precluded development of a separate TDC. However, if UNR cotton is going to expand cotton acreage, it must do so by allowing production of cotton on soils previously considered "marginal" cotton ground. Exploratory studies with COTMAN in UNR cotton have produced crop-development curves that differ markedly from wide-row cotton and from the current COTMAN target development curve (Gwathmey *et al.*, 1999; Vories, 2001). Effective late-season management with COTMAN will require accurate identification of the last effective boll population.

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RESEARCH DESCRIPTION

A field study was conducted at the Northeast Research and Extension Center (NEREC) on a fine-textured Sharkey silty clay soil. Gaucho-treated Roundup Ready cotton (DPL 451B/RR) was planted with a John Deere 750 grain drill with 7.5-in. drill spacing on 2 June 2000. The experimental design was a split plot with six replications, with population as the whole-plot effect and irrigation as the split-plot effect. Split-plot (irrigation) dimensions were 20 ft (32 rows) by approximately 200 ft.

An aerial application of urea was made on 5 July at 70 lb N/acre to the entire test. A relatively low nitrogen rate was selected due to the late planting. In order to avoid confounding nitrogen and irrigation effects by loss of urea, a 0.75-in. irrigation was applied to the entire test after urea application. No subsequent irrigation was applied to the nonirrigated plots. Irrigated plots were irrigated when the estimated soil water deficit reached approximately 1.5 in.

At the initiation of flowering, twenty plants per plot were marked for tagging. White flowers were tagged daily with the date and NAWF until 31 August. Flowers after 31 August were felt to have no chance to develop to mature bolls. Linear regression was used to compare the flowering and NAWF development of the crop without regard to stand density.

RESULTS

White flowers were first observed on 10 August, 69 days after planting (DAP, Table 1). Although first flower on the COTMAN Target Development Curve (TDC) is 60 DAP, delayed emergence in this study may explain this. After waiting until June for the soil to dry enough for traffic, seedbed preparation dried the soil further so that the crop had to be irrigated to achieve a stand. Mechanical problems delayed the initial irrigation until 8 June.

Although NAWF on the TDC begins at 9.25 and declines at a rate of 0.2 per day, cotton in this study did not begin as high or decline as fast (Table 1). Regression analysis indicated an NAWF at first flower of 6.7 for the irrigated plots and 5.2 for nonirrigated, declining approximately 0.1 per day for both. The effective flowering period, or the time between first flower and NAWF=5 for conventional cotton, was less than the 20 days associated with the TDC as expected, with 17 days for the irrigated plots and only 2 days for the nonirrigated plots.

A total of 1102 flower tags were recovered from 727 plants in the study, with 741 from irrigated plots and 361 from nonirrigated plots (Table 2). Although more than twice as many flowers were observed in the irrigated plots, regression analysis indicated that only 2 days separated the maximum flowering dates of the treatments.

PRACTICAL APPLICATION

NAWF at first flower averaged 6.7 and 5.2 for the irrigated and nonirrigated plots, respectively, which was much lower than the 9.25 for the TDC. Effective flowering period averaged 17 and 2 days for the irrigated and nonirrigated plots, respectively, also lower than the 20 days for the TDC. Although these data were insufficient to determine a last-effective-flower date, additional coordinated studies are planned for 2001 in several states. Comparing the data among the different locations will provide the information necessary to adequately determine whether a new target development curve is required for UNR cotton.

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Table 1. Nodes above white flower data from tagged flowers from ultra-narrow-row cotton at the University of Arkansas Northeast Research and Extension Center at Keiser in 2000.

Plots	First flower		NAWF = 5	Eff. flower[z] period	NAWF at max. flower
	DAP[y]	NAWF	DAP	days	
TDC[x]	60	9.25	80	20	--
All	69	6.30	81	12	4.9
Irrig.	69	6.70	86	17	5.5
Nonirr.	69	5.20	71	2	3.8

[z] Effective flower period = DAP at NAWF = 5 - DAP at first flower.

[y] Days after planting (DAP) observed for plots; NAWF calculated for observed DAP.

[x] TDC = COTMAN Target Development Curve.

Table 2. Tagged flower count data from ultra-narrow-row cotton at the University of Arkansas Northeast Research and Extension Center at Keiser in 2000.

		Maximum flower count	
Plots	Total flowers tagged	DAP[z]	# Tagged
All	1102	82	72
Irrig.	741	81	47
Nonirr.	361	83	25

[z] DAP = days after planting.

REFINING END-OF-SEASON COTTON IRRIGATION RECOMMENDATIONS

Earl D. Vories, Robert E. Glover, N. Ray Benson, V. Dale Wells and Charles T. Allen

RESEARCH PROBLEM

Irrigation termination recommendations for cotton tend to key on first open boll, a better indicator of the maturity of the first fruit than the whole crop. The objective of this research was to develop crop-based recommendations for timing the final irrigation. The findings from this study will lead to more efficient use of irrigation water and the energy associated with pumping.

BACKGROUND INFORMATION

Cotton growers across the Cotton Belt are adopting COTMAN to aid in end-of-season management decisions. Currently, research-based recommendations are available for termination of insecticides and application of defoliants based on physiological cutout [defined as nodes above white flower (NAWF) = 5]. Recommendations concerning the timing of the final irrigation are often based on first open boll, which provides a better indicator of the maturity of the first flowers than the entire crop. Such recommendations generally reflect fear of boll rot rather than provide an indicator of the water needs of the maturing bolls. A recommendation that relates the timing of the final irrigation to physiological cutout should better indicate the needs of the crop and fit the current approach taken with other management recommendations.

RESEARCH DESCRIPTION

Three furrow-irrigated large-plot irrigation studies were conducted in northeast Arkansas during the 2000 growing season. One was at the University of Arkansas Northeast Research and Extension Center (NEREC) at Keiser, on a field containing areas of Sharkey silty clay and Sharkey-Steele complex soils. A second was on Field 27 of Wildy Farms near Manila, Arkansas, containing areas of Sharkey silty clay, Sharkey-

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Steele complex, and Routon-Dundee-Crevasse complex soils. The third was on Field 89 of Wildy Farms, containing areas of Routon-Dundee-Crevasse complex and Amagon sandy loam soils. Table 1 shows the cultivar and significant dates for the crop at each site. Cultural practices up until irrigation termination followed Cooperative Extension Service recommendations.

Irrigation treatments consisted of five different irrigation termination times at each site. For each site, the first termination treatment was at approximately physiological cutout (NAWF = 5). An additional treatment was terminated with each subsequent irrigation. Rainfall exceeding one inch was considered equivalent to an irrigation. Table 2 contains the timing of the final irrigation for each of the termination treatments. Defoliant was applied without ethephon at approximately 50% open bolls. First harvest was made once most of the leaves were removed. After first harvest, ethephon was applied and a second harvest was made after the remaining bolls had opened. NAWF data were collected weekly from each plot.

RESULTS

NEREC

On average, the field reached physiological cutout on 27 July, 72 days after planting (DAP) (Table 1) and 8 days earlier than the COTMAN target development curve (data not shown). No significant irrigation termination effect for yield was observed for final irrigations ranging from 5 days (77 DD60) before cutout up to 32 days (729 DD60) after cutout (Tables 2 and 3). However, there was a significant response in earliness, as indicated by percent first harvest, with additional irrigations resulting in a later crop.

Wildy Field 27

On average, the field reached physiological cutout on 12 August, 91 DAP (Table 1), or 11 days later than the COTMAN target development curve. However, the plot-to-plot variation among cutout dates (data not shown) was quite large. In addition to the three separate soil classifications, two of them multi-soil complexes, there was also some Roundup™ drift observed from an adjacent field. A result of the variability was that, when the individual-plot data were observed after the season, the treatments were earlier than originally thought, with the latest final irrigation being 356 DD60 after cutout (Table 2).

A significant irrigation termination effect for yield was observed for final irrigations ranging from 8 days (186 DD60) before cutout up to 17 days (356 DD60) after cutout (Tables 2 and 3). Although the trend was for higher yield with each successive irrigation, no significant difference was observed among treatments terminated after field-average cutout. As before, there was a significant response in earliness, with additional irrigations resulting in a later crop.

Wildy Field 89

On average, the field reached physiological cutout on 10 August, 93 DAP (Table 1), or 13 days later than the COTMAN target development curve. Once again, the plot-to-plot variation among cutout dates (data not shown) was large. In addition to the two separate soil classifications, one of them a multi-soil complex, there had also been recent land grading on the field.

A significant irrigation termination effect for yield was observed for final irrigations ranging from cutout up to 26 days (558 DD60) after cutout (Tables 2 and 3). However, the yield difference among the final three termination treatments (final irrigation 227 DD60 after cutout) was not significant. As before, there was a significant response in earliness, with additional irrigations resulting in a later crop.

PRACTICAL APPLICATION

Two of three studies showed significant differences in seedcotton yield with later irrigation, although there were no differences for irrigation later than 227 DD60 after cutout. All three studies showed significant earliness effects, with a lower percent first harvest associated with later irrigation. Although these preliminary data are not sufficient to consider changing Cooperative Extension Service recommendations, similar coordinated studies are being conducted in Arkansas, Louisiana, and Missouri in 2001. Crop-based recommendations should be developed by comparing the findings from all of these studies.

Table 1. Details of cultivars used and significant dates for the three sites from the 2000 irrigation studies in northeast Arkansas.

		Date			
Location	Cultivar	Planting	Cutout	First harvest	Second harvest
1: NEREC	Suregrow 747	16 May	27 Jul	21 Sep	4 Oct
2: Wildy 27	BXN 47	13 May	12 Aug	27 Sep	5 Oct
3: Wildy 89	DPL 425R	9 May	10 Aug	20 Sep	5 Oct

Table 2. Timing of the final irrigation in the 2000 irrigation studies in northeast Arkansas.

		Timing of final irrigation			
Treatment	Date	Days after planting	DD60 after planting	Days after NAWF=5[z]	DD60 after NAWF=5
NEREC					
1	22 Jul	67	1268	-5	-77
2	27 Jul	72	1366	0	0
3	8 Aug	84	1643	12	277
4	17 Aug	93	1854	21	488
5	28 Aug	104	2095	32	729
Wildy field 27					
1	4 Aug	83	1462	-8	-186
2	10 Aug	89	1610	-2	-42
3	15 Aug	94	1699	3	55
4	22 Aug	101	1836	10	193
5	29 Aug	108	1999	17	356
Wildy field 89					
1	10 Aug	93	1655	0	0
2	15 Aug	98	1745	5	89
3	22 Aug	105	1882	12	227
4	29 Aug	112	2045	19	389
5	5 Sep	119	2213	26	558

[z] Negative values signify that the final irrigation was made before a field-average NAWF=5.

Table 3. Seedcotton yield and earliness findings from the 2000 irrigation studies in northeast Arkansas.

	Timing of final irrigation		Seedcotton	Percent
Treatment	Date	DD60 after NAWF=5[z]	yield	first harvest
			(lb/acre)	(%)
NEREC				
1	22 Jul	-77	2200	91
2	27 Jul	0	1960	90
3	8 Aug	277	2460	86
4	17 Aug	488	2330	82
5	28 Aug	729	2410	81
$LSD_{(0.05)}$			NS[y]	2.7
Wildy field 27				
1	4 Aug	-186	2570	85
2	10 Aug	-42	2870	84
3	15 Aug	55	2990	80
4	22 Aug	193	3060	79
5	29 Aug	356	3130	77
$LSD_{(0.05)}$			321	3.8
Wildy field 89				
1	10 Aug	0	1720	74
2	15 Aug	89	1960	70
3	22 Aug	227	2290	63
4	29 Aug	389	2260	59
5	5 Sep	558	2270	60
$LSD_{(0.05)}$			185	3.7

[z] Negative values signify that the final irrigation was made before a field-average NAWF=5.
[y] NS = not significant (P=0.05).

COTMAN™ FOR IRRIGATION TERMINATION: STUDIES TO IDENTIFY THE IRRIGATION TERMINATION WINDOW

Marwan S. Kharboutli and Steven R. Kelley[1]

RESEARCH PROBLEM

Cotton growers report that one of the most difficult decisions they must make each year is when to terminate irrigation. Yet little guidance is available to help growers make these critical decisions. The COTMAN system (Danforth and O'Leary, 1998) provides a framework for describing and communicating the physiological maturity of cotton. With the appropriate research, the COTMAN system could be a valuable tool in helping crop managers make the difficult decision of when to stop irrigating the crop.

BACKGROUND INFORMATION

For years, growers in southeast Arkansas have used irrigation to improve and stabilize cotton yields. Currently, about 85% of the cotton acreage in Desha County and surrounding area is irrigated. Field work by Vories *et al.* (1998) provided a basis to help growers making decisions on when to start irrigating, but very limited research has been done on irrigation termination. In their quest to achieve maximal yield, cotton growers tend to continue irrigating late into the growing season. The costs associated with irrigation are indeed substantial. But the cost of one or more late-season irrigations is generally not high since irrigation tubing is in place from earlier irrigations and the crop has been irrigated previously. Therefore, labor and equipment costs are normally low and the remaining costs are primarily in fuel for pumping water. However, there are other indirect costs associated with late-season irrigations. Late-season irrigations often delay crop maturity, increasing the risk of weather-related damage. Delayed crop maturity may cause yield/quality losses by moving cotton harvest beyond the optimal harvest window. Also, late irrigations extend the period of vulnerability to insect pests and increase the cost of controlling them. A system is therefore needed to help growers optimize irrigation termination to obtain maximal yields while avoiding unnecessary direct and indirect costs.

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The COTMAN system is becoming an increasingly valuable tool for managing cotton. While it was initially used to monitor pre-flowering plant growth and fruiting and as a guide for late-season insecticide termination, it may provide a system for reliably determining the optimal timing for irrigation termination. The BOLLMAN component of the COTMAN system monitors late-season boll development from an easily determined marker of crop physiological development; node above white flower 5 (NAWF = 5) or physiological cut-out (Oosterhuis *et al.*, 1996). From that point in crop development, further crop maturation is described using heat units accumulated above a 60 degree Farenheit threshold. Little work has been done on the utilization of the COTMAN system to define the most ideal time in the growing season for irrigation termination. Kelly *et al.* (2000) reported that the optimal stage of physiological development for irrigation termination in southeast Arkansas was near or slightly above NAWF = 5 + 500 heat units. The objective of this study was to use the COTMAN system in order to describe the earliest window of physiological development of cotton at which irrigation can safely be terminated without economic loss.

MATERIALS AND METHODS

Three irrigation-termination tests were conducted in 2000 on three separate cotton fields on the C.B. Stevens Farms near Tillar in Desha County, Arkansas. Stoneville BXN 47, Phytogen 355, and DPL 451 BtXRR were used in Test I, Test II, and Test III, respectively. Cotton was planted on 20 April in Test I and Test II while in Test III cotton was planted on 15 May 2000. Fields were maintained using standard production practices. All three tests were conducted using a Randomized Complete Block Design with four replications. Plots were four rows wide and ran the length of the test field, which averaged 526, 1069, and 1259 ft in Test I, Test II, and Test III, respectively. A four-row border area separated adjacent plots in Test I and Test II while in Test III an eight-row border area was maintained. All fields were irrigated using a standard seven-day schedule until 11, 9, and 21 August in Test I, II, and III, respectively, when the last irrigations were applied to the test fields. Afterward, irrigation was terminated in four plots in Test I and Test II and, for comparison, continued in four other plots in each field. Irrigation was terminated after 504 and 453 heat units had accumulated beyond NAWF = 5 in the irrigation-termination plots in Test I and II, respectively. Three irrigation-termination regimes were compared in Test III: 298, 422, and 559 heat units past NAWF5, which occurred on 21, 26, and 31 August, respectively. Complete plant mapping was done on 19 September, 20 September, and 5 October in Tests I, II, and III, respectively, by thoroughly examining10 plants in each plot and recording fruit presence/absence on each fruiting site. Height of plants was also taken along with mapping (measured from the cotyledon leaves to the tip of plant). Lint yield was determined by machine harvesting all four rows of the plots. Test I and Test II were harvested on 20 September while Test III was harvested on 12 October 2000. The data collected were analyzed using

ANOVA and LSD (0.05) Test. Variables analyzed were plant height, amount of lint per boll, lint per fruiting node, percent gin turnout, boll count and retention rate, lint yield, and net return. For Test I and Test II, however, only lint yield and net return will be given in this report. For economic comparisons, $0.60 per pound was applied to the lint yields.

RESULTS AND DISCUSSION

Boll Weight, Count, and Retention Rate

Only a few fruiting sites had significant differences among the three irrigation regimes (Test III) in terms of the amount of lint produced per boll (Table 1). However, 73% of the fruiting sites produced more lint per boll, numerically, in plots where irrigation was continued beyond 298 heat units past NAWF = 5 (Table 1). Similarly, gin turnout rates for most fruiting sites did not significantly differ among the three irrigation regimes, but rates were numerically greater in 88% of the fruiting sites when 559 or 422 heat units had accumulated past NAWF = 5 than in the 298 heat units regime (Table 1). When data were analyzed across all fruiting sites per node, the vast majority of nodes produced similar amounts of lint in the three irrigation regimes (Table 2). About 91% of the nodes produced more lint, numerically, when 559 or 422 heat units had accumulated past NAWF = 5 than in the 298 heat units regime. Where significant differences existed, more lint was produced when 559 heat units had accumulated past NAWF = 5 than in the 422 or 298 heat units regime (Table 2). Fruit count per node was also statistically similar among the three irrigation systems for most nodes (Table 2). Nearly 86% of the nodes had numerically greater boll counts when 559 or 422 heat units had accumulated past NAWF = 5 than in the 298 heat units regime. Where significant differences existed, fruit counts were greater when 559 heat units had accumulated past NAWF5 than in the 422 or 298 heat units regime (Table 2). Boll retention rates were similar for all nodes except nodes 9, 10, 17, and 22, which had greater retention rates in the NAWF = 5 + 559 heat units irrigation regime than in those of the 422 or 298 heat units regime (Table 2). Numerically, retention rates were greater in 85% of the nodes when 559 or 422 heat units had accumulated past NAWF = 5 than in the 298 heat units regime (Table 2).

Lint Yield

In Test I and Test II, no significant differences were seen in lint yield between the two irrigation regimes (Table 3). One additional irrigation (irrigation-continued system) resulted in a numerical increase in lint yield of about 55 and 60 lb/acre in Test I and Test II, respectively (Table 3). In Test III, plots in which irrigation was terminated at NAWF = 5 + 422 heat units produced significantly more lint than those where irrigation was terminated earlier at NAWF = 5 + 298 heat units (Table 2). However, further irrigation past NAWF = 5 + 422 heat units did not result in any yield increase. Lint yield in plots where irrigation was terminated at NAWF = 5 + 559 heat units was statistically similar to those of the two earlier irrigation-termination regimes (Table 2).

Economic Assessments

As with lint yield, the economic returns after irrigation costs were similar in Test I and Test II between the two irrigation-termination systems (Table 3). The additional irrigation made to plots in the irrigation-continued system did not translate into significantly more profits. Net returns were, however, numerically greater in the irrigation-continued than irrigation-terminated system (Table 3). In Test III, terminating irrigation at NAWF = 5 + 422 heat units resulted in a significant economic gain of about $28.25 per acre compared to terminating irrigation at NAWF = 5 + 298 heat units (Table 3). Further irrigation, however, did not translate into more economic gains.

PRACTICAL APPLICATION

The COTMAN system was used in this study to define the optimal time during the cotton growing season to terminate irrigation. There were no economic advantages for extending irrigation time further than NAWF = 5 + 500 heat units. However, economic losses were incurred when irrigation was terminated at an earlier stage during the cotton growing season (*i.e.,* NAWF = 5 + 298 heat units). This supports earlier findings that suggest the optimal stage of physiological development for irrigation termination in southeast Arkansas is near or slightly above NAWF = 5 + 500 heat units.

ACKNOWLEDGMENTS

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Table 1 (Test III). Effect of irrigation on amount of lint collected per boll and gin turnout. Desha County, Arkansas. 2000.

Node /	Lint			Gin turnout		
Fruiting site[z]	298 H.U.[y]	422 H.U.[y]	559 H.U.[y]	298 H.U.[y]	422 H.U.[y]	559 H.U.[y]
	---------------- (g/boll) ----------------			------------------ (%) ----------------		
5-1	0.90 a[x]	1.14 a	1.08 a	29.8 a	29.0 a	30.7 a
6-1	1.47 a	1.36 a	1.52 a	32.5 a	31.8 a	33.3 a
6-2	1.64 a	1.28 a	1.42 a	34.0 a	31.0 a	33.5 a
7-1	1.43 a	1.53 a	1.52 a	33.8 a	33.0 a	33.5 a
7-2	1.27 a	1.46 a	1.44 a	34.0 a	34.5 a	34.5 a
7-3	1.13 a	1.12 a	1.07 a	33.3 b	34.0 b	36.5 a
8-1	1.55 a	1.58 a	1.64 a	34.3 a	34.5 a	35.3 a
8-2	1.39 a	1.21 a	1.58 a	35.3 a	35.0 a	35.8 a
8-3	1.18 a	1.54 a	1.38 a	33.0 a	34.3 a	34.3 a
9-1	1.64 a	1.71 a	1.81 a	34.8 b	35.0 ab	36.0 a
9-2	1.33 ab	1.20 b	1.60 a	35.0 b	35.8 ab	36.8 a
9-3	0.87 a	0.98 a	1.45 a	33.0 a	32.0 a	36.3 a
10-1	1.70 a	1.55 a	1.67 a	36.3 a	36.0 a	36.8 a
10-2	1.58 a	1.33 a	1.41 a	36.3 a	35.3 a	36.8 a
11-1	1.74 a	1.74 a	1.88 a	37.0 a	37.5 a	37.8 a
11-2	1.47 a	1.52 a	1.54 a	35.0 b	36.3 ab	37.3 a
12-1	1.81 a	1.66 a	2.06 a	37.0 b	37.3 ab	37.8 a
12-2	1.29 a	1.64 a	1.68 a	36.7 a	36.3 a	37.8 a
13-1	1.86 a	1.89 a	1.87 a	37.5 a	37.3 a	38.3 a
13-2	1.02 a	1.57 a	1.38 a	37.7 a	37.8 a	37.0 a
14-1	1.89 a	1.83 a	1.86 a	37.5 a	37.8 a	38.5 a
14-2	1.46 a	1.45 a	1.58 a	38.0 a	37.3 a	38.8 a
15-1	1.56 b	1.94 a	1.97 a	37.5 a	38.5 a	38.8 a
15-2	1.10 a	1.05 a	1.41 a	37.0 a	34.3 a	37.8 a
16-1	1.77 a	1.51 a	1.53 a	37.3 a	37.8 a	38.8 a
16-2	1.17 a	1.12 a	1.32 a	39.0 a	37.7 a	40.8 a
17-1	1.49 a	1.52 a	1.72 a	38.0 a	36.5 a	38.3 a
17-2	1.13 ab	0.88 b	1.46 a	36.0 a	33.0 a	38.5 a
18-1	1.42 ab	1.22 b	1.71 a	37.3 a	37.5 a	38.3 a
19-1	1.41 a	1.32 a	1.36 a	38.5 a	38.3 a	36.3 a
20-1	1.48 a	0.99 a	1.04 a	37.0 a	34.5 a	32.8 a
21-1	0.61 b	0.57 b	1.26 a	26.7 a	28.5 a	33.3 a
22-1	0.46 a	0.45 a	0.30 a	28.5 a	33.5 a	27.5 a

[z] From bottom of plant.
[y] Heat units (DD60) accumulated past NAWF = 5.
[x] Means within rows followed by the same letter are not significantly different (P=0.05).

Table 2 (Test III). Effect of irrigation on the amount of lint collected per node, number of bolls per node, and percent boll retention. Desha County, Arkansas. 2000.

Node	Lint collected[y]			Number of bolls[y]			Boll retention[x]		
number[z]	298 H.U.[w]	422 H.U.	559 H.U.	298 H.U.	422 H.U.	559 H.U.	298 H.U.	422 H.U.	559 H.U.
	---------- (g) ----------						---------- (%) ----------		
4	0.00 a[v]	0.03 a	0.02 a	0.00 a	0.05 a	0.03 a	0.0 a	2.5 a	1.3 a
5	0.25 a	0.21 a	0.10 a	0.25 a	0.18 a	0.10 a	12.5 a	8.8 a	3.8 a
6	0.69 a	1.00 a	0.84 a	0.45 a	0.75 a	0.60 a	22.5 a	35.0 a	28.8
7	1.75 a	1.80 a	1.91 a	1.28 a	1.23 a	1.33 a	57.5 a	57.5 a	57.5 a
8	2.03 a	1.80 a	2.56 a	1.38 a	1.20 a	1.60 a	66.3 a	53.8 a	72.5 a
9	1.81 b	2.00 b	2.62 a	1.25 b	1.33 ab	1.55 a	57.5 b	63.8 ab	68.8 a
10	2.12 ab	1.84 b	2.49 a	1.30 b	1.28 b	1.60 a	62.5 ab	58.8 b	75.0 a
11	1.91 a	2.01 a	2.10 a	1.15 a	1.20 a	1.23 a	55.0 a	60.0 a	55.0 a
12	1.98 b	1.84 b	2.47 a	1.20 ab	1.13 b	1.33 a	57.5 a	53.8 a	60.0 a
13	1.84 a	1.56 a	1.87 a	1.10 a	0.88 a	1.05 a	52.5 a	43.8 a	46.3 a
14	1.76 b	1.71 b	2.19 a	1.00 b	1.03 b	1.25 a	48.8 a	46.3 a	56.3 a
15	1.14 a	1.30 a	1.75 a	0.78 a	0.78 a	1.03 a	38.8 a	36.3 a	47.5 a
16	1.20 a	1.07 a	1.52 a	0.78 a	0.73 a	1.03 a	35.0 a	36.3 a	51.3 a
17	1.01 ab	0.74 b	1.25 a	0.70 ab	0.53 b	0.78 a	35.0 ab	26.3 b	37.5 a
18	0.69 a	0.75 a	1.00 a	0.53 a	0.60 a	0.68 a	25.0 a	28.8 a	33.8 a
19	0.53 a	0.40 a	0.63 a	0.43 ab	0.30 b	0.50 a	21.3 a	15.0 a	22.5 a
20	0.21 a	0.15 a	0.30 a	0.18 a	0.18 a	0.25 a	7.5 a	8.8 a	12.5 a
21	0.23 a	0.09 a	0.11 a	0.28 a	0.18 a	0.13 a	12.5 a	8.8 a	6.3 a
22	0.04 b	0.07 ab	0.08 a	0.08 b	0.13 ab	0.20 a	3.8 b	6.3 ab	10.0 a
23	0.02 b	0.03 ab	0.06 a	0.05 a	0.08 a	0.15 a	2.5 a	3.8 a	7.5 a
24	0.02 a	0.02 a	0.03 a	0.05 a	0.05 a	0.10 a	2.4 a	2.5 a	5.0 a
25	0.01 a	0.02 a	0.01 a	0.03 a	0.03 a	0.03 a	1.3 a	1.3 a	1.3 a

[z] From bottom of plant.
[y] Total per node/10 (plants/sample), across all fruiting positions.
[x] Total boll count per node/10 (plants/sample) x 100, first and second fruiting positions only.
[w] Heat units (DD60) accumulated past NAWF = 5.
[v] Means within rows followed by the same letter are not significantly different (P=0.05).

Table 3. Effect of additional irrigation on lint yield and net return in southeast Arkansas. Stevens Farms, Desha County, Arkansas. 2000.

Irrigation regime	Lint yield	Gross revenue[z]	Cost of extra irrigation	Net return
	(lb/acre)	----------------------	($/acre)	--------------------------
Test I				
Terminated NAWF = 5 + 504 H.U.[x]	1019.4 a[y]	611.63 a	-	611.63 a
Continued (1 X) NAWF = 5 + 656 H. U.[x]	1074.6 a	644.75 a	2.00	642.75 a
Test II				
Terminated NAWF = 5 + 453 H.U.[x]	1202.4 a	721.43 a	-	721.43 a
Continued (1X) NAWF = 5 + 601 H.U.[x]	1262.6 a	757.55 a	2.00	755.55 a
Test III				
NAWF = 5 + 298 H.U.[x]	1188.1 b	712.85 b	-	712.85 b
NAWF = 5 + 422 H.U.[x]	1238.5 a	743.09 a	2.00 (1X)	741.09 a
NAWF = 5 + 559 H.U.[x]	1203.4 ab	722.01 ab	4.00 (2X)	718.01 ab

[z] $0.60 per pound applied to lint yield.

[y] Means within columns followed by the same letter are not significantly different (P=0.05).

[x] Heat units (DD60).

UTILIZING CROP MONITORING TO EVALUATE THE EFFECTS OF PGRs ON COTTON GROWTH, MATURITY, AND YIELD IN NORTHEAST ARKANSAS

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RESEARCH PROBLEM

PIX™ (mepiquat chloride, 1,1-dimethylpiperidinium) is a plant growth regulator (PGR) developed to be used as a growth retardant for controlling plant height in cotton. Although Arkansas research has shown inconsistent yield responses of cotton to PIX applications, its use continues to be of interest to the state's producers. Much of the interest in PGRs is attributed to the reports of positive effects on plant growth and enhanced earliness. Development of cotton monitoring programs, e.g., COTMAN, has allowed more precise evaluation of cotton growth and development. The use of such programs in research may help identify the effects of PGRs on the crop and help researchers show justification for their use. Therefore, the objective of this study was to evaluate the effects of three mepiquat chloride-based (growth retarding) PGRs on the growth, maturity, yield, and economics of cotton grown in northeast Arkansas.

BACKGROUND INFORMATION

Using percent-open-boll measurements, York (1983) showed that PIX-treated plots tended to be earlier than control plots. He concluded, however, that maturity differences became insignificant by the time plots were harvested. In his study, which included eight environments, PIX applications significantly increased lint yield in only three environments and had no effect on yield in four environments. In a five-year summary of PIX studies in Arkansas, Oosterhuis *et al.* (1991) reported that a significant yield increase associated with PIX applications occurred only 29% of the time while final plant height was reduced 100% of the time. Additionally, their report showed that PIX enhanced earliness only 50% of the time. Kerby (1985) showed similar trends with respect to PIX effects on yield and concluded that beneficial responses to PIX are more likely to occur when conditions favor excessive vegetative growth. Results of Kerby's

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study would suggest that cultural practices that reduce the chance of excessive vegetative growth may negate the need for growth retarding PGRs.

RESEARCH DESCRIPTION

Cotton (*Gossypium hirsutum L.* cv. DPL 5111), was planted 26 April 2000 on a center-pivot irrigated field at David Wildy farms in northeast Arkansas. Plots were established prior to first square and were 12 rows wide (38-inch centers), constituting approximately one acre each. The experimental design was a randomized complete block with three replications. Treatments included 80 lb N/acre with no PGR applications; 100 lb N/acre with no PGR applications; 100 lb N/acre with PIX applications; 100 lb N/acre with PIX Plus applications; and 100 lb N/acre with PIX Ultra applications. Other than nitrogen rate and applications of PGRs, all production practices were consistent across plots and included best management practices for optimal cotton production.

Applications of PGRs were designed to maintain a plant mepiquat chloride concentration level of approximately 12 ppm (Landivar *et al.*, 1992). Application timing and rate recommendations were generated by the computer simulation model "*MEPRT*" and utilized plant measurement inputs as described by Landivar (1998).

Beginning at approximately first square, COTMAN data were collected weekly as described by Tugwell *et al.* (1998). Output from COTMAN was used to track the development of all treatments (Fig. 1). Monitoring with COTMAN continued until all plots were past cutout (NAWF = 5) and data obtained from weekly measurements were used to provide plant growth parameters to the MEPRT program. PGR application rates and timing were based on recommendations generated from MEPRT (Table 1). Prior to harvest, a sample of 50 bolls was hand-picked from each plot and used to determine average seedcotton weight per boll. All plots were defoliated on 6 September 2000 using a one-time application of Finish (1 quart product/acre) and Folex 6 EC (4.26 oz product/acre). Twelve rows from each plot were machine harvested on 20 September 2000 and seedcotton weights recorded and converted to a per-acre yield. Lint yield estimates were based on an assumption of 34.0 % gin turnout. Plant growth characteristics generated from COTMAN output were used to evaluate the effects of PGR on crop development (Table 2).

RESULTS

Graphical representation of crop growth and development, although visually different from COTMAN's target development curve (TDC), showed very few differences among treatments (Fig. 1). The *shift* of all treatments to the right of the TDC indicates a delay in the onset of square initiation and could have resulted from a delayed emergence associated with cool temperatures at planting. Since pre-flower growth curves for all treatments tended to parallel the TDC once square initiation occurred, the pace of crop development did not appear to be delayed as flowering occurred. Growth curves from PGR treatments and non-PGR treatments tended to separate more after flower initiation and some minor differences could be seen graphically with respect to days to NAWF = 5.

Although not statistically different, first-position boll retention tended to be higher with all mepiquat chloride-based PGR treatments. Maturity, measured as days from planting to NAWF = 5, was not significantly different among treatments. Numerical differences for maturity, however, showed a tendency for early maturity with the application of mepiquat chloride-based PGRs. Additionally, no significant differences in treatment were found with respect to lint yield per acre or boll weight. As was the case with boll retention and maturity, yields of PGR-treated plots tended to be numerically higher than yields of plots receiving no PGR.

Revenue was calculated based on a price of $0.60 per pound of lint. Numerical yields from each plot were used in the calculation of revenue and, based on the farmer's records, a production cost of $321.00 was removed from the gross income of each plot for general production inputs other than PGR and nitrogen rate. Revenue, as calculated in this test, did not increase with numerical yield increases. Revenue ranged from a low of $110.33 for the PIX Ultra treatment to a high of $147.68 for the 80 lb nitrogen and no PGR treatment.

PRACTICAL APPLICATION

Results from this test did not indicate any significant yield, maturity, or growth advantage associated with PGR treatments. Mepiquat chloride-based (growth retarding) PGRs did not substantially alter cotton growth and development in this study, and the costs associated with PGRs negatively affected crop revenue. Utilizing plant monitoring (COTMAN) techniques in cotton research may help researchers to better understand and identify treatment effects. Monitoring crop development with COTMAN appears to provide a much needed tool for describing PGR effects on cotton growth. A better method for detecting differences in cotton growth may allow researchers to refine current recommendations and help producers avoid unnecessary inputs.

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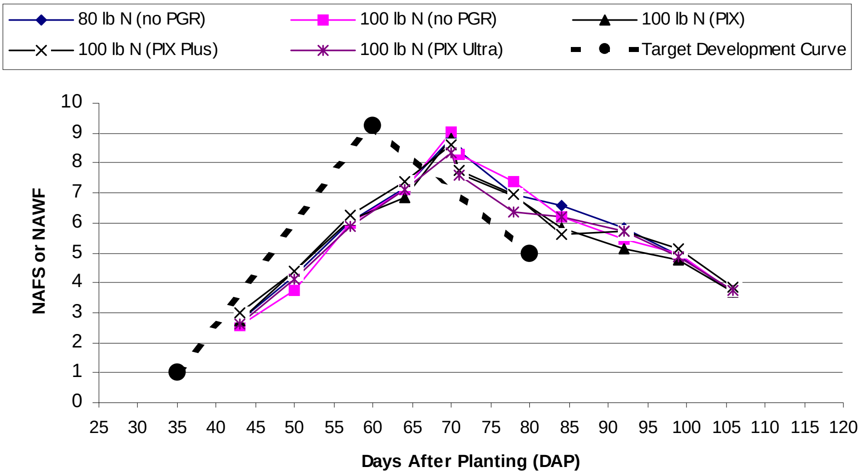

Fig. 1. COTMAN growth curves for PGR and nitrogen treatments.

Table 1. PGR treatments and nitrogen rates for the 2000 plant growth regulator study, Wildy Farms.

Treatment[z]	Nitrogen cost[y]	Date of Application 23 Jun	06 Jul	20 Jul	Total cost[x]
	($/acre)	------------- (rate/acre)		----------------	($/acre)
PIX (100 lb N)	28.80	12 oz	10 oz	6 oz	60.43
PIX Plus (100 lb N)	28.80	12 oz	10 oz	6 oz	62.44
PIX Ultra (100 lb N)	28.80	12 oz	10 oz	10 oz	65.85
No PGR (100 lb N)	28.80	0	0	0	28.80
No PGR (80 lb N)	24.48	0	0	0	24.48

[z] Treatment includes PGR and total nitrogen applied per acre.
[y] Nitrogen cost represents total spent for nitrogen at the specified rates per acre.
[x] Total cost includes nitrogen cost, a $3.25 PGR application cost (for each date), and assumes a cost of $0.78, $0.85, and $0.85 per ounce of PIX, PIX Plus and PIX Ultra, respectively.

Table 2. Results of the 2000 plant growth regulator study, Wildy farms.

Treatment[z]	Yield	Cutout[y]	Boll weight	Plant height	Boll retention[x]	Revenue[w]
	(lb/acre)	(days)	(g)	(inches)	(1st pos.)	($/acre)
PIX (100 lb N)	875	95.0	4.5	37.1	70.3	143.48
PIX Plus (100 lb N)	831	94.0	4.8	36.7	72.0	115.33
PIX Ultra (100 lb N)	829	97.7	4.6	37.0	71.0	110.33
No PGR (100 lb N)	823	98.3	4.5	32.2	70.2	143.93
No PGR (80 lb N)	822	98.3	4.8	40.9	68.9	147.68
Mean	836	96.7	4.7	36.7	70.5	
C.V. (%)	5	5.7	7.1	14.3	3.1	
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	

[z] Treatment includes PGR and total nitrogen applied per acre.
[y] Days from planting to NAWF = 5.
[x] Percent retention (on 18 August) of all first position bolls.
[w] Assumes $321.00 production cost for all plots plus the cost difference associated with each treatment.