MANAGEMENT OF ULTRA NARROW COTTON

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# MANAGEMENT OF ULTRA NARROW COTTON

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MANAGEMENT OF ULTRA NARROW ROW COTTON

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Dennis Patrick Delaney, son of Patrick Leston Delaney and Beverly (Mandock) Delaney, was born July 7, 1956, in Owosso, Michigan. He graduated from Ovid-Elsie High School in 1974. He attended Michigan State University and graduated with a Bachelor of Science degree in Agronomy in 1978. He entered Graduate School, Clemson University, in July 1978, and graduated with a Master of Science degree in Agronomy in 1980. He entered the Alabama Agricultural Experiment Station following graduation, transferring in 1984 to the Alabama Cooperative Extension Service and remains employed by Auburn University. He entered graduate school to pursue a doctorate degree in 1997 at Auburn University. He married Mary Anne Delaney, daughter of Gerald L. and Dorothy (Ward) Linebaugh, on September 15, 1978. They have one son, Brian Patrick Delaney, born April 23, 1983.

DISSERTATION ABSTRACT

MANAGEMENT OF ULTRA NARROW ROW COTTON

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Ultra Narrow Row cotton (*Gossypium hirsutum* L.) production systems may have the potential to increase lint yields, decrease risks to losses from water stress, and allow the use of conservation systems which could contribute to long-term soil productivity. Recent technological developments have improved the feasibility of production of Ultra Narrow Row (UNR) cotton, defined as cotton grown with row spacing of 25-cm or less, but management techniques are poorly defined. We conducted three coordinated field research trials in central and south Alabama from 1998 through 2001 to investigate planting dates and plant populations for UNR (20-cm) cotton, methods to control plant height for efficient harvesting, and cropping systems that utilize cover crops and conservation tillage with UNR cotton production. In the first experiment, planting dates of May, June and July, were tested with 198 000, 296 000, 395 000, and 494 000 plants ha$^{-1}$. May plantings generally yielded > June > July, although with a dry spring June yielded > July > May. Yields from May plantings tended to increase with plant populations below 494 000 plants ha$^{-1}$, while June planted yields tended to decrease with increasing populations, with little effect in July. In the second trial, mepiquat chloride (MC) growth regulator was applied to UNR cotton using seven decision methods, either preplanned (0, 0.0493 or 0.0984 kg a.i. ha$^{-1}$ total) or in response to plant growth (2.5- and 5.1-cm internode length, Pix STIK, or Deltapine Cotton Growth Regulator Guide [Deltapine CGRG]). Height was adequately controlled (less than 81-cm) by all decision methods recommending $\geq$ 0.0493 kg a.i. ha$^{-1}$ of MC, in the one year (1999) with excessive height. The 5.1-cm internode method resulted in the best combination of plant height control while minimizing MC applications. Lint yields were increased in only one year with MC application. In the third trial, legumes (white lupin [*Lupinus albus* L.] + crimson clover [*Trifolium incarnatum* L.]) were compared to rye (*Secale cereale* L.) as a cover crop for UNR and wide rows, with no-till and conventional tillage systems on a drought prone soil. Conventional tillage systems yielded greater than no-till in two of three years, on this drought prone soil. Cover crop type had little effect on yield where adequate plant stands were obtained. UNR cotton yielded over 50% more than wide rows in one year, over 15% more in another year, and the same in another, with never a relative yield decrease. These results indicate that UNR cotton production could be a more profitable system for cotton producers in the southeast United States.

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# INTRODUCTION

Recent technological developments have raised questions concerning the feasibility of commercial adoption of Ultra Narrow Row (UNR) systems, with row spacing of 25-cm or less for upland cotton (*Gossypium hirsutum* L.). The UNR cotton system allows more uniform spacing of cotton plants as compared to traditional row spacings of 91- to 102-cm. More uniform spacing of plants can lead to less inter-row plant competition, and better utilization of sunlight. The more uniform spacing of cotton plants in UNR systems may also allow higher plant populations, with fewer bolls per plant needed for equivalent cotton lint yields as compared to lower plant populations in wider rows.

Since cotton is an indeterminate plant, the requirement for fewer bolls per plant needed for equivalent yield may also shorten the growing season needed for adequate vegetative and reproductive plant growth. A shorter cotton growing season could allow producers to plant later, and would enable more options for utilization of cover crops and doublecropping of winter crops in conservation tillage systems. A shortened period of cotton plant growth, in conjunction with conservation tillage techniques, may also assist in avoidance of short-term droughts which often limit cotton yields in the southeastern United States.

Previous research has shown yield increases and other advantages for this system, but until recently, management problems prevented widespread adoption. The close spacing of UNR cotton eliminates the use of the spindle picker harvesters that are normally used with wider rows. Current technology requires that mechanical harvest of UNR cotton be accomplished with the use of a finger stripper harvester. If cotton plants are allowed to reach excessive height (over 81 cm) or to branch excessively, stem and side branch breakage can occur during harvest, with excessive trash resulting in quality discounts of the ginned lint. Weeds can also be a major problem with UNR cotton, resulting in slow harvest and trash in the ginned cotton.

Recent technological developments promise to alleviate many of these harvest problems. The increasing understanding and use of mepiquat chloride (N,N-dimethylpiperidium chloride) plant growth regulator may help producers avoid excessive cotton height and branching. The recent release of cotton cultivars genetically-engineered for resistance to broadcast applications of non-selective herbicides allows improved weed control without the need for between-row cultivation or directed herbicide sprays. Improved grain drills and other planting equipment for UNR cotton now allow more precise placement of seed, particularly in conservation tillage, that may result in more uniform stands.

The objectives of this study were to determine the effects of: 1) planting dates and plant populations on Ultra Narrow Row cotton growth and yield; 2) plant growth regulator (mepiquat chloride) rates and decision methods on Ultra Narrow Row cotton growth and yield; and 3) the suitability of cropping systems that included legume or rye cover crops, with and without conservation tillage, for wide and UNR cotton production on a marginal soil.

# LITERATURE REVIEW

Upland cotton (*Gossypium hirsutum* L.) is a major crop in the southeastern United States, with a planted area in Alabama area ranging from 200 000 ha in 1998 to 247 000 ha in 2001 (Alabama Agricultural Statistics Service, 2002). *Gossypium hirsutum* is botanically classified as a perennial shrub, but is normally managed as an annual crop in the United States (Oosterhuis and Egilla, 1996).

## Row Spacing

Most cotton cultivars grown in this region are indeterminate types, indicating their tendency to continue growing as long as space, nutrients and other conditions are favorable (Oosterhuis, 1990). Cotton in this area is traditionally grown in wide rows (91.4 to 121.9 cm) to facilitate cultural practices, such as between-row mechanical cultivation and machine harvesting.

Waddle et al. (1956) researched row spacing from 45.7 cm to 121.9 cm on heavy clay soils in Arkansas, and reported that the 45.7-cm rows gave the highest yield. Numerous studies since then have pointed out the ability of cotton plants to compensate for a wide variety of row spacing, with little difference in yield when conditions were favorable for cotton growth, but increased lint yields when conditions were limiting (Jost and Cothren, 1999; Gerik et al., 1998; Vories et al., 2001).

In theory, more equidistant plants should be more productive than plants spaced closely in wide rows, due to more light interception per plant and less inter-plant competition for resources. Krieg (1996) noted that there was greater light interception per unit of soil area at the same Leaf Area Index (LAI) in narrower rows than with wider ones. At equivalent LAI values, cotton in very narrow rows (38.1-cm spacing or less) had greater light interception than 76.2-cm rows, which was greater than with 101.6-cm rows. The greater light interception could indicate that the leaf area was more uniformly distributed over the soil surface with narrow rows, instead of concentrated over the row centers as with wide rows. This resulted in greater cotton growth rates as measured by grams of dry matter accumulated per unit area of soil and per unit of leaf area. The faster growth rate resulted in more fruiting sites early in the season, and greater fruit retention, compared to wider rows. Due to limited soil water availability at the west Texas location, with up to 40% of available soil moisture normally lost to evaporation in wide row spacings, very narrow rows resulted in better utilization of soil moisture by the crop and higher yields.

In comparisons of 19.1-, 38.1-, and 76.2-cm row spacings in eastern Texas Gerik et al. (1998), found that lint yield was increased 37% in one year and 21% in the next for cotton grown in 19.1- and 38.1-cm rows, as compared to 101.6-cm row spacing. Lint yield also increased as plant populations increased from 123 500 to 247 000 plants $ha^{-1}$ in 19.1- and 38.1-cm rows, but decreased with higher populations in 76.2-cm rows. The more uniform plant spacing in narrower rows resulted in more boll set on lower fruiting limbs than in wider rows, resulting in earlier boll set, but not differences in final crop maturity or lint quality. Boll set at the first position from the main stem was 79% of the total in 19.1-cm rows, compared to 69% in 38.1- and 76.2-cm rows. The percentage of bolls set at the second position was lower on 19-cm rows (20%), as compared to 38.1- and 76.2-cm rows (29 and 30%, respectively), indicating earlier boll set and less growth of fruiting branches. They also found that the primary reason for the yield differences noted was the total number of bolls set per unit area, and speculated that by moving boll set earlier in the season, that insect control costs could be substantially reduced.

Further investigations (Gerik et al., 2000) with row spacings of 19.1-, 38.1-, 76.2-, 96.5-, and 101.6-cm and seeding rates of 148 000 to 445 000 seeds $ha^{-1}$ found that yields were substantially higher in very narrow rows (19.1- and 38.1-cm). In one trial, 19.1-cm rows increased yields by 46%, and 38.1-cm rows increased yields by 20%, compared to 101.6-cm rows. In another trial, 38.1-cm rows yielded 20% higher than 96.5-cm rows. In these studies, there were no differences in lint fiber grades between row spacings, or between cultivars grown under the UNR system.

Heitholt et al. (1993) compared cotton row spacings of 0.5- and 1.0-m with normal and okra-leaf type cottons near Stoneville, Mississippi. They found small or no significant differences in lint yields, boll distribution by nodes, earliness or fiber quality between row spacings. However, climatic and soil conditions were not limiting factors of plant growth, as compared to several other studies that did show yield differences with narrower rows. All row spacing treatments in this study were thinned to equivalent populations, as compared to most other studies that used higher plant populations with narrower rows.

In theory, moving boll set earlier in the season with more equidistant row spacings, and the need for lower numbers of bolls at the second or higher positions on fruiting branches should result in earlier maturity. Jost and Cothren (2001) found that when cotton was grown on a clay soil in east Texas that limited plant growth, 19-cm rows achieved maturity (60% open boll) ten days earlier than wide rows (76- and 101-cm). Lint yields were also significantly higher for the narrow rows (19- and 38-cm) than wider rows. Early boll set $m^{-2}$ was equivalent for all treatments except for 19-cm rows at a high population (46 plants $m^{-2}$). The following year, with the same treatments on a more productive silt loam soil, no differences in maturity or yield were found between narrow rows (19- and 38-cm) and wider rows (76- and 101-cm). They attributed this to the plasticity of growth of the cotton plant when growth factors were less limiting. On the clay soil, significant LAI differences were found between narrow and wide row spacings by mid-season (77 Days After Planting (DAP)), while plant density had more effect on LAI on the silt loam soil than did row spacing. The differences in plant growth between the soil types and years are illustrated by LAI values at 77 DAP. On the clay soil LAI values were less than 3.5, while on the silt loam soil LAI values ranged up to 6.58 for the highest plant densities.

The use of narrower rows and increased plant populations can result in excessive LAI, however. Underbrink et al. (2000) stated that increasing LAI above 5.0 in UNR cotton causes shading of lower leaves and less available carbohydrates for lower fruit. This shading caused a decrease in boll set on lower branches and in the first and second fruiting positions from the main stem.

Fiber properties were also affected by row spacing in Jost and Cothren's (2001) study. Micronaire was not affected by row spacing, but length was shorter in the narrow row spacings in the year that cotton was grown on the clay soil. Strength also showed a trend to be lower with the narrow rows, but the effect was not as consistent across plant populations. On the silt loam soil the following year, with less limitation on plant growth, there were no significant differences between row spacings or plant populations for fiber qualities.

In a similar study on a clay soil, Jost and Cothren (2000) found in a year with substantial rainfall, that there was no significant difference in yields between row spacing from 19- to 101-cm, when all treatments yielded greater than 1296 kg $ha^{-1}$ of lint. However, cotton planted on the same soil type in the following year with low rainfall and higher temperatures produced significantly higher yields with 19- and 38-cm row spacings as compared to 76- or 101-cm spacings (1149 and 1056 kg $ha^{-1}$ vs. 862 and 842 kg $ha^{-1}$, respectively). Plant height was also reduced in 19-cm rows, as compared to wider spacings. They observed that the higher population of plants used with the narrow rows in this study resulted in a smaller plant size and a larger percentage of bolls to be set at first and second positions, thus avoiding some effects of late season moisture deficits.

In a three-year study in northeast Arkansas, Vories et al. (2001) compared 19-cm rows to traditional 97-cm rows in large scale plots (0.5 ha). Lint yields were equivalent for two of the three years, but narrow rows yielded significantly more lint in the one year that had substantially less rainfall in May than the 30-year average. Seed cotton yields were higher with narrow rows in two of three years, but lower lint turnout after ginning for narrow rows (29.0% vs. 33.0%) negated much of the difference. Plant populations were also greatly reduced by dry weather after planting, with only 202 000 plants $ha^{-1}$ in narrow rows that year vs. 370 000 plants $ha^{-1}$ in the other two years, although seeding rates were the same each year. The relatively higher yield in this year, in spite of fewer plants $ha^{-1}$, may indicate that the plant population was higher than optimum in the other two years, when yield did not differ. Plant height was reduced in 19-cm rows compared to wide rows in each year of the study, even though a growth regulator was applied in only one year. Lint micronaire was consistently lower for narrow rows than wide, but values were still within the base range desired by spinners. Vories et al. (2001) speculated that the micronaire difference may be due to the harvesting method used, in that the finger stripper used for UNR cotton may have harvested immature bolls that would not have been harvested by the spindle picker in wide rows. They found that fixed costs were substantially less for UNR plots, although variable costs were higher.

## Plant Populations

Plant populations have also been the object of much research. In 1930, J.O. Ware found that yields were equivalent with plant populations ranging from 24 700 to 123 500 plants $ha^{-1}$, in several different row spacings. Current plant population recommendations (Monks et al., 1997) for Alabama suggest that final plant populations in wide rows should be from 86 500 to 123 500 plants $ha^{-1}$. Higher plant populations in UNR cotton can assist in cultural practices such as weed control, by more shading of the soil surface, as well as machine harvest, by leading to less branching of individual plants (Atwell, 1996).

Allen et al. (1998), working in southeast Arkansas, found that optimum populations for UNR cotton, defined as cotton planted in rows of 25-cm or less (Atwell, 1996), were from 172 900 to 301 300 plants $ha^{-1}$. At very high populations (432 200 plants $ha^{-1}$), yields were reduced, similar to the results of Jost and Cothren (2001), when yields were reduced with populations of 460 000 plants $ha^{-1}$. Allen et al. (1998) also used regression analysis on a thrips (Thysanoptera) control study that resulted in variable plant populations. Analysis showed that optimum yields would have been from a population of 271 700 plants $ha^{-1}$, with yields decreasing with populations above 321 000 to 346 000 plants $ha^{-1}$. They also noted a compressed fruiting window, and the potential for saving on insect control costs. However, the thrips damage that resulted in varying populations within the study area could have confounded their results. Jones et al. (2000) found no significant differences in lint yield or turnout for UNR cotton plant populations ranging from 185 000 to 494 000 plants $ha^{-1}$. In most published UNR cotton population experiments, with the notable exception of Jones et al. (2000), variable seeding rates were used to arrive at plant populations. The final populations achieved for each year and treatment varied according to environmental conditions, so that the conditions that affected cotton plants during germination and early growth could also have affected results.

## Planting Dates

Studies in Georgia (Bader et al., 1999; and Bader et al., 2000) indicated that UNR cotton outyielded wide rows in four of five on-farm trials in 1998, with a mean increase of 195 kg $ha^{-1}$. In 1999, with late (June) planting UNR cotton yielded 115 kg $ha^{-1}$ more lint than 91-cm rows. They also reported that two other population studies with irrigated UNR cotton showed little difference in yields, with populations from 62 000 to 370 000 plants $ha^{-1}$. This could be attributed to the lack of water stress, which allowed lower populations to compensate. In another dryland study in Georgia (Harris, et al., 1999), delayed (June) planting resulted in a 200% lint yield increase for UNR cotton over wide rows.

Trials in north and south Alabama (Belcher et al., 1999) showed a yield advantage for UNR cotton in the Tennessee Valley (north) with 909 kg $ha^{-1}$ of lint compared to 861 kg $ha^{-1}$ with wide rows. The same trial conducted on sandier soils in the Wiregrass area of south Alabama showed a much larger advantage for UNR over wide rows, with average yields of 1123 kg $ha^{-1}$ and 836 kg $ha^{-1}$ of lint, respectively.

Similarly, studies in Florida (Wiatrak et al., 1998) with double-crop planting of cotton after small grain harvest in June, showed a lint yield advantage for UNR over 91-cm rows (1205 and 880 kg ha $^{-1}$, respectively). They also noted that plant height was reduced for UNR cotton, although equal amounts of plant growth regulators were applied to all treatments. Boll numbers per plant in UNR were about 40% of those in wide rows. UNR plant populations, however, were 3.1 times as high as in wider rows, so that total number of bolls ha$^{-1}$ was higher.

## Cover Crops

UNR cotton production systems may also present more opportunities for the use of winter cover crops in conservation tillage cotton. Fesha et al. (2002) reported that long-term use of conservation tillage systems with winter cover or grain crops resulted in improved soil quality, with increased water stable aggregates and soil water retention. Cropping systems that include small grain cover or grain crops can also result in rapid buildup of soil organic carbon (Reeves and Delaney, 2002).

Current recommendations call for terminating cover crops at least 2 weeks prior to planting cotton (Patterson, 1996). The shorter fruiting season for UNR cotton may allow later kill of cover crops, resulting in more vegetative growth and more benefits from the covers, in areas where the cotton growing season is limited.

Total desiccation of the cover crop prior to cotton planting helps to minimize soil moisture loss due to transpiration by the cover, enhances planter operation and cotton stand establishment (Brown, et a. 1984; Grisso, et al. 1984). They noted that in areas with a short cotton growing season, however, killing cover crops at least two weeks prior to cotton planting may prevent full growth and benefits from the cover crop. Killing legumes two weeks or more before planting cotton may help avoid deleterious effects of legumes on cotton stand by soil insects, as well as avoiding effects on stands caused by factors such as ammonia toxicity from decomposing legumes (Brown and Whitwell, 1984; and Grisso et al., 1984).

Cool season legumes offer particular advantages as a cover crop by their ability to fix nitrogen for the following summer crop. Estimates range from 60 kg $ha^{-1}$ of N for Austrian winter peas (*Pisum sativum* L.) to over 168 kg $ha^{-1}$ for blue lupin (*Lupinus angustifolius* L.) (Ball and Mitchell, 1986). Other researchers documented nitrogen contributions of 71 kg $ha^{-1}$ (Thompson and Varco, 1996), 101 kg $ha^{-1}$ (Frye et al., 1987) and 133 kg $ha^{-1}$ (Brown et al. 1984) for hairy vetch (*Vicia vilosa* L.); and up to 133 kg $ha^{-1}$ for crimson clover (*Trifolium incarnatum* L.) (Brown et al. 1984). These researchers also noted crop yield advantages for legumes that could not be totally explained by their nitrogen contribution alone. No-till planting of cotton into legumes has also been reported to increase the number of fruiting sites on lower branches and increase earliness, as compared to planting into a cover crop of wheat (Stevens et al., 1992).

In experiments on coastal plain soils in Alabama and South Carolina (Reeves et al., 1998), compared nitrogen requirements for UNR cotton after winter fallow, black oats (*Avena strigosa* Shreb.), and either a white lupin (*Lupinus albus* L.) or Austrian winter pea (*Pisum sativum* L.) winter legume cover crop. They found that yield potential was increased by the use of legume cover crops in three of four site-years, with the exception being a site-year with poor growth of the legume. Lint yields were maximized with the winter legumes and the addition of 67 to 90 kg $ha^{-1}$ of fertilizer nitrogen (N). Ninety kg $ha^{-1}$ of N was usually required for maximum yields of cotton after black oats or fallow, but these yields were not as high as the winter legume + fertilizer N combination. Cover crop biomass production and type in this study was also related to cotton lint yield, with the highest biomass treatment (white lupin) also producing the highest cotton yield.

Cotton cropping system studies by Reeves et al. (2000) showed that a continuous UNR cotton produced the highest returns, averaged for the two years of the study, due primarily to higher yields than 102-cm cotton row spacing. Intensive management systems utilizing rotations of corn (*Zea mays* L.), sunn hemp (*Crotalaria juncea* L.), winter wheat (*Triticum aestivium* L.) for grain, and UNR cotton with conservation tillage had the second highest returns over variable costs in the study, but had less variable returns and less risk. The intensive systems also returned over 7280 kg $ha^{-1}$ of carbon to the soil, as compared to less than 1120 kg $ha^{-1}$ for the conventional continuous cotton production systems, which should contribute to better long-term productivity of the soil.

Later in the same study (Prior et al., 2002) noted the positive effects of no-tillage on $CO_2$ gas exchange in wide row cotton, but that there was less effect of tillage systems on UNR cotton. The reduced effect was presumably due to more early shading of the soil by the plant canopy and more plant-to-plant competition from closer spacings and higher populations. $CO_2$ gas exchange after first bloom was consistently lower in UNR cotton leaves than in wide rows, also probably due to more early leaf mass, more plant-to-plant competition, and earlier canopy closure.

## Harvest Considerations

Cotton in Alabama is typically harvested with a spindle-type picker after the cotton bolls have opened. Spindle pickers use revolving, sharpened spindles to twist seed cotton from open cotton bolls. Until the late 1980's, no commercial spindle-type pickers were available which could harvest rows narrower than 91-cm. However, their current availability has lead to rapid adoption of 76-cm row spacing in some areas, with acreage of Narrow Row cotton (76-cm rows or less) increasing from 25 500 ha in 1973 to over 202 500 ha in 1995 in the U.S. (Weir, 1996).

The development of mechanical spindle pickers for 76-cm rows has led to increased interest in narrower row spacings for cotton production. Burmester (1996) demonstrated an average 7% increase in cotton lint yields with 76-cm row spacing in Alabama, compared to traditional 102-cm rows. He also pointed out the inconsistency of published results from narrowing row spacing in the southeast U.S. Increases in yield from 76-cm or narrower row spacings were generally observed under conditions that limited growth of cotton plants, such as heavier (higher clay content) soils or shorter growing seasons, which often did not have canopy closure in row middles before early bloom. Weir (1996) reported on over 50 replicated trials in California that showed an increase in yield of 6.9% for 76-cm rows as compared to

97- or 102-cm spacing. In northern areas of California, with a shorter growing season, 76-cm row spacing yielded an average of 10% more lint than wider rows.

Early attempts to mechanically harvest cotton usually involved a mule drawn “sled” which raked entire cotton bolls from the plant. In 1964, engineers in Mississippi reported on using the same concept to develop a mechanical “finger stripper” or platform harvester, which combed the cotton bolls from plants using angle iron fingers and a beater or brush (Tupper and Hughes, 1964). This allowed harvest of any row width of cotton, but resistance from cotton gin operators resulted, due to lower lint turnout and increased trash content in the seed cotton (T. Corley, personal communication, 1998). Lint grade reductions caused by increased trash content and aggressive cleaning at the gin, and increased cleaning costs, also decreased the lint price received by cotton producers and lead to their reluctance to adopt this harvesting system (Renck et al., 2000).

Cotton to be harvested with a “finger stripper” harvester must be clean of weeds, short, straight or relatively unbranching, and dry for efficient harvest (Atwell et al., 1996). The development of technology to manage cotton plants to meet these requirements, in the mid to late 1990’s, has allowed cotton growers and researchers to re-examine the feasibility of cotton production using narrow rows and finger strippers for harvest. Atwell also defined cotton with row spacing of 25.4-cm or less as “Ultra Narrow Row Cotton” (UNRC or UNR cotton).

Cotton to be harvested with a “finger stripper” machine must be free of weeds. Weeds, particularly broadleaves and vines, can interfere with harvesting, and cause machinery plugging, slow harvesting, and increased trash in harvested seed cotton (Hayes and Gwathney, 1999). The development in 1993, and subsequent commercial release, of "Roundup Ready" [R] (Monsanto Company, St. Louis, MO) cotton cultivars, genetically engineered for tolerance to over-the-top applications of glyphosate (N-(phosphonomethyl)glycine) herbicide, enabled producers to consistently control weeds in cotton without the need for mechanical cultivation or post-directed herbicide sprays.

Excellent weed control (100% of the grasses and broadleaves studied) has been achieved (Culpepper and York, 1999) in no-till and conventionally planted UNR cotton using a combination of soil applied herbicides at planting and POST applications of glyphosate in cotton with the Roundup Ready trait. Similarly, Mobley et al. (2000) found that a combination of soil applied and foliar herbicides in UNR cotton resulted in 93% or greater control of broadleaf weeds, and that treatments including a soil applied herbicide at planting generally resulted in greater yields. Similar results were noted by Hayes et al. (1999), but they also emphasized the importance of proper application timing, with two foliar applications of glyphosate often needed for increased weed control.

The need for finger stripper harvested cotton plants to be short and unbranched was reported by Wanjura and Brashears (1983). They reported that the percentage of sticks in seed cotton increased with plant size. These sticks can be ground up in the ginning process, and together with bark from main and lateral stems, are difficult to remove from ginned cotton before spinning. Cotton lint classified with "bark" content is heavily discounted (USDA-AMS, 1999). Supak et al. (1992), working primarily with brush type strippers, reported that plant size and conditions affected the occurrence of bark grades more than harvest equipment modifications.

Cotton lint quality is a major concern for cotton producers, with selling price dependent upon quality. A study (Anthony et al., 2000) using seed cotton produced in six locations in the Midsouth and Southeast U.S., with wide and UNR systems, examined lint turnout and quality in a large-scale ginning process. Turnout averaged 34.8% for wide row cotton, while UNR cotton lint turnout was only 30.7%, due to increased trash content. Most lint quality measurements were not significantly different between wide rows and UNR, except for bark content. Fifty percent of the UNR cotton received a bark grade, as compared to none from the wide rows. The authors speculated that the use of a single saw-type lint cleaner may not have adequately cleaned the UNR cotton.

Decreased branching of UNR cotton can be accomplished with management, primarily by increasing plant populations and by applications of plant growth regulators (Atwell, 1996). Atwell also discussed the need for a systems approach, by using narrow rows, increasing plant populations, and application of mepiquat chloride (N,N-dimethylpiperidium chloride), to keep height below the optimum of 81 cm, and to decrease branching. He noted that the number and diameter of vegetative branches decreased as row spacing decreased. He also found that the primary effect of mepiquat chloride application in UNR cotton was decreasing vegetative branch length and size, as opposed to effects on branch numbers or plant height.

## Growth Regulators

Mepiquat chloride, commonly know by the patented trade name of "Pix", reduces cotton plant height, while minimizing deleterious effects on other aspects of plant growth, such as decreased yield and reduced leaf area that can be caused by plant growth regulators. The exact mechanism is still being debated since its development in 1973 and commercial introduction in 1980 (anon., BASF, 1996). However, the consensus is that it inhibits the production of gibberellins and their effects on cell wall expansion, thereby decreasing stem elongation and plant height. In theory, this effect should divert plant resources to other uses, such as boll and lint development, increase earliness and harvestable yield, and facilitate machine harvesting. Under drought or other stress conditions, however, plant height and growth can be reduced excessively with high application rates of mepiquat chloride, and yield can be reduced (Hake et al., 1991).

The introduction of mepiquat chloride has enabled cotton producers to control cotton plant growth in productive growing situations, by application to cotton during periods of rapid vegetative growth, and to keep UNR cotton at the recommended 81-cm height or less. Most recommendations for UNR cotton production call for three to four applications, starting at the matchhead square (flower bud) stage. The recommended rate is normally 0.0123 to 0.0246 kg a.i. $ha^{-1}$

applied every 7 to 10 days, depending on cotton growth, for a total of 0.0493 to 0.0984 kg a.i. $ha^{-1}$ (Atwell, 1996), up to a maximum rate of 0.1476 kg a.i. $ha^{-1}$ per year in unusual situations. Multiple applications of low rates of mepiquat chloride have been proposed, with in-season decisions made for application when plants are rapidly growing and not under stress, but ceasing application during drought or other stress, thereby avoiding potential negative effects (Fletcher et al., 1994).

Cotton responds differently to mepiquat chloride at different growth stages, with less effect observed during periods of rapid vegetative growth, and more effect during reproductive periods, when fruiting structures divert nutrients away from vegetative growth (Hake et al., 1991). Plant size also affects response, with dilution within a larger plant mass causing less effect (Livingston et al., 2000).

Yield responses can also be inconsistent, with some studies showing lint yield increases (Stickler, 1988; Cothren, 1988; Hake et al., 1991; and R. Atkins, unpublished data, 1997), but yield suppression has also been noted (Snipes et al., 1985; Tupper et al., 1995; and Urwiler and Oosterhuis, 1986), or both effects in different years (Zhao and Oosterhuis, 1998). Many other studies have also noted little change in yields from application of mepiquat chloride (Landivar and Searcy, 1999; Jones et al., 2000; Oosterhuis et al., 1995; and Stewart et al., 2001). Stickler (1988) noted that in those trials where cotton grew to be over one meter tall, there was an average 8% lint yield increase. On those fields where cotton was less than one meter tall at harvest, indicating other stresses were present, there was an average 4% yield decrease due to mepiquat chloride application.

The primary advantage noted for mepiquat chloride applications has been in reducing excessive plant growth to increase machine harvest efficiency, and by increasing the number or percentage of bolls at lower fruiting branches (Munk et al., 1998; Oosterhuis, et al., 1998; and Zhao and Oosterhuis, 2001). Increased rates of early flowering have also been noted, which support the trend of increasing boll set at lower fruiting branches (Biles and Cothren, 2001), and of increasing crop maturity (Meredith, 1996).

Mepiquat chloride also can result in LAI reduction of treated leaves by 5 to 10%, and of stem dry weight by 20%, through reduction of growth of main stems and branches (Hake et al., 1991). These reductions in plant growth could be beneficial for UNR cotton production by preventing excessive vegetative mass caused by high plant populations or good growing conditions, and by preventing excessive branch length that would interfere with finger stripper harvest.

Researchers have noted that "feedback systems" may have merit in predicting the value of mepiquat chloride applications. Fletcher et al. (1994) discussed a series of trials where the only yield benefit to application was in a trial where fruit set was poor, and plants had excessive vegetative growth measurements. They also noted that multiple low rate applications had more value than did the same amount applied as a single application. This is in agreement with Cook and Kennedy (2000) who showed that applications of mepiquat chloride could enhance compensation of boll loss from lower fruiting positions, by increasing boll set at higher positions.

Several decision aid methods for mepiquat chloride application on wide (91-cm or greater) row spacing have been developed to optimize rates and timing. However, these methods have not been tested under the unique constraints of the UNR cotton production system, and need to be further tested under this system for applicability.

Among the strategies developed to refine mepiquat chloride application rates and timing are computer programs, including GOSSYM/COMAX prediction software (Watkins et al., 1998). However, daily inputs are required for many parameters including solar radiation, temperature ranges, rainfall or irrigation, and wind speed. This is in addition to initial inputs of emergence date, population, row spacing, fertilizer applications, and several soil characteristics. The complexity of this program, and the need for regular field calibration, has resulted in little adoption of this program by Alabama cotton producers (C. Burmester, personal communication, 1998).

Other approaches include measurement of height-to-node ratios, either for the entire plant or more appropriately, the rate of change in the ratio (Kerby et al., 1999). Increasing values of the ratio, above a predetermined optimal value, indicates that growth is excessive, and that application of mepiquat chloride would be of value. A decline in the ratio would indicate that vegetative growth is slowing, and that mepiquat chloride application would be of little value, or even detrimental.

Another method, or "MEPRT Stick", developed by Landivar et al. (1996) involves measuring the average length of the uppermost top five internodes (ALT5), taking advantage of the premise that nodes below these have completed almost all elongation, and that the top five internodes still have potential for vertical growth. Measurement of only the top five nodes, instead of the entire plant, could make this method more sensitive to recent conditions and vegetative growth. A measuring ruler-type device was developed that a production manager or scout can use to measure the top five nodes of the plant, along one edge of the ruler. The ruler is calibrated so that when the user reads directly across to the ruler to other edge, the average internode length (ALT5) is given for these nodes. The ALT5 side is divided into color-coded sections with recommendations, such that when ALT5 is less than 3.6 cm, no mepiquat chloride is recommended and may be detrimental. When ALT5 is between 3.6 and 7.1 cm, mepiquat chloride may or may not be needed, but when ALT5 exceeds 7.1 cm, excessive stem growth is taking place and mepiquat chloride application will likely be advantageous. The "MEPRT Stick" method was commercially developed and printed for producer use (BASF Corporation, 1996), as the "Pix STIK™".

One problem with the simplified Pix STIK method is that it does not account for the amount of mepiquat chloride existing in the plant from previous applications, which may continue to suppress vegetative growth (Landivar et al., 1995). Computer software has been developed which takes into account existing plant concentrations of mepiquat chloride, as well the current potential for growth, expressed by the ALT5 ratio. Landivar (1998) developed computer software also known as MEPRT, which incorporates measurements of plant height, main stem nodes, and plant density, together with the above measurements (ALT5) to derive a concentration of mepiquat chloride in the plant. If the concentration is below a pre-determined desired value (usually 10 to 12 ppm), an additional application of mepiquat chloride would be recommended. However, most cotton growers do not have computer access in the field as they are making growth regulator decisions.

The "Deltapine CGRG" (Deltapine Seed Cotton Growth Regulator Guide©, Deltapine Seed, Scott, MS) takes the MEPRT Stick approach one step further, by including plant height and number of main stem nodes of the plant. The DPL CGRG user finds the length of the fifth internode from the terminal using the ruler printed on it, similar to the "Pix STIK" but then adjusts for the other factors using a slide rule function, to arrive at the suggested application rate.

In conclusion, recent developments in weed control, plant growth management, and other technology may allow effective production of cotton in ultra narrow rows (UNR). In situations of plant stress, such as drought, poor soil quality or delayed planting, UNR cotton has often outyielded wide row cotton. Since UNR cotton also has an earlier and shorter fruiting period, delayed planting may also be possible in areas with a limited summer growing season, enabling cotton producers to delay killing of cover crops until optimal growth and benefits are obtained from them.

## PLANT POPULATIONS AND PLANTING DATES FOR ULTRA NARROW ROW (UNR) COTTON


### ABSTRACT

Ultra Narrow Row cotton (*Gossypium hirsutum* L.) production systems may have the potential to extend the planting season, creating opportunities for greater use of winter cover crops or doublecropping. The more uniform spacing of Ultra Narrow Row cotton may also allow higher plant populations, with fewer bolls per plant needed to maintain yields. A 3-year field study was conducted near Shorter, AL on a Compass sandy loam (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) soil to investigate the effects of planting dates and plant populations on plant growth and yield of cotton grown with a 20-cm row spacing. Three planting dates of May, June and July were evaluated with populations of 198 000, 296 000, 395 000, and 494 000 plants $ha^{-1}$. Leaf Area Index at early bloom varied by year and planting date, but was not affected by populations. May planted lint yields (1998 =1129 to 1380, 1999 = 1737 to 2104 kg $ha^{-1}$) were greater than June (1998 = 972 to 1170 kg $ha^{-1}$, 1999 = 1431 to 1752 kg $ha^{-1}$) which were greater than July (1998 < 168 kg $ha^{-1}$, 1999 = 461 to 607 kg $ha^{-1}$) in two of three years. There were significant interactions of plant populations with planting dates for yield in two of three years, with May plantings tending to increase with populations below 494 000

plants $ha^{-1}$, and June yields decreasing with population. Ultra Narrow Row cotton planting can be delayed, but may result in decreased yields and require adjustments in plant populations.

**Abbreviations:** DAP, days after planting; LAI, leaf area index; N, nitrogen; UNR, ultra narrow row.

## INTRODUCTION

Cotton (*Gossypium hirsutum* L.) in central Alabama is traditionally planted in wide (91- to 102-cm) rows from mid-April to late May. Cotton planted after these dates often suffers yield declines from mid-summer soil moisture deficits, but earlier planting limits the use of cover crops, which could enhance soil quality and moisture conservation. Fesha et al. (2002) reported that long-term use of conservation tillage systems with winter cover or grain crops resulted in improved soil quality, with increased water stable aggregates and soil water retention. Cropping systems that include small grain cover or grain crops can also result in rapid buildup of soil organic carbon (Reeves and Delaney, 2002).

Current recommendations call for terminating cover crops at least two weeks prior to planting cotton (Patterson, 1996). Complete desiccation of the cover crop prior to cotton planting helps to minimize soil moisture loss due to transpiration by the cover, and enhances planter operation and cotton stand establishment (Brown, et al. 1984; Grisso, et al. 1984). They noted that in areas with a short cotton growing season, however, killing cover crops at least two weeks prior to cotton planting may prevent full growth and benefits from the cover crop.

Ultra Narrow Row (UNR) cotton production systems may present more opportunities for the use of winter cover crops in conservation tillage cotton. UNR cotton, defined as cotton planted in rows of 25-cm or less (Atwell, 1996), planted at high populations may require only three to four bolls per stalk to produce high lint yields and may result in a shorter production season. In theory, moving boll set earlier in the season with more equidistant row spacings, and the need for lower numbers of bolls at the second or greater positions (later) on fruiting branches should also result in earlier maturity. Krieg (1996) noted that there was greater light interception per unit of soil area at the same Leaf Area Index (LAI) in narrower rows (38.1-cm spacing or less) than with wider ones (76.2- to 101.6-cm). The more uniform distribution of leaf area over the soil surface with narrow rows resulted in greater early season cotton growth rates, resulting in earlier fruiting sites and retention, compared to wider rows. Due to limited soil water availability at the west Texas location, the quicker fruit set resulted in better utilization of soil moisture by the crop and higher yields in narrower rows. The shorter fruiting season for UNR cotton may allow later kill of cover crops, and thus more benefits from them, in production systems where the cotton growing season is limited due to soil moisture or other factors.

Jost and Cothren (2001) found that when cotton was grown on a clay soil in east Texas that limited plant growth, 19-cm rows achieved maturity (60% open boll) ten days earlier than wide rows (76- and 101-cm). Lint yields were also significantly higher for the narrow rows (19- and 38-cm) than wider rows. They also found that plant height was reduced in 19-cm rows, as compared to wider spacings. They observed that the higher population of plants used with the narrow rows in this study resulted in a smaller plant size and a larger percentage of the bolls to be set at earlier positions, thus avoiding some effects of late season moisture deficits.

In a dryland study in Georgia (Harris, et al., 1999), delayed (June) planting resulted in a 200% lint yield increase for UNR cotton over wide rows planted at the same time. Similarly, studies in Florida (Wiatrak et al., 1998) with double-crop planting of cotton after small grain harvest in June, showed a lint yield advantage for UNR over 91-cm rows (1205 and 880 kg ha $^{-1}$, respectively).

Research (Reeves et al., 2000) has shown that UNR cotton can be successfully planted in early June in Alabama, thereby allowing later termination and more optimum growth of cover crops. Intensive management systems utilizing rotations of corn (*Zea mays* L.), sunn hemp (*Crotalaria juncea* L.), winter wheat (*Triticum aestivium* L.) for grain, and UNR cotton with conservation tillage had the second highest returns over variable costs in the study, after continuous UNR cotton, when averaged for the two years of the study but had less variable returns and less risk. The intensive systems also returned over 7280 kg ha$^{-1}$ of carbon to the soil, as compared to less than 1120 kg ha$^{-1}$ for the conventional continuous cotton production systems, which should contribute to improved long-term productivity of the soil. In the first year of the study, lint yield of UNR cotton planted in June was similar to that planted in May. However, in the second year, UNR cotton planted in June after wheat in the intensive system yielded significantly less than May planted UNR cotton (442 vs. 687 kg $ha^{-1}$) due to drought.

UNR cotton cannot be harvested with currently available spindle pickers and must be harvested with a finger-type stripper harvester (Atwell, 1996), and is grown at relatively high plant populations to decrease branching and facilitate harvesting. If excessive branching does occur, plant bark, sticks, and other trash will be pulled into the machine along with cotton bolls and seedcotton. These contaminants are difficult to remove at the cotton gin, and can result in significant lint quality discounts for cotton producers. Allen et al. (1998), working in southeast Arkansas, found that optimum populations for UNR cotton were from 172 900 to 301 300 plants $ha^{-1}$, compared to 86 500 to 123 500 plant $ha^{-1}$ (Monks et al., 1997) with traditional wide row systems. However, at very high populations (432 200 plants $ha^{-1}$), Allen et al. (1998) stated that UNR cotton lint yields were reduced, similar to the results of Jost and Cothren (2001), when yields were reduced with populations of 460 000 plants $ha^{-1}$. However, Jones et al. (2000), in experiments in Mississippi and South Carolina, found no significant differences in lint yield for UNR cotton plant with populations ranging from 185 000 to 494 000 plants $ha^{-1}$.

It was speculated in several of these studies that plant-to-plant competition for resources, particularly sunlight and soil moisture under dryland conditions, at the may have caused the reduction in lint yields at the highest plant populations. This theory is reinforced by findings in Georgia (Bader et al., 1999; and Bader et al.,

2000) with irrigated UNR cotton that showed little difference in yields, with populations ranging from 62 000 to 370 000 plants ha$^{-1}$. Prior et al., (2002) noted that $CO_2$ gas exchange after first bloom was consistently lower in UNR cotton leaves than in wide rows, likely due to more early leaf mass and plant-to-plant competition. In most published UNR cotton population experiments, with the notable exception of Jones et al. (2000), variable seeding rates were used to arrive at plant populations. The final populations achieved each site-year varied according to environmental conditions, so that conditions affecting germination and early growth could also have affected results, and make it difficult to quantify optimum plant populations.

The introduction of transgenic cotton resistant to non-selective herbicides and to lepidopteron insects in the mid-1990's in the U.S has allowed producers to solve many production problems in UNR cotton, such as weed control (Culpepper and York, 1999; Mobley et al. 2000; and Hayes et al. 1999) and boll loss. However, seed costs can constitute a major production expense, particularly for the transgenic varieties often used in this system, so that optimum plant populations need to be better defined.

The potential for delayed planting of UNR cotton grown in the southeastern United States is still poorly defined. Several studies have examined delayed (June) planting for UNR cotton, while others have examined plant populations. However, no reports had been published at the initiation of this study to examining the interactions of planting dates and plant populations for UNR cotton grown in the Coastal Plain region. The objectives of this study are to determine the effects of combinations of planting dates and plant populations on the growth and yield of Ultra Narrow Row cotton.

## MATERIALS AND METHODS

### Site Characteristics and Cover Crop Management

The study was conducted for three years (1998 through 2000) the EV Smith Field Crops Unit (latitude: 32° 27'N, longitude: 85° 53'W, altitude: 65 m) of the Alabama Agricultural Experiment Station in east-central AL. The soil type was a Compass sandy loam (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults). The experimental area was subsoiled with a Paratill[1] bent-leg subsoiler (Bingham Brothers, Lubbock, TX) to a depth of 36 to 41 cm in the fall, then drilled with a rye (*Secale cereale* L.) cover crop perpendicular to the direction of cotton rows. The Paratill uses a front-mounted coulter to cut crop residue, and a shank that is bent 45 degrees on the lower portion, with the lower foot approximately 25 cm from vertical. This configuration allows disruption of root-restricting soil layers, while minimizing surface disruption and burial of crop residue. Several studies on this soil, including Reeves and Mullins (1995) and Reeves and Touchton (1986), have shown that deep tillage below the inherent hardpan is necessary.

[1]Trade and company names are used for the convenience of the reader and do not imply Auburn University or USDA-ARS endorsement over comparable products or companies.

Rye was terminated with glyphosate (N-(phosphonomethyl)glycine) at 1.12 kg a.i. $ha^{-1}$ applied to all plots in mid-April, approximately three weeks before the first planting, and was re-applied three to five days before each cotton planting date to control emerged weeds. Rye was rolled with a crimping roller in the planned direction of cotton planting after the initial glyphosate application, to further ensure kill and to press it to the soil surface. Sampling of the cover crop immediately before termination determined that above ground dry matter production was 3800, 4940 and 2540 kg $ha^{-1}$ in 1998, 1999 and 2000, respectively.

## Cotton Crop Management

Treatments were arranged in a four-replication, split-plot Randomized Complete Block design. Main plots were Planting Dates of May, June and July; while split-plots were Plant Populations of 198 000, 296 000, 395 000, and 494 000 plants $ha^{-1}$. Plot size was 3.0 m wide * 7.6 m long.

The transgenic cotton cultivar Paymaster PM 1220 BG/RR (Delta and Pine Land Co., Scott. MS) was used in 1998 and 1999, while PM 1218 BG/RR, a cultivar with similar breeding background and growth habits, was used in 2000, after production of PM 1220 BG/RR was discontinued by the company. All plots were planted with a no-till drill (Great Plains, Lenexa, KS) using 20-cm row spacing into a killed rye (*Secale cereale* L.) cover crop in the first week of May, June, and July. Approximately 700 000 seeds $ha^{-1}$ were planted in an attempt to obtain an excessive plant stand which could be thinned to the desired spacing.

All plots were hand-thinned to their assigned treatment populations of 198 000, 296 000, 395 000, and 494 000 plants $ha^{-1}$ at the early four-leaf stage, between 21 and 30 days after planting. The timing of thinning was chosen to be past the time of most plant losses to seedling diseases, but before significant competition between plants within the stand. Due to mechanical problems and adverse weather conditions causing poor emergence, the two highest populations of 395 000 and 494 000 plants $ha^{-1}$ in May planted plots were not attained in 1998 and 2000.

All plots were maintained weed-free and treated with insecticides and growth regulators according to Alabama Cooperative Extension System (ACES) guidelines (Alabama Pest Management Handbook, 1998). Fluometuron (1, 1-dimthyl-3-(a,a,a-trifluoro-m-toyl) urea) and pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) at 1.12 kg a.i. $ha^{-1}$ were applied preemergence at each planting date. A single application of 1.12 kg a.i. $ha^{-1}$ of glyphosate was made to each planting at the four-leaf stage of cotton.

Mepiquat chloride (N,N-dimethylpiperidium chloride) plant growth regulator was applied to each main plot (Planting Date) treatment after the matchhead square stage, using the MEPRT Stick method (Landivar et al., 1996), in order to maintain 5.1-cm or less internode length in the five uppermost nodes. At maturity, all plots were defoliated according to ACES guidelines for crop and weather conditions.

## Plant Growth Analysis

Leaf Area Index was measured at early and late bloom using a portable LAI-2000 Plant Canopy Analyzer (Li-Cor, Lincoln, NE) to measure canopy closure and shading effects. According to manufacturer's recommendations, two reference readings were made above the canopy, immediately followed by four readings at the soil surface beneath the canopy at three locations within each plot. A 90-degree radius cap was attached to the lens to focus readings within the plot. Internal software calculated Leaf Area Index (LAI) from light interception by the canopy, and arrived at an average LAI value for the plot. Readings were made two to three hours before sunset, or with an umbrella shade, to minimize intense light reflection effects among leaves within the canopy.

Counts of open and closed bolls from two adjacent rows, each 2.4 m long, were made to determine differences in maturity within a Planting Date. Open and closed boll counts were made when most treatments within a Planting Date were estimated to have 50-60% open bolls, or when the majority of bolls examined had mature seed and lint.

After defoliation, ten plants per plot were randomly selected for detailed plant mapping, with boll positions and absence recorded, and seedcotton weights taken from these ten plants. Height measurements were made from the cotyledonary node to the terminal of the plant. Node counts were made from the cotylendonary node (designated as node 0) to the terminal. Plant mapping data was inputted into PMAP 6.2 (Plant Map Analysis Program, Texas A&M University Research &

Extension Center, Corpus Christi, TX). PMAP 6.2 was then used to calculate selected plant growth parameter means, including height, vegetative and reproductive nodes, and number and retention of bolls by position on the plant for each plot.

## Harvest and Lint Quality

When all harvestable bolls had opened, plots were desiccated to facilitate harvest with paraquat (1,1'-dimethyl-4,4'-bipyridinium) at 0.45 kg a.i. $ha^{-1}$, and the center 2.1 m of each plot harvested three to seven days later with a AC 760 XTB finger-type stripper harvester (Allis-Chalmers, Milwaukee, WI) equipped with a bur and stick cleaner. Seedcotton yields were recorded, and approximately 500-gram grab samples were taken for trash, turnout and quality analysis.

Weighed seedcotton samples were hand-cleaned of burs and sticks, re-weighed and then ginned on a 10-saw laboratory mini-gin. Weights of cotton seed and lint were recorded to calculate cotton lint percentage (turnout). Subsamples of lint were analyzed for quality with High Volume Instrumentation (HVI) by the Auburn University Textile Engineering Department HVI Laboratory for the 1998 and 1999 crop years, and for 2000 by the USDA - Agricultural Marketing Service Birmingham, Alabama Classing Office.

Data from each plot was analyzed using was analyzed using SAS Systems for Windows V8 (SAS Institute, Inc., Cary, NC) @ $p \leq 0.10$, *a priori*.

## RESULTS AND DISCUSSION

Weather patterns, particularly rainfall, were different in each crop year, impacting cotton crop growth and growth regulator decision methods for each year (Fig. 1). The 1998 crop year was marked by moderate rainfall in May through August, with 5.1 to 7.6 cm per month, and over 22.9 cm in September, as the crop was maturing. The 1999 crop year had much more plentiful rainfall in early summer, with 10.2 cm or more in each of May, June, and July, then less than 3.8 cm in August. The year 2000 was extremely hot and dry, with less than 5.1 cm of precipitation in each of the four months after planting.

Due to varying weather conditions for each year, there were statistically significant ($p \leq 0.05$) interactions between Treatment and Year for the majority of parameters measured and analyzed. In addition, there were significant ($p \leq 0.05$) three-way interactions among Planting Date, Plant Population, and Year for almost all measurements, with the exception of some lint fiber properties that were little affected by treatments. Because of these significant two and three way interactions, treatments and analysis within each cropping year will be discussed separately.

### Plant Growth

Leaf Area Index (LAI) measured at Early Bloom was affected by Planting Date and the interaction of Planting Date and Plant Population in all three years (Tables 1, 2, and 3), although there was no significant main effect of Plant Population on LAI in any year. This is somewhat surprising, given the measurement was relatively early in the cotton growth cycle, when higher populations and closer spacing of plants should have resulted in greater total leaf area or LAI, and contrasts with the results of Krieg (1996), and Jost and Cothren (2001), who showed increased early season LAI values as plant populations increased.

Leaf Area Index measured at Late Bloom showed significant ($p \leq 0.05$) or highly significant interactions ($p < 0.01$) between Planting Date and Plant Population in two years (1998 and 2000, respectively). The only exception was 1999, when all LAI values measured were above 3.6 by late bloom, and the only significant effect was for Planting Date. This was also the year when there was little stress from limited soil moisture due to relatively above average rainfall from May through July. Leaf Area Index measured at Early and at Late Bloom were also poorly correlated to Lint Yields ($r^2 \leq 0.5$) for all combinations studied, showing that LAI measurements would not be a good predictor of lint yield for UNR cotton. Even though LAI was above 5.0 (with a maximum of 5.2) in some treatments in 1999 and 2000, there was no corresponding decrease in boll set at the first and second fruiting positions, in contrast to results reported by Underbrink et al. (2000).

Plant height was between 40 and 70 cm in all treatments for all three years, so that all treatments were acceptably short enough (less than 81-cm) for efficient harvest (Atwell, 1996). Plant height was significantly affected by Planting Date ($p \leq 0.01$) in all three years. While there were significant interactions ($p \leq 0.001$) of Planting Date and Plant Populations in 1998 and 2000, most differences were less than 4 cm, or of little practical importance to cotton producers, as compared to differences of 8 to 10 cm between Planting Dates.

The percentage of total bolls that were first position ranged from 64 to 96%, with an overall mean of 83%. This is in agreement with Gerik et al. (1998), who noted that the percentage of first position bolls was 79% in 19 cm rows, as compared to only 69% in wider rows. There were significant interactions between Planting Date and Plant Population for every year, although most of the variation was from the Planting Date factor, and there was no clear pattern or correlation ($r^2 \leq 0.6$) for percentage of first position bolls and Plant Population.

Boll retention was significantly affected by both Planting Date and Plant Population and their interaction, particularly for the first position from the stem (Tables 4, 5, and 6). First position boll retention ranged from 37 to 56%, with the primary influence coming from Planting Date, but also significant effects from Plant Population and interactions in 1998 and 2000. Boll retention was slightly increased by higher populations in May, had variable effects in June, while decreasing from the low population to higher ones with July plantings in 1998. In 1999, the year with better rainfall distribution, there was no effect of Plant Population on boll retention, with June > May > July. In 2000, first position boll retention was highest with the low population in May with 71%. In later plantings, there was little difference in retention, with most combinations retaining about 50%.

Maturity as measured by percentage open bolls loosely followed yield trends within most Planting Dates and Years. However, due to significant interactions of

Planting Date and Plant Population in two of three years (1998 and 2000), there was poor correlation ($r^2 < 0.5$) between lint yields and percentage open bolls. Since the open and closed boll counts were made at an arbitrary maturity date for a given Planting Date, percentage open boll comparisons should be made only for Plant Populations within a given Planting Date and Year combination. Due to delayed maturity and a killing freeze in November 1998 on July Planted plots, the few opened bolls (<3%) were hand harvested for yield and lint samples.

## Lint Yield and Quality

There were significant interactions between planting dates and populations for lint yield, with May plantings tending to increase in yield with populations below 494 000 plant ha$^{-1}$, while yields from June plantings decreased with increasing populations (Tables 7, 8, and 9). In general, May planted lint yields (1998 =1129 to 1380, 1999 = 1737 to 2104 kg ha$^{-1}$) were greater than June (1998 = 972 to 1170 kg ha$^{-1}$, 1999 = 1431 to 1752 kg ha$^{-1}$) which were greater than July (1998 < 168 kg ha$^{-1}$, 1999 = 461 to 607 kg ha$^{-1}$) in two of three years. In a year with an extremely dry early summer (2000), the ranking of yields was changed, with June planted lint yields (1344 to 1660 kg ha$^{-1}$) > July (857 to 1315 kg ha$^{-1}$) > May (1210 to 1223 kg ha$^{-1}$).

Regression analysis of Plant Population and Lint Yield showed poor correlations, due to the interactions with Planting Dates (and Years), with $r^2 \leq 0.6$ for all combinations studied. Limited moisture availability during bloom and boll filling periods may have caused some combinations of high populations within planting dates to compete excessively for soil moisture, resulting in decreased yields. Higher population treatments with higher rainfall amounts during boll set and fill were likely able to set more bolls, resulting in higher yields. In two of three years (1998 and 2000), there was a highly significant interaction ($p \leq 0.001$) between Planting Date and Plant Population for lint yield, showing the interaction of short-term weather effects and plant populations.

Lint turnout (Tables 10, 11, and 12) ranged from 30 – 36% after ginning machine-harvested samples, with significant interactions of Planting Date and Plant Populations. However, Planting Date had the greatest magnitude of influence in each year, with Plant Populations having various effects within the main plots.

Bur and stick content was primarily affected by Planting Dates ($p \leq 0.001$) in all three years, but was also affected by Plant Populations within Planting Dates ($p \leq 0.001$) in 1998 and 2000. Again, there was no clear trend when regression analysis was applied. Bur and stick (trash) content ranged from 16.5 to 17.9% in 1998, 15 to 23.5 in 1999, and 19.0 to 24.8% in 2000 (Table 13). There was a significant ($p \leq 0.001$) effect of Planting Date in each year on bur and stick content, however, since there was no significant effect of Plant Populations or interactions with Planting Date, data were combined for analysis. No lint samples were judged as having "bark" grades, probably because burs and stick were removed from seed cotton before contact with gin saws.

Seed cotton per plant was highly variable, with CV's (Coefficient of Variation) of 51%, 38%, and 32% in 1998, 1999, and 2000, respectively. The number of total bolls per plant was also highly variable, with CV's (Coefficient of Variation) 30%, 27%, and 27% in 1998, 1999, and 2000, respectively. Although there were significant interactions between Planting Date and Plant Population for both seed cotton and total bolls per plant, the variability of this data makes it difficult to draw assumptions about the effects of Plant Population and plant-to-plant competition on boll size and weight. Although plots were hand-thinned to desired populations, slight variations in plant spacing or plant health may have caused some plants to be more competitive than others within the same plot. A much larger sample size than the 10 plants used in this study may be needed to overcome the effects of this natural variation within the stand, even with a relatively high plant population .

Lint quality was also affected by treatments, primarily Planting Date and Year, due to weather influences. Micronaire was particularly affected (Tables 14, 15, and 16), with values ranging from 28 to 56 (non-dimensional units) for various treatments over the course of the experiment. Cotton lint with values outside the base range of 35 to 49 units would be subject to discounts in the marketplace due to adverse effects on processing and yarn quality (anon., USDA-AMS, 1999). Although there were also highly significant ($p<0.0001$) differences due to Plant Population and interactions of Planting Date and Plant Population in two of three years for micronaire, they were relatively small compared to the influence of Planting Date and Year.

In 1998, micronaire for May and July planted treatments fell within the base range, while June planted cotton micronaire was low (Table 14). The reason for the low readings are not clear, but might be explained by the observations of Vories et al. (2001), who noted that stripper harvested cotton tended to have lower micronaire than spindle picked. This is likely due to the harvested seed cotton including immature bolls, typically with lower micronaire, that would have been left on the plant by spindle pickers. Spindle pickers can only harvest seed cotton from open and fluffed bolls, while finger strippers tend to harvest entire bolls, whether open or not.

In 1999, all treatments fell within the base range (anon., USDA-AMS, 1999), although there were significant differences between Planting Dates (Tables 15). In 2000 (Table 16), micronaire was within the base range for May planted, extremely high (50 to 59) for June planting, and low for July plantings (30 to 31). The reason for the high readings in June are not known, but could have been caused by shedding of immature top bolls during the dry early summer, allowing the plant resources available with late summer rains to flow to mature bolls and add additional fiber thickness. Low micronaire readings for July plantings could have been caused by lack of resources, notably warm temperatures and daylength, to complete maturity of the fibers, while the finger stripper was able to harvest these bolls, regardless of maturity.

Although there were significant differences and interactions for Planting Date and Plant Population for other fiber properties, including length, strength, and uniformity, these were generally within their respective base ranges for quality, and differences would not have affected lint price or suitability for spinning.

## CONCLUSIONS

Based on these results, it appears that producers can successfully plant UNR cotton until early June with acceptable yields, although May plantings yielded significantly higher in two out of the three years of the study. July planted cotton lint yields were too low for economical returns in two of three years, averaging only 125 kg $ha^{-1}$ in 1998 and 507 kg $ha^{-1}$ in 1999. Delaying planting of UNR cotton into June would allow producers more options for cropping systems, including allowing winter cover crops to reach more mature growth stages, cool season grazing opportunities, and for double cropping after small grain harvest. Returns from the harvest of a cool season crop before planting cotton may offset loss of revenue from reduced yields with June planted cotton in some years.

Producers should consider increasing plant populations for May plantings to between 296 000 and 395 000 plants $ha^{-1}$, while 198 000 plants $ha^{-1}$ appears to be sufficient for maximum yields of June plantings of UNR cotton. Plant populations above these levels may have excessive plant-to-plant competition under certain weather conditions, resulting in reduced yield. Acceptable lint quality was always obtained with May plantings, while June and July plantings sometimes had micronaire values that were too low or too high, and lint quality discounts would have been applied. While many other factors were studied, weather conditions affecting each Planting Date within a year had the greatest effect. Varying Plant Populations, while being statistically significant and interacting with Planting Date, had relatively less effect on the plant growth and lint quality factors studied.

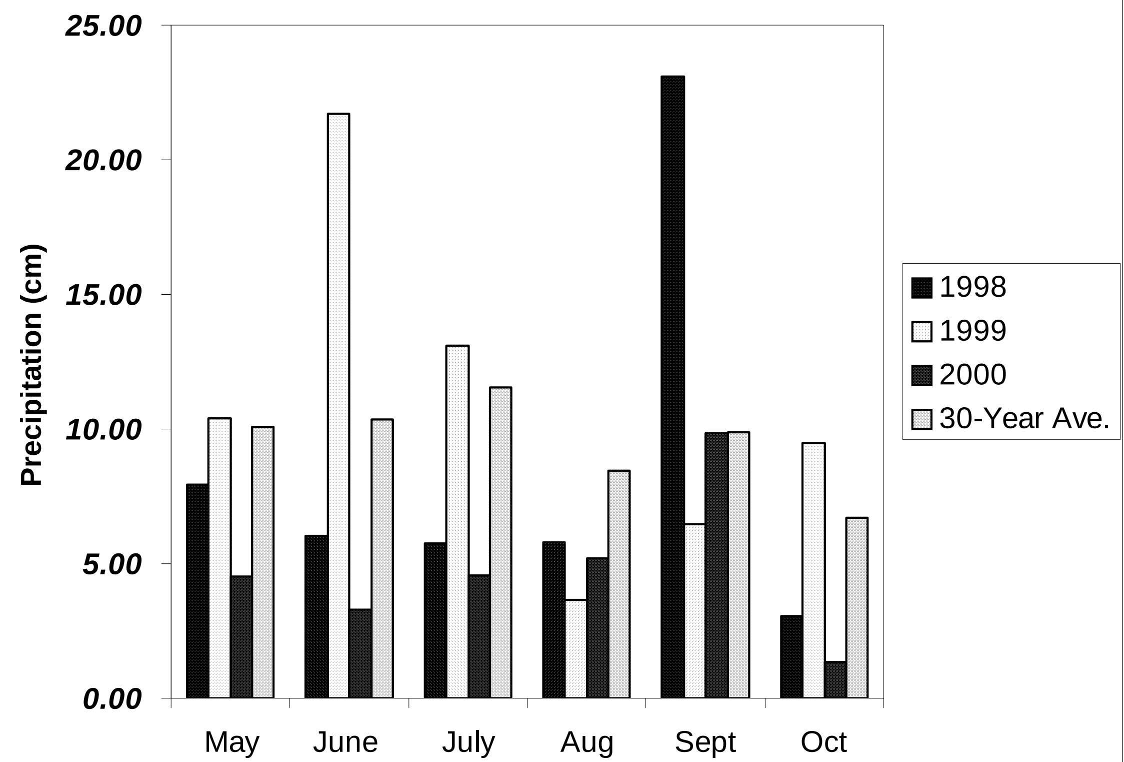

Fig. 1. Monthly Rainfall Totals at EV Smith During Cotton Growing Season, 1998 - 2000

Table 1. Leaf Area Index at Early Bloom for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1998

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | - | - | - | - |
| June | 3.32 | 3.25 | 2.96 | 2.81 |
| July | 2.40 | 2.00 | 2.45 | 2.47 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 0.38 |
| Plant Population | NS | - |
| Planting Date * Plant Population | * | 0.34 |

*, *** significant at the 0.05 and 0.001 level, respectively
NS, nonsignificant at the 0.05 level

Table 2. Leaf Area Index at Early Bloom for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1999

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 4.01 | 4.47 | 4.88 | 4.60 |
| June | 4.22 | 4.00 | 3.86 | 3.16 |
| July | 3.74 | 3.92 | 5.17 | 4.96 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | ** | 0.55 |
| Plant Population | NS | - |
| Planting Date * Plant Population | * | 0.79 |

*, ** significant at the 0.05 and 0.01level, respectively
NS, nonsignificant at the 0.05 level

Table 3. Leaf Area Index at Early Bloom for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 2000

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 2.67 | 2.34 | - | - |
| June | 3.60 | 3.59 | 3.64 | 4.26 |
| July | 2.22 | 3.42 | 4.06 | 4.16 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 0.42 |
| Plant Population | NS | - |
| Planting Date * Plant Population | *** | 0.57 |

*** significant at the 0.001 level
NS, nonsignificant at the 0.05 level

Table 4. Boll Retention Percentage at the First Position for Ultra Narrow Row Cotton Planting Dates and Populations at EVS Research Center, Shorter, AL in 1998

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 39.1 | 42.9 | - | - |
| June | 45.2 | 46.9 | 40.7 | 43.8 |
| July | 66.4 | 51.9 | 49.3 | 50.4 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 3.0 |
| Plant Population | *** | 7.7 |
| Planting Date * Plant Population | *** | 13.4 |

*** significant at the .001 level

Table 5. Boll Retention Percentage at the First Position for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1999, with Plant Populations Combined Due to Lack of Significance

| Planting Date | 1999 |
|---|---|
| May | 48.3 |
| June | 52.6 |
| July | 37.3 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 4.8 |
| Plant Population | NS | - |
| Planting Date * Plant Population | NS | - |

*** significant at the 0.001 level
NS, nonsignificant at the 0.05 level

Table 6. Boll Retention Percentage at the First Position for Ultra Narrow Row Cotton Planting Dates and Populations at EVS Research Center, Shorter, AL in 2000

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 70.6 | 58.3 | - | - |
| June | 49.3 | 47.6 | 53.9 | 51.9 |
| July | 49.7 | 53.2 | 46.4 | 50.8 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | ** | 9.4 |
| Plant Population | *** | 4.9 |
| Planting Date * Plant Population | *** | 8.5 |

**, *** significant at the 0.01 and 0.001 level, respectively

Table 7. Lint Yield in kg ha$^{-1}$ for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1998

| | Plant Population (1 000 plants ha$^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 1128 | 1380 | - | - |
| June | 1171 | 1098 | 984 | 972 |
| July | 155 | 121 | 96 | 130 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 41 |
| Plant Population | *** | 99 |
| Planting Date * Plant Population | *** | 171 |

*** significant at the 0.001 level

Table 8. Lint Yield in kg ha$^{-1}$ for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1999

| | Plant Population (1 000 plants ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 | **Mean** |
| May | 2071 | 1891 | 2104 | 1737 | **1951** |
| June | 1752 | 1708 | 1525 | 1432 | **1604** |
| July | 549 | 412 | 607 | 461 | **507** |
| **Mean** | **1457** | **1337** | **1412** | **1210** | |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 189 |
| Plant Population | *** | 118 |
| Planting Date * Plant Population | NS | - |

*** significant at the 0.001 level
NS, nonsignificant at the 0.05 level

Table 9. Lint Yield in kg $ha^{-1}$ for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 2000

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 1223 | 1210 | - | - |
| June | 1659 | 1360 | 1350 | 1340 |
| July | 856 | 1262 | 1314 | 1316 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 134 |
| Plant Population | *** | 135 |
| Planting Date * Plant Population | *** | 234 |

*** significant at the 0.001 level

Table 10. Lint Turnout as Percent of Seed Cotton for Ultra Narrow Row Cotton Planting Dates and Populations Planting Dates at EV Smith Research Center, Shorter, AL in 1998

| | Plant Population (1 000 plants $ha^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 36 | 35 | - | - |
| June | 31 | 32 | 32 | 33 |
| July[∈] | 38 | 39 | 38 | 38 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 1 |
| Plant Population | *** | 1 |
| Planting Date * Plant Population | *** | 1 |

*** significant at the 0.001 level

[∈]Hand harvested, so no trash included in total seed cotton

Table 11. Lint Turnout as Percent of Seed Cotton for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1999

| | Plant Population (1 000 plants ha$^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 34 | 35 | 35 | 34 |
| June | 30 | 29 | 31 | 31 |
| July | 31 | 29 | 31 | 31 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | * | 2 |
| Plant Population | * | 1 |
| Planting Date * Plant Population | * | 1 |

* significant at the 0.05 level

Table 12. Lint Turnout as Percent of Seed Cotton for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 2000

| | Plant Population (1 000 plants ha$^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 34 | 34 | - | - |
| June | 34 | 37 | 36 | 33 |
| July | 28 | 30 | 31 | 31 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 1 |
| Plant Population | *** | 1 |
| Planting Date * Plant Population | *** | 2 |

*** significant at the 0.001 level

Table 13. Bur and Stick (trash) Content in Percent of Seed Cotton for Ultra Narrow Row Cotton at EV Smith Research Center, Shorter, AL, with Plant Populations Combined Due to Lack of Significance

| Planting Date | 1998 | 1999 | 2000 |
|---|---|---|---|
| May | 16.5 | 15.0 | 19.0 |
| June | 17.9 | 21.8 | 20.0 |
| July | 0[∈] | 23.5 | 24.8 |
| **Statistics** | | | |
| Significance | *** | *** | *** |
| LSD($\alpha$=0.10) | 1.6 | 2.0 | 2.0 |

*** significant at the .001 level

[∈]Hand harvested, so no trash was included in total seed cotton

Table 14. Lint Micronaire (units) for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1998

| | Plant Population (1 000 plants ha$^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 43.3 | 44.5 | - | - |
| June | 28.5 | 28.0 | 28.3 | 28.3 |
| July | 41.5 | 42.5 | 43.8 | 45.5 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 6.5 |
| Plant Population | *** | 1.3 |
| Planting Date * Plant Population | *** | 2.3 |

*** significant at the 0.001 level

Table 15. Lint Micronaire (units) for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 1999, with Plant Population Treatments Combined Due to Lack of Significance

| Planting Date | 1999 |
|---|---|
| May | 42.6 |
| June | 37.6 |
| July | 37.8 |

**Statistics**

| | Significance | LSD($\alpha$=0.10) |
|---|---|---|
| Planting Date | *** | 4.4 |
| Plant Population | NS | - |
| Planting Date * Plant Population | NS | - |

*** significant at the 0.001 level
NS, nonsignificant at the 0.05 level

Table 16. Lint Micronaire (units) for Ultra Narrow Row Cotton Planting Dates and Populations at EV Smith Research Center, Shorter, AL in 2000

| | Plant Population (1 000 plants ha$^{-1}$) | | | |
|---|---|---|---|---|
| Planting Date | 198 | 296 | 395 | 494 |
| May | 42.8 | 40.5 | - | - |
| June | 49.8 | 58.0 | 58.8 | 52.8 |
| July | 30.5 | 29.8 | 30.8 | 31.3 |

**Statistics**

| | Significance | LSD(α=0.10) |
|---|---|---|
| Planting Date | *** | 1.2 |
| Plant Population | *** | 2.1 |
| Planting Date * Plant Population | *** | 3.6 |

*** significant at the 0.001 level

## DECISION METHODS FOR GROWTH REGULATORS IN ULTRA NARROW ROW COTTON

### ABSTRACT

Ultra Narrow Row cotton (*Gossypium hirsutum* L.) production systems have been shown to have the potential to increase lint yields, particularly where soil moisture or growing seasons are limited, however, harvest considerations require that it be short (< 81 cm) and relatively unbranched. Mepiquat chloride (N,N-dimethylpiperidium chloride) has been shown to reduce cotton plant height and branching, however, optimum rates and timing have not been established for the Ultra Narrow Row system. A 3-year field study was conducted near Shorter, AL on a Compass sandy loam (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) soil to investigate the effects of seven decision methods for mepiquat chloride rates and timing on cotton grown with 20-cm row spacing on plant growth and yield. Treatments included pre-planned applications of 0.0493 and 0.0984 kg a.i. $ha^{-1}$ as well as methods which adjusted for plant growth (2.5- and 5.1-cm internode,

[1]Trade and company names are used for the convenience of the reader and do not imply Auburn University or USDA-ARS endorsement over comparable products or companies.

Pix STIK[1] and Deltapine Crop Growth Regulator Guide (CGRG). Due to dry weather effects, untreated plants exceeded 81 cm in only one of three years, in that year all methods resulted in cotton short enough for efficient harvest. In one of three years, mepiquat chloride application increased yield, with 0.0246 kg a.i. $ha^{-1}$ (5.1-cm internode method) adequate in 1998. Several treatment methods increased earliness in 1999 or 2000. The 5.1-cm internode method offered the best combination of minimizing mepiquat chloride rates, while avoiding excessive plant height, yield decreases, and other negative factors.

**Abbreviations:** ALT5, average length of top five internodes; CGRG, Crop Growth Regulator Guide; DAP, days after planting; LAI, leaf area index; MC, mepiquat chloride; N, nitrogen; UNR, ultra narrow row.

## INTRODUCTION

Cotton (*Gossypium hirsutum* L.) in Central Alabama is traditionally planted in wide (91- to 102-cm) rows from mid-April to late May. Ultra Narrow Row (UNR) cotton, defined as cotton planted in 25-cm or narrower rows (Atwell, 1996), is planted at high populations which may require only three to four bolls per stalk to produce high lint yields, and may also result in a shorter production season. Earlier research (Waddle et al., 1956; Gerik et al., 1998) has shown that very narrow row spacing can increase lint yield of cotton when conditions were limiting for vegetative growth.

The closer between-row spacing and higher populations should enable cotton plants to reach a higher Leaf Area Index (LAI) or ratio of leaf surface area to soil surface area more quickly, thereby intercepting more sunlight earlier in the season than in traditional wider rows (Hietholt et al., 1993). Earlier canopy closure from a greater leaf surface area should shade the soil sooner in the growing season, lessening evaporation and weed competition. Quicker production of vegetative mass with UNR cotton may also result in avoidance of late summer drought effects, if the growing season could be shortened (Krieg, 1996).

The introduction of transgenic cotton, with traits resistant to certain lepidopteran insects (Bollguard$^R$ or “BG”) and to certain broad-spectrum herbicides (Roundup Ready$^R$ or “RR”) in the mid-1990’s in the U.S has allowed producers to solve many production problems in UNR cotton, such as weed control and boll loss to lepidopteron insects.

UNR cotton is grown at relatively high plant populations to decrease branching and facilitate machine harvesting with a finger-type stripper harvester. Because spindle picker harvesters cannot harvest cotton with row spacing of 25-cm or less, UNR cotton must be managed for the finger stripper method of harvest. If excessive plant height and branching occurs, plant bark, sticks, and other trash will be pulled into the machine along with cotton bolls and seed cotton. These contaminants are difficult to remove during processing, and can result in significant lint quality discounts for cotton producers upon sale. Most recommendations for UNR cotton call for the final plant height to be less than 81 cm to facilitate harvest with finger-type stripper harvesters and avoid excessive lint contamination (Atwell, 1996).

## Mepiquat Chloride

Mepiquat chloride (N,N-dimethylpiperidium chloride), commonly know by the patented trade name of "Pix", has been shown to reduce cotton plant height, while minimizing the deleterious effects on other aspects of plant growth, such as yield and reduced leaf area, often caused by plant growth regulators (Landivar and Searcy, 1999). The exact mechanism is still being debated since its development in 1973 and commercial introduction in 1980 (anon., BASF, 1996). However, the consensus is that it inhibits the production of gibberellins and their effects on cell wall expansion, thereby decreasing stem elongation and plant height. Theoretically, this should divert plant resources to other uses, such as boll and lint development, increase earliness and harvestable yield, and facilitate machine harvesting. Under drought or other stress conditions, however, plant height and growth can be reduced excessively with high rates of mepiquat chloride (MC) applications, and yield can be reduced (Hake et al., 1991).

The primary advantage noted for MC applications has been in reducing rank plant growth to increase machine harvest efficiency, and by increasing the number or percentage of bolls at lower fruiting branches (Munk et al., 1998; Oosterhuis, et al., 1998; and Zhao and Oosterhuis, 2001). Increased rates of early flowering have also been noted, which support the trend of increasing boll set at lower fruiting branches (Biles and Cothren, 2001), and of increasing crop maturity (Meredith, 1996).

MC can result in LAI reduction of treated leaves by 5 to 10%, and of stem dry weight by 20%, through reduction of growth of main stems and branches (Hake et al., 1991). Preventing excessive branch length and excessive vegetative mass is critical to UNR cotton production because of their interference with finger stripper harvest (Atwell, 1996).

Most recommendations for MC in UNR cotton production call for three to four applications, starting at the matchhead square (flower bud) stage. The recommended rate is normally 0.0123 to 0.0246 kg a.i. $ha^{-1}$ every 7 to 10 days, depending on cotton growth, for a total of 0.0493 to 0.0984 kg a.i. $ha^{-1}$ (Atwell, 1996), up to a maximum labeled rate of 0.1476 kg a.i. $ha^{-1}$ annually in unusual situations (Atwell, 1996; anon., BASF, 1996). Multiple applications of low rates of MC have been proposed, with in-season decisions made for application when plants are rapidly growing and not under stress, but ceasing application during drought or other stress, thereby avoiding potential negative effects (Fletcher et al., 1994).

Cotton responds differently to MC at different growth stages, with less effect observed during periods of rapid vegetative growth, and more effect during reproductive periods, when fruiting structures divert nutrients away from vegetative growth. Plant size also affects response, with dilution within a larger plant mass causing less effect (Livingston et al., 2000).

Only the top five internodes, counting down from the cotton plant's terminal, have the potential to significantly elongate and increase plant height (Landivar et al., 1996). Those internodes that are farther from the terminal growing point become woody and cease elongating. Decision recommendations and aids have been developed, including computer software (Watkins et al., 1998; and Landivar, 1998) to take advantage of this characteristic by using the length of the top five internodes to determine if application of growth regulators would be advantageous. However all published testing of these decision aids has been with wide row (91- to 102-cm spacing) cotton. These recommendations typically call for early applications of MC at the matchhead to early bloom stage, with subsequent applications to keep the top five internodes at 5.1-cm or less. However, plant growth control of UNR cotton is more critical to harvest efficiency, and it must be kept shorter than wide row cotton, so these methods may not adequately control growth.

Two methods that have been developed or adopted by private industry for use in wide row cotton also include measurements of the top five internodes, but also include other factors, such as recent plant growth and previous MC applications, and can be used in the field by cotton producers. One of these methods, the "MEPRT Stick" developed by Landivar et al. (1996), involves measuring the average length of the uppermost top five internodes (ALT5) with a calibrated ruler. Measurement of only the top five nodes, instead of the entire plant, makes this method more sensitive to recent conditions and vegetative growth. A measuring ruler device was developed that a production manager or scout can use to measure the top five nodes of the plant along one edge of the ruler. The ALT5 side is divided into color-coded sections with recommendations, such that when ALT5 is less than 3.6 cm, no mepiquat chloride is recommended and may be detrimental. When ALT5 is between 3.6 and 7.1 cm, mepiquat chloride may or may not be needed, but when ALT5 exceeds 7.1 cm, excessive stem growth is occurring and MC application will likely be advantageous. The "MEPRT Stick" method was commercially developed and printed for producer use (BASF Corporation, 1996), as the "Pix STIK™".

The "Deltapine CGRG" (Deltapine Seed Cotton Growth Regulator Guide©, Deltapine Seed, Scott, MS) takes this approach one step further, by including total plant height and number of main stem nodes of the plant in recommending MC applications. The Deltapine CGRG user finds the length of the fifth internode from the terminal using the ruler printed on it, similar to the "Pix STIK", but then adjusts for the other factors using a slide rule function to arrive at the suggested application rate.

These decision aid methods for MC application can be helpful for cotton plant growth management on wide (91-cm or greater row spacing) to optimize rates and timing. However, these methods have not been tested under the unique constraints of the UNR cotton production system, and need to be further tested. The few recommendations that have been made (Atwell, 1996; anon., BASF, 1996) have been made by private industry and not independently verified. The objectives of this study are to evaluate the use of several decision methods for MC on UNR cotton, and their effects on cotton plant growth and yield.

# MATERIALS AND METHODS

## Site Characteristics and Cover Crop Management

Experiments were conducted for three years (1998 through 2000) at the EV Smith Field Crops Unit (latitude: 32° 27' N, longitude: 85° 53' W, altitude: 65 m) of the Alabama Agricultural Experiment Station in east-central AL to investigate several decision methods for MC application in UNR cotton. The soil type was a Compass sandy loam (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults). The experimental area was subsoiled with a Paratill bent-leg subsoiler (Bingham Brothers, Lubbock, TX) to a depth of 36 to 41 cm in the fall, then drilled with a rye (*Secale cereale* L.) cover crop perpendicular to the direction of cotton rows. The Paratill uses a front-mounted coulter to cut crop residue, and a shank that is bent 45 degrees on the lower portion, with the lower foot approximately 25 cm from vertical. This configuration allows disruption of root-restricting soil layers, while minimizing surface disruption and burial of crop residue. Several studies on this soil, including Reeves and Mullins (1995) and Reeves and Touchton (1986), have shown that deep tillage below the inherent hardpan is necessary.

The rye cover crop was killed with glyphosate (N-(phosphonomethyl) glycine) at 1.12 kg a.i. $ha^{-1}$ applied to all plots in mid-April, approximately three weeks before planting, and was re-applied just prior to planting to control emerged weeds. A crimping roller was used in the planned direction of cotton planting after the initial glyphosate application, to further ensure complete kill of the cover crop, and to align long stemmed residue with cotton planting equipment for easier management. Sampling of the cover crop immediately before termination showed that dry matter production was 3800, 4940, and 2540 kg $ha^{-1}$ in 1998, 1999, and 2000, respectively.

### Cotton Crop Management

All plots were planted with a no-till drill (Great Plains, Salina, KS) using 20-cm row spacing into the killed rye cover crop in a four-replication, Randomized Complete Block design in the first week of May of each year. Plot size was 3.0 m wide * 7.6 m long. The transgenic cotton cultivar Paymaster PM 1220 BG/RR (Delta and Pine Land Co., Scott. MS) was used in 1998 & 1999, while PM 1218 BG/RR, a cultivar with similar breeding background and growth habits, was used in 2000, after production of PM 1220 BG/RR was discontinued by the company. Four hundred forty-five thousand seeds $ha^{-1}$ were planted each year. Due to poor plant emergence caused by severe early season drought, only three replications with adequate plant stands were available in 2000.

All plots were maintained weed-free and treated with insecticides and herbicides according to Alabama Cooperative Extension System (ACES) guidelines (Alabama Cooperative Extension System, 1998). Fluometuron (1, 1-dimthyl-3-(a,a,a-trifluoro-m-toyl) urea) and pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) at 1.12 kg a.i. $ha^{-1}$ were both applied preemergence to cotton immediately planting. A single application of 1.12 kg a.i. $ha^{-1}$ of glyphosate was made at the 4-leaf stage of cotton.

A total of 112 kg $ha^{-1}$ of nitrogen was applied to the cotton with 34 kg $ha^{-1}$ applied at planting. The remainder was applied after cotton emergence, but before early bloom. Ammonium nitrate (34% nitrogen) was used as the nitrogen source. Additional nutrients and lime were applied according to soil test and ACES recommendations.

## Mepiquat Chloride Treatments

Several decision methods for growth regulator management and application were selected for further study in UNR cotton. These included the "standard" recommendation (Atwell, 1996) of four applications of 0.0246 kg a.i. $ha^{-1}$ of MC every 7 to 10 days (0.0984 kg a.i. $ha^{-1}$ total), starting at the matchhead square stage. A one-half rate (0.0493 kg a.i. $ha^{-1}$ total) treatment was included as well to determine if reduced rates could be used, thereby saving production costs for producers. Four treatments were also included using plant growth or "feedback" measurements (Fletcher, 1994; Landivar, 1996). In these treatments, 0.0246 kg a.i. $ha^{-1}$ of MC was initially applied at matchhead square. At 7 to 10 day intervals, the length of the top five internodes, and total height and nodes of 10 cotton plants per plot were recorded. For the "2.5-cm" treatment, 0.0246 kg a.i. $ha^{-1}$ of MC was again applied whenever growth exceeded an average of 2.5-cm (12.7-cm total for the top five internodes); while in the "5.1-cm" treatment, 0.0246 kg a.i. $ha^{-1}$ of MC was applied whenever growth exceeded an average of 5.1-cm (25.4-cm total for the top five internodes). Also included were methods using the “Pix STIK” method, with applications rates and timing as recommended by Pix STIK; the “Deltapine CGRG method, with application rates and timing as recommended by Deltapine CGRG, and an untreated check (no mepiquat chloride applications).

These measurements were used with the assigned decision aid method/treatment to arrive at an application and rate decision, which was applied the following morning. Treatments were halted when plant height and node measurements did not change from one measurement date to the following one, indicating the end of main stem growth.

Mepiquat chloride (“Pix” 4.2% a.i. formulation, BASF Corporation, Research Triangle Park, NC) was applied with an ATV or tractor-mounted $CO_2$ sprayer. The prescribed rate of mepiquat chloride was applied in 187 L $ha^{-1}$ of spray solution, with the addition of 0.25% v/v of non-ionic surfactant (Activate Plus, Riverside/Terra Corp., Sioux City, IA) to increase rainfastness, per Pix label instructions. Plots were arranged so that sprayer wheel traffic did not enter the area to be harvested.

## Plant Growth Analysis

Leaf Area Index was measured at early and late bloom using a portable LAI-2000 Plant Canopy Analyzer (Li-Cor, Lincoln, NE) to measure canopy closure rates and shading effects. According to manufacturer’s recommendations, two reference readings were made above the canopy, immediately followed by four readings at the soil surface beneath the canopy at three locations within each plot. A 90-degree radius cap was attached to the lens to focus readings within the plot. Internal software calculated Leaf Area Index (LAI) from light interception by the canopy, and arrived at an average LAI value for the plot. Readings were made two to three hours before sunset, or with an umbrella shade, to minimize intense light reflection effects among leaves within the canopy.

Counts of open and closed bolls from two adjacent rows, each 2.4 m long, were made to determine relative differences in maturity between treatments when most plots had 50-60% open bolls, or when the majority of bolls examined had mature seed and lint.

## Harvest and Lint Quality

At maturity, all plots were defoliated according to ACES guidelines. Ten plants per plot were randomly selected for detailed plant mapping, with boll positions and absence recorded, and seedcotton weights taken from these ten plants. Height measurements were made from the cotyledonary node to the terminal of the plant. Node counts were made from the cotylendonary node (designated as node 0) to the terminal. Plant mapping data was inputted into PMAP 6.2 (Plant Map Analysis Program, Texas A&M University Research & Extension Center, Corpus Christi, TX). PMAP 6.2 was then used to calculate selected plant growth parameter means for each plot, including height, vegetative and reproductive nodes, and number and retention of bolls by position on the plant.

When all harvestable bolls had opened, plots were desiccated to facilitate harvest with paraquat (1,1'-dimethyl-4,4'-bipyridinium) at 0.45 kg a.i. $ha^{-1}$, and the center 2.1 m of each plot harvested three to seven days later with a AC 760 XTB finger-type stripper harvester (Allis-Chalmers, Milwaukee, WI) equipped with a bur and stick cleaner. Seedcotton yields were recorded, and approximately 500-gram grab samples were taken for trash, turnout and quality analysis.

Seedcotton samples were weighed, hand-cleaned, reweighed, and then ginned on a 10-saw laboratory mini-gin. Weights of cotton seed and lint were recorded to calculate cotton lint percentage (turnout). Subsamples of lint were analyzed for quality with High Volume Instrumentation (HVI) by the Auburn University Textile Engineering Department HVI Laboratory for the 1998 and 1999 crop years, and for 2000 by the USDA - Agricultural Marketing Service Birmingham, Alabama Classing Office.

Data from each plot was analyzed using was analyzed using SAS Systems for Windows V8 (SAS Institute, Inc., Cary, NC) @ $p \leq 0.10$, *a priori*.

## RESULTS AND DISCUSSION

Weather patterns, particularly rainfall, were different in each crop year, and this affected cotton crop growth and growth regulator decision methods for each year (Fig. 1). The 1998 crop year was marked by moderate rainfall in May through

August, with 5.1 to 7.6 cm per month, and over 22.9 cm in September, as the crop was maturing. The 1999 crop year had much more plentiful rainfall in early summer, with 10.2 cm or more in each of May, June, and July, each exceeding the 30-year average. However, August was much drier than normal, with less than 3.8 cm. The year 2000 was extremely hot and dry, with less than 5.1 cm of precipitation in each of the four months after planting.

## Mepiquat Chloride Applications

Application rates of mepiquat chloride ranged from 0.0246 to 0.0984 kg a.i. $ha^{-1}$ of product per season (Table 17). Lowest rates (0.0246 to 0.0370 kg a.i. $ha^{-1}$) were recommended by use of the "5.1-cm internode" method, while highest rates were recommended by the "2.5-cm internode" and "Pix STIK" methods (0.0493 to 0.0984 kg a.i. $ha^{-1}$). The recommended rates of mepiquat chloride also varied by crop year, with most methods recommending more in 1999, a relatively high rainfall year, and the least in 2000, an extremely dry year.

Since weather varied greatly from year-to-year at this location, almost all variables tested resulted in a significant ($p \leq 0.10$) interaction of Year by Treatment Methods. For ease of discussion, results from each year will be discussed separately.

## Plant Growth

Final height was unaffected by treatment method in 1998, while in 1999, all methods reduced plant height compared to the check (Table 18). In 2000, only the "0.0984 kg a.i. $ha^{-1}$" and "5.1-cm internode" methods significantly reduced plant height (7.6 cm or more) compared to the untreated check. Only in 1999 were any treatments taller than the recommended 81-cm maximum height (Atwell, 1996) for efficient harvest: the untreated check. The limited soil moisture conditions encountered in early spring of 1998 and 2000, likely combined with the plant-to-plant competition from high populations, to limit height without the application of MC. Jost and Cothren (2000) found that plant height was reduced in 19-cm rows, as compared to wider spacings, regardless of MC application. Vories et al. (2001) also noted a height reduction in UNR cotton compared to wide rows, whether or not MC had been applied, indicating that competitive effects within the UNR system may serve a role in limiting plant height, and that less MC application may be needed than previously reported (Atwell, 1996; anon., BASF, 1996).

Due to the limited branching from the relatively high plant populations with UNR cotton, there was approximately two weeks difference observed between Early Bloom (10%) and Late Bloom ("cutout" or white blooms within three nodes from the plant terminal) stages when LAI measurements were taken. This is in contrast to wide row cotton when early bloom to cutout normally takes place over a period of five to six weeks (Hake et al., 1991).

Leaf Area Index (LAI) at early bloom was not affected by growth regulators in 1998, but was significantly less at late bloom for the “Deltapine CGRG” than the “Pix STIK” treatment (2.66 vs. 3.21, respectively, LSD [0.10] = 0.42). The reason for the difference is unclear, since less growth regulator was applied to the Deltapine CGRG treatment. Mean LAI averaged for all treatments in 1998 was 2.99 at Early Bloom and 2.90 at Late Bloom.

In 1999, there was no significant difference between any of the growth regulator treatments for LAI at Early or Late Bloom. Mean LAI averaged across all treatments was 4.65 at Early Bloom, and 4.49 at Late Bloom.

In 2000, an extremely dry year, both the Untreated Check and 0.0494 kg a.i. $ha^{-1}$ treatments had a significantly higher LAI at Early Bloom (2.97) than the 0.0984 g a.i. $ha^{-1}$ and 5.1 -cm internode treatments (2.82 and 2.34, respectively, LSD [0.10] = 0.29). By Late Bloom, the Untreated Check, 2.5 cm internode, and 0.0494 kg a.i. $ha^{-1}$ and 0.0984 g a.i. $ha^{-1}$ treatments all had a higher LAI than the 5.1 cm internode and Deltapine CGRG (2.96, 3.02, and 2.97 vs. 2.34, and 2.15, respectively; LSD [0.10] = 0.57).

In all years, LAI averaged across treatments dropped slightly from Early Bloom to Late Bloom, indicating that the greatest leaf area was achieved by the initiation of reproductive growth stages. The relative lack of difference between the measurements, however, indicates that LAI measurements could be taken at either growth stage. In 1998, the Deltapine CGRG treatment had significantly more vegetative nodes than either the Pix Stick or the Untreated check (6.7 vs. 7.2 and 7.4, respectively; LSD [0.10] = 0.4). The Pix STIK application amount was higher in that year, and may have triggered earlier fruiting branch development, but the reason for more vegetative branches with the Deltapine CGRG than the check is unknown.

There were no differences between any treatments for reproductive nodes in 1998. There were no significant differences between any treatments in 1999 for total number of vegetative or reproductive nodes, although final height was reduced by all growth regulator treatments, compared to the untreated check.

In 2000, the drought year, there was a significant difference in vegetative nodes between the 5.1 cm internode method and the Pix STIK treatment (7.9 vs. 6.7, respectively; LSD [0.10] = 1.0), although both received the same amount of mepiquat chloride. There were no significant differences between any treatments in 2000 for number of reproductive nodes.

In 1998, first position boll retention was significantly increased by the 2.5-cm internode method, relative to the 0.0493 kg a.i. per $ha^{-1}$ treatment, 5.1-cm internode method and the check, with 60.3 vs. 47.8, 44.2, and 46.4% respectively (LSD[0.10] = 12.9). No differences in boll retention were recorded in 1999 or 2000.

In 1998, applications of mepiquat chloride did not increase boll opening percentages, (Table 19) as compared to the check, while in 1999, there were several significant differences. The 0.0494 kg a.i. $ha^{-1}$ treatment was the earliest opening in 1999, although not significantly different from the 0.0984 g a.i. $ha^{-1}$, 5.1-cm internode, Pix STIK, or untreated check treatments. Slowest opening was the

Deltapine CGRG with only 28% open bolls compared to 50% open bolls for the 0.0494 kg a.i. $ha^{-1}$ treatment.

In 2000 (Table 19), the only significant difference for boll opening was between the Pix STIK method (19% open) and the untreated check (37%). These results are in contrast to several other studies that have shown increased earliness with applications of mepiquat chloride (Hake et al., 1991; Munk et al., 1998; Oosterhuis, et al., 1998; and Zhao and Oosterhuis, 2001). Many of these studies noted increased rates of early flowering, which led to increased boll set at lower fruiting branches (Biles and Cothren, 2001), and of increasing crop maturity (Meredith, 1996). Since plant-to-plant competition in UNR due to the high population rates tends to limit plant size and branching, and increase earliness (Jost and Cothren (2000), the earliness effects of MC may be masked by the tendencies of the UNR system to set a higher percentage of bolls at early positions.

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## Lint Yield and Quality

In 1998, all methods except the "Deltapine CGRG" increased lint yields (Table 20) compared to the check, with yields from 822 to 1061 kg $ha^{-1}$ (LSD[0.10] = 164). In 1999, the only significant difference in yields was for the Deltapine CGRG treatment compared to the 2.5 cm internode method (1606 kg $ha^{-1}$ vs. 1878 kg $ha^{-1}$, respectively, LSD[0.10] = 230). Yields were unaffected by MC applications in 2000, likely due to early season drought stress limiting plant growth, with yields from 1236 to 1365 kg $ha^{-1}$. It is not known why the Deltapine CGRG method would have different effects on yield than other treatments also receiving MC in 1998 and 1999, since other treatments received more, equal, or lesser amounts. Several other researchers have shown little effect of MC on lint yields in wide row cotton (Landivar and Searcy, 1999; Jones et al., 2000; Oosterhuis et al., 1995; and Stewart et al., 2001).

Lint turnout was only marginally affected by treatments in 1998 (Table 21), with untreated cotton plots having a slightly higher turnout than the 0.0984 kg a.i. $ha^{-1}$ treatment (35.8 vs. 34.3%, LSD [0.10] = 1.4). In 1999 and 2000, there were no significant differences between treatments for lint turnout. These results indicate that MC application and rates has little effect on the overall turnout, or the amount of trash (data not shown) when defoliated according to ACES guidelines.

Lint quality was also marginally affected by treatments, but several significant differences were noted. Micronaire was higher for the Pix STIK (35.7 units) than for the 2.5-cm internode (31.7 units, LSD[0.10] = 0.40) method in 1998. In 1999 and 2000, there were no significant differences for micronaire between treatments.

In 1998, there were small, but significant differences for lint length and strength. The 5.1-cm internode treatment had a longer fiber length measurement than the Pix Stick (2.84 vs. 2.74 cm, LSD[0.10] = 0.09), and the Deltapine CGRG and 2.5-cm internode treatments each had slightly stronger lint than the 0.0984 kg a.i. $ha^{-1}$ MC and untreated check treatments (29.9 and 30.1 vs. 27.9 and 27.9g/tex, respectively, LSD[0.10] = 1.9). In 1999 and 2000, there were no significant differences between treatments. Most lint quality measurements, even when significantly different, were within base quality standards (anon., USDA-AMS, 1999), so that there would have been little or no difference in the lint price received by the producer.

## CONCLUSIONS

The method and rate of mepiquat chloride applications had little effect on UNR cotton yields during the three years of this study. In only one of three years did application of MC significantly increase yield, with total applications of 0.0246 kg a.i. $ha^{-1}$ (5.1-cm internode method) adequate in 1998. Height was sufficiently controlled by most combinations and decision methods, with dry summer weather and plant-to-plant competition keeping cotton plant height less than the recommended maximum height (81 cm) two of three years. Even in the year when untreated cotton plants grew above the desired height (1999), all decision methods prescribed at least 0.0493 kg a.i. $ha^{-1}$ of MC, enough to keep cotton short enough for efficient harvest. The 5.1-cm internode method offered the best combination of minimizing MC rates, while avoiding the risk of excessive plant height, yield decreases, and other negative factors.

Table 17. Total rates of Mepiquat Chloride in kg a.i. $ha^{-1}$ Applied to UNR Cotton with Different Decision Methods at EVS Smith Research Center, Shorter, AL

| Method | 1998 | 1999 | 2000 |
|---|---|---|---|
| Total of 0.0984 kg ai $ha^{-1}$ | 0.0984 | 0.0984 | 0.0984 |
| Total of 0.0493 kg ai $ha^{-1}$ | 0.0493 | 0.0493 | 0.0493 |
| 2.5 cm Internode Method | 0.0984 | 0.0984 | 0.0493 |
| 5.1 cm Internode Method | 0.0246 | 0.0493 | 0.0493 |
| Deltapine CGRG Method | 0.0740 | 0.0861 | 0.0615 |
| Pix STIK Method | 0.0861 | 0.0984 | 0.0615 |
| Untreated Check | 0 | 0 | 0 |

Table 18. Plant Heights in cm of UNR Cotton with Different Decision Methods at EVS Smith Research Center, Shorter, AL from 1998 to 2000

| Method | 1998 | 1999 | 2000 |
|---|---|---|---|
| Total of 0.0984 kg a.i. $ha^{-1}$ | 49 | 67 | 47 |
| Total of 0.0493 kg a.i. $ha^{-1}$ | 46 | 75 | 53 |
| 2.5 cm Internode Method | 47 | 66 | 50 |
| 5.1 cm Internode Method | 47 | 78 | 49 |
| Deltapine CGRG Method | 49 | 75 | 55 |
| Pix STIK Method | 44 | 63 | 51 |
| Untreated Check | 47 | 97 | 57 |
| P(F) | 0.6 | 0.0007 | 0.03 |
| LSD (α=0.10) | NS | 10.6 | 7.7 |

NS, not significant at the 0.10 level

Table 19. Boll Opening in percent at Maturity of UNR Cotton with Different Decision Methods at EVS Smith Research Center, Shorter, AL from 1998 to 2000

| Method | 1998 | 1999 | 2000 |
|---|---|---|---|
| Total of 0.0984 kg a.i. $ha^{-1}$ | 50 | 46 | 25 |
| Total of 0.0493 kg a.i. $ha^{-1}$ | 62 | 50 | 28 |
| 2.5 cm Internode Method | 59 | 32 | 31 |
| 5.1 cm Internode Method | 61 | 44 | 28 |
| Deltapine CGRG Method | 59 | 28 | 33 |
| Pix STIK Method | 52 | 41 | 19 |
| Untreated Check | 56 | 35 | 37 |
| P(F) | 0.610 | 0.029 | 0.059 |
| LSD ($\alpha$=0.10) | NS | 16.7 | 16.1 |

NS, not significant at the 0.10 level

Table 20. Lint Yields in kg $ha^{-1}$ of UNR Cotton with Different Decision Methods for Mepiquat Chloride at EVS Smith Research Center, Shorter, AL from 1998 to 2000

| Method | 1998 | 1999 | 2000 |
|---|---|---|---|
| Total of 0.0984 kg a.i. $ha^{-1}$ | 972 | 1808 | 1236 |
| Total of 0.0493 kg a.i. $ha^{-1}$ | 977 | 1749 | 1413 |
| 2.5 cm Internode Method | 983 | 1822 | 1309 |
| 5.1 cm Internode Method | 1061 | 1878 | 1325 |
| Deltapine CGRG Method | 890 | 1606 | 1278 |
| Pix STIK Method | 1052 | 1721 | 1365 |
| Untreated Check | 822 | 1762 | 1299 |
| P(F) | 0.1 | 0.054 | 0.12 |
| LSD ($\alpha$=0.10) | 164 | 230 | NS |

NS, not significant at the 0.10 level

Table 21. Lint Turnout in percent of UNR Cotton with Different Decision Methods at EVS Smith Research Center, Shorter, AL from 1998 to 2000

| Method | 1998 | 1999 | 2000 |
|---|---|---|---|
| Total of 0.0984 kg ai $ha^{-1}$ | 34 | 38 | 33 |
| Total of 0.0493 kg ai $ha^{-1}$ | 35 | 35 | 34 |
| 2.5 cm Internode Method | 35 | 36 | 34 |
| 5.1 cm Internode Method | 35 | 39 | 34 |
| Deltapine CGRG Method | 35 | 35 | 34 |
| Pix STIK Method | 35 | 35 | 33 |
| Untreated Check | 36 | 39 | 35 |
| P(F) | 0.07 | 0.32 | 0.42 |
| LSD (α=0.10) | 1.4 | NS | NS |

NS, not significant at the 0.10 level

## COVER CROPS AND TILLAGE COMBINATIONS FOR ULTRA NARROW ROW COTTON

### ABSTRACT

Cotton (*Gossypium hirsutum* L.) production in the southeast U.S. is often adversely affected by lack of soil moisture, particularly on marginal soils with low water holding capacity. Ultra Narrow Row (≤ 25-cm row spacing) cotton production systems, as well as the use of conservation tillage and high residue cover crops, are potential strategies to limit risks from short-tem droughts. A 4-year field study was conducted on a Lucy loamy sand (loamy, kaolinitic, thermic Arenic Kandiudults) near Headland, AL to evaluate combinations of legume (white lupin [*Lupinus albus* L.] + crimson clover [*Trifolium incarnatum* L.]) and rye (*Secale cereale* L.) cover crops, conventional and no-tillage techniques, and wide (91-cm) and Ultra Narrow Row (20-cm) spacings on cotton growth and yield. Ultra Narrow Row (UNR) cotton yields were higher than wide rows in 1998 (1020 vs. 668 kg ha$^{-1}$). In 1999, with a wet early spring, there were no yield differences for row spacing, although conventional tillage increased lint yields compared to no-till in legume (1063 vs. 969 kg ha$^{-1}$) and rye cover crops (1033 vs. 749 kg ha$^{-1}$). Due to an extreme drought in 2000, cotton plots were abandoned. In 2001, UNR cotton yielded 1553 kg ha$^{-1}$ vs. 1347 kg ha$^{-1}$ for wide rows, and conventional yielded higher than no-tillage (1587 vs.

1314 kg $ha^{-1}$). The 50% lint yield increase in 1998 and 15% increase in 2001 for UNR systems offer opportunities for cotton growers to adopt UNR cotton as a consistently higher yielding and lower risk system.

**Abbreviations:** DAP, days after planting; LAI, leaf area index; N, nitrogen; UNR, ultra narrow row.

[1]Trade and company names are used for the convenience of the reader and do not imply Auburn University or USDA-ARS endorsement over comparable products or companies.

## INTRODUCTION

Soils in the southeastern region of Alabama, known as the “Wiregrass” area, tend to be coarse textured and low in organic matter. These aspects result in low water holding capacity which, combined with high summer temperatures and erratic rainfall patterns, can adversely affect growth and production of non-irrigated cotton.

## Cover Crops

No-till production techniques on these soils can conserve soil moisture and help minimize effects of short-term drought. The use of cover crops with no-till techniques can further reduce soil moisture loss by evaporation, and may increase yields in years when rainfall is limited (Brown et al., 1984; Stevens et al., 1992). In addition, use of cover crops that are allowed to make optimum growth can contribute to increased soil organic matter, tilth, and other soil quality parameters, further increasing soil-moisture holding capacity and decreasing risks of dry weather effects on returns (Reeves et al., 2000). Fesha et al. (2002) reported that long-term use of conservation tillage systems with winter cover or grain crops resulted in improved soil quality, with increased water stable aggregates and soil water retention. Cropping systems that include small grain cover or grain crops can also result in rapid buildup of soil organic carbon (Reeves and Delaney, 2002). The improved soil quality and moisture retention resulting from conservation tillage systems with cover crops can lessen risk of crop losses to the short-term droughts that frequently occur on these soils.

Cotton in south Alabama is traditionally planted in wide (91-to 102-cm) rows from mid-April to late May. Cotton planted after these dates often suffers yield declines, but earlier planting limits the use of cover crops, which can enhance soil quality and moisture conservation. Ultra Narrow Row (UNR) cotton, defined as row spacing of 25.4-cm or less (Atwell, 1996), is usually planted at high populations and may require only three to four bolls per stalk to produce high lint yields. The requirement for less growth by individual plants may also result in a shorter production season, enabling later planting. Earlier research (Reeves et al., 2000) has shown that UNR cotton can be successfully planted in early June in Alabama, which could allow optimum growth of winter cover crops or harvest of a small grain crop. Several other studies in the region (Bader et al., 1999; Bader et al., 2000; Harris, et al., 1999; and Wiatrak et al., 1998) have shown increased yields with UNR cotton compared to wider rows when planting was delayed.

Rye (*Secale cereale* L.) is typically used as a winter cover crop for row crop production in the region, but the use of legumes as cover crops that can fix nitrogen for their own growth, as well as for the following summer crop may offer advantages. White lupin (*Lupinus albus* L.) (Reeves et al., 1998) and crimson clover (*Trifolium incarnatum* L.) (Brown et al. 1984), have both been used successfully as cover crops in the region. In experiments on coastal plain soils in Alabama and South Carolina, Reeves et al. (1998) compared nitrogen requirements for UNR cotton after winter fallow, black oats (*Avena strigosa* Shreb.), and white lupin (*Lupinus albus* L.) or Austrian winter pea (*Pisum sativum* L.) winter legume cover crops. Cotton yield potential was increased by the use of legume cover crops in three of four site-years. Lint yields were maximized with the winter legumes and the addition of 67 to 90 kg $ha^{-1}$ of fertilizer nitrogen (N). Ninety kg $ha^{-1}$ of N was usually required for maximum yields of cotton after black oats or fallow, but the yields that resulted were not as high as the winter legume + fertilizer N combination. Cover crop biomass production and type in this study were also related to cotton lint yield, with the highest biomass treatment (white lupin) also producing the highest cotton yield.

## Row Spacing

Krieg (1996) and Gerik et al. (1998) noted that in situations of limited soil water availability, that narrower cotton rows (UNR) in conjunction with higher plant populations, resulted in quicker fruit set, better utilization of soil moisture, and higher yields in narrower rows compared to traditional wider row spacings. Jost and Cothren (2001) also found that when cotton was grown on a clay soil in east Texas that limited plant growth, 19-cm rows achieved maturity (60% open boll) 10 days earlier than wide rows (76- and 101-cm). Lint yields were also significantly higher for narrow rows (19- and 38-cm) than wider rows. The quicker boll set of UNR cotton may enable it to avoid the effects of late-season droughts by completing vegetative growth and boll set before available soil moisture is depleted.

Trials in north and south Alabama (Belcher et al., 1999) showed a yield advantage for UNR cotton on a clay loam soil in the Tennessee Valley (north) with 909 kg $ha^{-1}$ of lint compared to 861 kg $ha^{-1}$ with wide rows. The same trial conducted on sandier soils in the Wiregrass area of south Alabama showed a much larger advantage for UNR over wide rows, with average yields of 1123 kg $ha^{-1}$ and 836 kg $ha^{-1}$ of lint, respectively, indicating an increased advantage for UNR cotton systems on soils where moisture holding capacity is more limited.

## Harvest Considerations

Wide row cotton in the southeast U.S. is typically harvested with a spindle-type picker after the cotton bolls have opened. Spindle pickers use revolving, sharpened spindles to twist seed cotton from open cotton bolls, however, currently available spindle pickers are not capable of harvesting UNR cotton with row spacing of 25-cm or less. UNR cotton must be managed for the finger-type stripper method of harvest, which combs seed cotton and entire cotton bolls from plants using angle iron fingers and a beater or brush (Tupper and Hughes, 1964).

If excessive plant height and branching occurs, plant bark, sticks, and other trash will be pulled into the machine along with cotton bolls and seed cotton. Cotton to be harvested with a "finger stripper" harvester must be clean of weeds, short, straight or relatively unbranching, and dry for efficient harvest (Atwell et al., 1996). Weeds, particularly broadleaves and vines, can interfere with harvesting, and cause machinery plugging, slow harvesting, and increased trash in harvested seed cotton (Hayes and Gwathney, 1999). The development in 1993, and subsequent commercial release, of "Roundup Ready" [R] (Monsanto Company, St. Louis, MO) cotton cultivars, genetically engineered for tolerance to over-the-top applications of glyphosate (N-(phosphonomethyl)glycine) herbicide, enables producers to consistently control weeds in cotton without the need for between-row mechanical cultivation or post-directed herbicide sprays, which are normally weed control prartices with cotton production in wide rows.

The need for finger stripper harvested cotton plants to be short and unbranched was reported by Wanjura and Brashears (1983). They reported that the percentage of sticks in seed cotton increased with plant size. These sticks can be ground up in the ginning process, and together with bark from main and lateral stems, are difficult to remove from ginned cotton before spinning. Cotton lint classified with "bark" content is heavily discounted (USDA-AMS, 1999). Supak et al. (1992) reported that plant size and conditions affected the occurrence of bark grades more than stripper harvest equipment modifications.

Cotton lint quality is a major concern for cotton producers, with selling price dependent upon quality. A study (Anthony et al., 2000) using seed cotton produced in six locations in the Midsouth and Southeast U.S., with wide and UNR systems, examined lint turnout and quality in a large-scale ginning process. Turnout averaged 34.8% for wide row cotton, while UNR cotton lint turnout was only 30.7%, due to increased trash content. Most lint quality measurements were not significantly different between wide rows and UNR, except for bark content. Fifty percent of the UNR cotton received a bark grade, as compared to none from the wide rows. Vories et al. (2001) also noted a lower micronaire with UNR than with wider rows, presumably due to the finger stripper harvesting immature bolls with lower micronaire that could not be harvested by the spindle picker.

## Tillage

It has been previously discussed that no-till production techniques on these soils can conserve soil moisture and help minimize effects of short-term drought, however no-till techniques and soil cover may not be as critical with UNR cotton production. Prior et al. (2002) noted the positive effects of no-tillage on $CO_2$ gas exchange in wide row cotton, but that there was less effect of tillage systems on UNR cotton. The reduced effect was presumably due to more early shading of the soil by the plant canopy and more plant-to-plant competition from closer spacings and higher populations. $CO_2$ gas exchange after first bloom was consistently lower in UNR cotton leaves than in wide rows, also probably due to more early leaf mass, more plant-to-plant competition, and earlier canopy closure. The quicker canopy closure in UNR cotton also noted by Krieg (1996) and Jost and Cothren (2001) and resulting shading of the soil surface may partially substitute for the surface residue in no-till systems slowing evaporation of soil moisture.

Various aspects of the UNR cotton production system have been examined by researchers in the southeast U.S., including the use of cover crops, tillage and various row spacings. However, no published studies have compared these factors in a combined experiment. The objectives of this study are to investigate plant growth and yield of cotton growth in wide and Ultra Narrow Rows with legume and rye cover crops, with and without the use of conservation tillage techniques, on a drought-prone soil in southeast Alabama.

## MATERIALS AND METHODS

### Site Characteristics

A study was conducted over four cotton cropping years (1998 through 2001) at the Wiregrass Regional Research and Extension Center (latitude: 31° 21' N, longitude: 85° 20' W, altitude: 112m) in the southern Coastal Plain of southeast AL to investigate the relative effects of cover crop types, tillage techniques, and row spacings. The soil type was a Lucy loamy sand (loamy, kaolinitic, thermic Arenic Kandiudults). The site chosen for the experiment is particularly drought-prone, with surface horizons of 46 to 91 cm of loamy sand with low water-holding capacity. This has resulted in a history (B. Gamble, personal communication, 1997) of low cotton yields of 560 kg $ha^{-1}$ or less, typical of many marginally productive fields in the area.

The experimental design chosen was a strip-split plot design with four replications. For ease of machinery operations, Cover Crops (rye vs. legume) were horizontal plots, Tillage treatments (no-till vs. conventional) were vertical plots, and Row Width (91-cm vs. 20-cm spacing) were subplots. Each subplot size was 3.6 m wide by 15.2 m long. The same area was used for the experiment in each year. Cover crops were rotated for each year of planting to minimize diseases, while Tillage and Row Width treatments remained in the same locations each year of the experiment.

## Cover Crop Management

Cover crops were planted in October or November of each year (1997 through 2000), after harvest of the preceding summer crop, when adequate soil moisture was available. Conventional disk and harrow tillage was used to prepare the fall seedbed. Rye treatments were planted with a grain drill at 101 kg $ha^{-1}$ in all years of the test. In the legume treatments, 'Lunoble' white lupin was drilled at 112 kg $ha^{-1}$ in 1997, however, it suffered substantial winterkill during the winter of 1997-98. In the fall of 1998 through 2000, 'AU Homer' white lupin replaced Lunoble and crimson clover was added to the legume cover crop treatments. After cultipacking with a corrugated roller to firm the seedbed, 'AU Robin' crimson clover was broadcast in the legume treatments at the rate of 22 kg $ha^{-1}$, and cultipacked again. Concurrent research (D. W. Reeves, personal communication, 1998) has shown this combination to be complementary, with white lupin having an upright growth habit, and crimson clover more close growing to the soil surface. All legumes were inoculated with the proper commercial peat-based inoculant (*Rhizobium sp*.) immediately before planting. All cover crops were planted perpendicular to the planned direction of cotton rows, and were cultipacked with a corrugated roller immediately after planting to ensure good seed-soil contact. Forty-five kg $ha^{-1}$ of N (nitrogen) was applied to rye cover crops of mid-February in each year to ensure adequate growth before termination. Ammonium nitrate (34% N) was used as the N source.

Two 0.25 meter$^2$ samples were taken from each main cover crop plot at anthesis to measure dry matter production and oven-dried before weighing. All cover crops were then terminated with broadcast application of glyphosate (N-(phosphonomethyl)glycine) at 2.24 kg a.i. ha$^{-1}$. Termination dates were 06 April 1998, 09 April 1999, 07 April 2000, and 09 April 2001.

**Tillage**

No-till (NT) treatment plots were rolled with a crimping roller in the planned direction of cotton planting to ensure adequate kill of the cover crops, align residue with the cotton rows, and press the residue to the soil surface for better residue handling by planting equipment. Cover crops in conventional tillage (CONV) plots were shredded by a flail mower, followed by disk harrowing, chisel plowing to a depth of 20 to 25 cm, and smoothing with a spring-tooth harrow immediately before planting cotton.

All plots were subsoiled each spring with a Paratill bent-leg parabolic subsoiler (Bingham Brothers Inc., Lubbock, TX), 36 to 41 cm deep, in the direction of cotton planting. Spacing was set to subsoil immediately under the 91 cm (Wide) rows, but was set for full width soil disruption before UNR cotton (20 cm rows). The Paratill uses a front-mounted coulter to cut crop residue, and a shank that is bent 45 degrees on the lower portion, with the lower foot approximately 25 cm from vertical. This configuration allows disruption of root-restricting soil layers, while minimizing surface disruption and burial of crop residue. Several studies on the

Coastal Plain soils of south Alabama, including Reeves and Mullins (1995) and Reeves and Touchton (1986), have shown that deep tillage below the hardpan is needed for optimum crop yields.

## Cotton Crop Management

At least one month after cover crop termination, and after rainfall had settled the seedbed, plots were planted with cotton in May. Wide row plots were planted with a JD 7100 no-till row crop planter (John Deere, Moline, IL) equipped with row cleaners to remove excessive cover crop residue from the row path that could interfere with planting depth control. UNR plots were planted with a no-till drill (Great Plains Mfg., Salina, KS) equipped with opening coulters and spiked closing wheels, using 20 cm between-row spacing

The transgenic cotton cultivar Paymaster PM 1220 BG/RR (Delta and Pine Land Co., Scott, MS) was used in 1998 & 1999, while PM 1218 BG/RR, a cultivar with similar breeding background and growth habits, was used in 2000 and 2001, after production of PM 1220 BG/RR was discontinued by the company. Cotton in wide rows (91 cm) was planted at the rate of 207 000 seeds $ha^{-1}$, while UNR cotton was planted at the rate of 449 000 seeds $ha^{-1}$.

Due to extremely dry weather in the spring of 1998 (Fig. 2), an acceptable stand of cotton was not obtained, and the test was replanted in early June. Record severe drought in the spring and early summer of 2000 resulted in extremely dry soil conditions, and cotton plots again failed to establish a satisfactory stand, thus the crop was abandoned.

All plots were maintained weed-free and treated with herbicides, insecticides and growth regulators according to Alabama Cooperative Extension System (ACES) guidelines (Alabama Cooperative Extension System, 1998). Fluometuron (1, 1-dimthyl-3-(a,a,a-trifluoro-m-toyl) urea) at 1.12 kg a.i. $ha^{-1}$ and pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine) at 0.84 kg a.i. $ha^{-1}$ were both applied preemergence immediately after planting. A single application of 1.12 kg a.i. $ha^{-1}$ of glyphosate was made at the 4-leaf stage of cotton.

A total of 112 kg $ha^{-1}$ of N was applied to the cotton, with 34 kg $ha^{-1}$ at planting, and the remainder applied after cotton emergence, but before early bloom. Ammonium nitrate (34% N) was used as the N source. Additional nutrients and lime were applied according to soil test and ACES recommendations.

Mepiquat chloride (N,N-dimethylpiperidium chloride) plant growth regulator was applied to each treatment at the matchhead square stage for UNR cotton, and the early bloom stage for Wide Rows, according to ACES guidelines. The MEPRT Stick method (Landivar et al., 1996) was used to recommend rates and timing of mepiquat chloride in order to maintain internode length of 5.1-cm or less in the five uppermost nodes.

## Plant Growth

Leaf Area Index (LAI) was measured at early and late bloom using a portable LAI-2000 Plant Canopy Analyzer (Li-Cor, Lincoln, NE) to measure canopy closure and soil shading effects.   According to manufacturer's recommendations, two reference readings were made above the canopy, immediately followed by four readings at the soil surface beneath the canopy at three locations within each plot.  A 90-degree radius cap was attached to the lens to focus readings within the plot. Internal software calculated LAI from relative light interception by the canopy, and arrived at an average LAI value for the plot.  Readings were made two to three hours before sunset, or with an umbrella shade, to minimize effects of intense light reflection among leaves within the canopy.

Counts of open and closed bolls from two adjacent rows, each 2.4 m long, were made to determine relative differences in maturity between treatments when most plots had 50-60% open bolls, or when most bolls were determined mature by examining seed and lint.

At maturity, all plots within a treatment were defoliated according to ACES guidelines.  Ten plants per plot were randomly selected for detailed plant mapping, with boll positions and absence recorded, and seed cotton weights taken from these ten plants.  Height measurements were made from the cotyledonary node to the terminal of the plant.  Node counts were made from the cotylendonary node (designated as node 0) to the terminal.  Plant mapping data was inputted into PMAP 6.2 (Plant Map Analysis Program, Texas A&M University Research & Extension Center, Corpus Christi, TX).  PMAP 6.2 was then used to calculate selected plant growth parameter means, including height, vegetative and reproductive nodes, and number and retention of bolls by position on the plant for each plot.

### Harvest and Lint Quality

When all harvestable bolls had opened, plots were machine harvested according to treatment. Plots were trimmed to 13.7 m long to minimize edge effects on cotton yield. The center two rows of each Wide Row cotton plot were harvested after boll opening with a spindle picker (International Harvester Company, Chicago, IL.). UNR cotton plots were also desiccated to facilitate harvest with paraquat (1,1'-dimethyl-4,4'-bipyridinium) at 0.45 kg a.i. $ha^{-1}$. The center 2.1 m of each UNR cotton plot was harvested three to seven days after desiccation with an AC 760 XTB finger-type stripper harvester (Allis-Chalmers, Milwaukee, WI) equipped with a bur and stick cleaner. Seed cotton yields were recorded, and approximately 500-gram grab samples were taken for trash, turnout and lint quality analysis.

Seed cotton samples were weighed and then ginned on a 10-saw laboratory mini-gin without pre-cleaning. Weights of cotton seed and lint were recorded to calculate cotton lint percentage (turnout). Subsamples of lint were analyzed for quality with High Volume Instrumentation (HVI) by the Auburn University Textile Engineering Department HVI Laboratory for the 1998 and 1999 crop years, and for 2001 by the USDA - Agricultural Marketing Service (AMS) Birmingham, Alabama Classing Office.

Data from each plot was analyzed using SAS Systems for Windows V8 (SAS Institute, Inc., Cary, NC) @ $p \leq 0.10$, *a priori*.

# RESULTS AND DISCUSSION

The 1998 cotton cropping season was marked by dry weather in early spring (Fig. 2) with only one cm of rainfall in May, necessitating replanting in June after additional rainfall was received. A hurricane with heavy rain in late September caused some boll rot, but did little other damage. In 1999, rainfall early in the season was more evenly distributed, with 9.5 or more cm in May, June and July. The spring of 2000 was extremely dry, with only 0.3 cm received in May, and no appreciable rain received until mid-June, causing abandonment of the cotton crop. In 2001, rainfall was moderate in May, but over 25 cm was received in June, causing vigorous growth of cotton in all plots, and exceptionally high cotton lint yields (1203 to 1417 kg per $ha^{-1}$) for this usually marginally productive site. No irrigation was applied in any year.

Bronze Wilt Syndrome was observed in cotton in August of 1998 and 1999, with the stunting and death of some cotton plants after blooming, however there was no treatment effect observed. After the cultivar was changed for the 2000 and 2001 crop years, no further losses due to Bronze Wilt were observed.

Due to varying weather conditions for each year, there were statistically significant interactions ($p \leq 0.10$) between treatments and years for almost all measurements recorded and analyzed. Because these treatment * year interactions resulted in complex statistical interactions of Cover Crop, Tillage, Row Spacing and Year, treatments within each year will be discussed separately.

## Cover Crops

Cover crop dry matter yields varied by year, due to weather effects. Like most variables measured, there was a significant interaction (P[F] = 0.029) of year with cover crop dry matter yields. In 1999, rye yielded more dry matter than legumes (4415 vs. 3395 kg $ha^{-1}$, LSD [0.10] = 973). In 2000, rye again yielded numerically higher dry matter (9440 vs. 5400 kg $ha^{-1}$) although this difference was not significant, due to a large amount of variation in sample weights (CV = 43). There was a much larger difference between rye and legume dry matter weights (10 605 vs. 3495 kg $ha^{-1}$, LSD [0.10] = 3358) in 2001. The relatively small size (two 0.25 $meter^2$ per cover crop plot) of the samples taken probably contributed to the variation that masked large numerical differences in dry matter yields in 2000. Sample dry matter weights from 1998, as well as N content from all years, are not available. The application of N fertilizer to the rye cover crop likely contributed to the high dry matter yields measured in 2000 and 2001.

## Cotton Plant Growth

Plant population counts showed that UNR had a higher population in 1998 than Wide Row (366 000 vs. 94 000 plants $ha^{-1}$, LSD [0.10] = 54 000). In 1999, there was an interaction between Tillage and Row Width, with populations of 91 000 plants $ha^{-1}$ for both CONV Wide Rows and NT Wide Rows vs. 343 000 plants $ha^{-1}$ for CONV UNR, and 242 000 plants $ha^{-1}$ for NT UNR treatments (LSD [0.10] = 52

000 for comparisons within Tillage systems). This lower stand count with NT UNR treatments indicated a problem with placing seed accurately through heavy cover crops with the no-till drill.

In 2001, there was a significant interaction of Cover and Tillage effects (P[F] = 0.070), as well as a significant Row Spacing effect (P[F] < 0.001). UNR cotton had significantly higher plant populations in all combinations of Cover and Tillage, with the exception of NT into rye (Table 22). Lower plant populations with this treatment indicated the difficulty of placing cotton seed into the heavy (10 605 kg $ha^{-1}$) residue with the no-till drill without row cleaners, while the wide row planter equipped with row cleaners could more accurately place seed. The sandy soil was relatively loose after spring subsoiling, even with settling rains, and coulters often tended to pinch cover crop residue into the seed furrow without cutting.

LAI measurements showed a significant interaction of Row Width * Cover * Tillage in 1998, with UNR consistently having a higher LAI than Wide Rows at early bloom (Table 23). In 1999, there was a significant Tillage * Row Width interaction, again with UNR having a higher LAI at this early growth stage. CONV Wide Rows had an LAI of 1.9 while NT Wide Rows had an LAI of 1.2 (LSD [0.05] = 0.5). CONV/UNR had a LAI of 4.9, while NT/UNR had a LAI of 2.4 (LSD [0.05] = 0.5). LAI measurements in 2001 again had a significant interaction of Row Width * Cover * Tillage. Most UNR treatments again had a higher LAI reading at early bloom than did Wide Rows, with the exception of conventional tillage after a legume cover crop (Table 24). A higher LAI measurement at early bloom indicated that UNR cotton typically had a denser leaf canopy shading the soil surface, and that a higher percentage of available sunlight was being intercepted and available for plant growth at this early stage. LAI readings at Late Bloom followed similar trends and are not reported here.

The number of vegetative nodes was unchanged by any factor or combination in any year, averaging 6.8 in 1998, 6.5 in 1999, and 7.0 in 2001. Number of reproductive nodes was not changed by treatment in 1998, while they were statistically greater with Wide Rows than UNR in 1999 and 2001, with 13.2 vs. 11.0, and 16.6 vs. 13.8, respectively. The higher plant population with UNR as compared to Wide Rows would have caused more plant-to-plant competition for resources, and slowed late season (reproductive) vertical stem growth. Similar decreases in growth with UNR were noted by Jost and Cothren (2001) and Krieg (1996).

The percentage of total bolls that were set at the first position was not significantly changed by treatment in 1998; while in 1999, UNR cotton had significantly more (91%) of the bolls at the first position, compared to 82% with Wide Rows. The same effect was observed in 2001, when 88% of UNR bolls were first position, significantly more than the 70% for Wide Rows. In both years, no other factors caused a significant change in boll positions. These differences are in agreement with findings by Gerik et al. (1998), who noted that the percentage of first position bolls was 79% in 19-cm rows, as compared to only 69% in wider rows. This indicates a quicker boll set for the UNR system, which could help avoid some of the effects of late season droughts common on these sandy soils in south Alabama.

Boll opening counts to measure relative maturity showed that UNR treatments were typically one week earlier (data not shown) than corresponding Wide Row treatments within Tillage and Cover Crops, with interactions with years. However, any gain in boll opening rates was negated by the need for a desiccation step before UNR finger stripper harvesting, leading to harvest-readiness at the same time for UNR and Wide Row treatments.

Plant height for UNR cotton was always less than 60 cm, well under the 81-cm maximum recommended by Atwell (1996) for efficient harvesting with finger-type stripper. Wide row cotton was always less than 72 cm in height, which also allowed efficient harvest with the spindle picker used.

### Lint Yield and Quality

Lint Yield measurements showed that UNR cotton systems yielded higher (1020 vs. 668 kg $ha^{-1}$, LSD [0.10] = 56) than Wide Row in 1998, with no interactions with other factors. The higher early bloom LAI, combined with delayed (re)planting, may have contributed to the over 50% increase in yield with UNR systems when the growing season was limited.

In 1999, there was a significant Tillage * Cover interaction for lint yield, but no differences attributable to a Row Width effect. CONV plots after legumes yielded 1063 kg $ha^{-1}$ compared to 969 kg $ha^{-1}$ (LSD [0.10] = 55) for NT after legumes. We theorize that early season leaching of soil N from a wet spring season, and slow breakdown of cover crops in a dry late season may have caused N deficiency in NT rye plots, resulting in higher yields for CONV vs. NT (1033 vs. 749 kg $ha^{-1}$ , LSD [0.10] = 55). Slower breakdown and availability of legume N under NT, due to lack of soil incorporation and a dry late season, may have also contributed to the lower yield and to the lower LAI measurements (previously discussed) in those treatments.

In 2001, there were only main factor effects for lint yield, without significant interactions. UNR yielded higher than Wide Rows (1553 vs. 1347 kg $ha^{-1}$, LSD [0.10] = 77), and CONV yielded more than NT (1587 vs. 1314 kg $ha^{-1}$, LSD [0.10] = 167), averaged across Cover Crops. The abundant rainfall in June and poorer stands for NT, particularly following a rye cover crop, may have combined to negate the advantages from soil moisture conservation with NT that are usually seen on this drought-prone site.

Lint turnout was higher for Wide Rows than UNR in each year with Wide Row turnout of 39 vs. 31%, 42 vs. 36%, and 41 vs. 32% in 1998, 1999, and 2001, respectively. This effect was highly significant in each year ($p \leq 0.001$). This was expected since the finger stripper used in the UNR plots often harvests entire bolls, including burs. Even with the bur and stick cleaner on-board the finger stripper, more trash remains in the seed cotton going to the gin, raising costs for the ginner and increases the likelihood of trash remaining in lint after cleaning (Anthony, et al., 2000; Atwell et al., 1996).

Three of sixteen UNR samples (19%) in 2001 had bark grades assigned to them by the classing office, significantly more ($p<0.05$) than the one of sixteen (6%)

bark grade for Wide Row in that year. One UNR sample in 1998 had a bark grade, while no other samples were graded with bark. Due to the limited number of samples, no other statistically significant differences were noted with regard to Cover Crops or Tillage factors in any year. Anthony et al. (2000) had also noted increased levels of bark in UNR cotton, with 50% of UNR samples grading with bark vs. none for Wide Rows.

Micronaire was significantly higher in 1998 for Wide Rows vs. UNR (43.8 and 39.7 respectively). The same trend was observed in 1999 and 2001, with Wide Row treatments having a significantly higher reading than UNR plots in 1999 (47.9 and 42.9, respectively), and 2001 (45.0 and 39.5, respectively). These findings are in agreement with the findings of Vories et al. (2001), who speculated that the lower micronaire they found in UNR cotton may be due to harvest of immature bolls by the finger stripper that a spindle picker would miss on Wide Rows. The differences observed in this trial, however, are of little practical importance to cotton producers since all values were within the base quality range for micronaire (anon., USDA-AMS, 1999), and would not be subjected to price differentials.

Other cotton lint quality parameters, including length, strength, and uniformity were significantly affected in various years by the different factors or their interactions, but the differences were so small to be of little practical importance. All mean values of these other lint quality measurements fell within the base quality ranges established by USDA-AMS.

# CONCLUSIONS

It appears that UNR cotton, with closer between-row spacing and higher plant populations, took advantage of higher early season intercepted sunlight (LAI) to yield over 50% more than Wide Row cotton in a year (1998) with delayed planting and a dry early summer. In a year with a relatively wet early spring and dry late summer (1999), Wide Row cotton plant growth was not limited by available soil moisture and continued vegetative growth through late bloom to produce yield equal to UNR systems. In the third year (2001) with limited early season rainfall, UNR yielded 15% more lint than Wide Row systems.

Tillage treatments did not affect cotton yields in 1998, while conventional tillage increased cotton yields in 1999, particularly with a rye cover crop. The increase in yields with conventional tillage was likely due to better stands and the difficulty in accurate seed placement in heavy crop residue. Conventional tillage also increased yields in 2001 relative to no-tillage, again due primarily to the difficulties of seed placement in high-residue cover crops.

Cover crops had little effect on lint yields or other parameters measured with the exception of plant populations. Only in 1999, with no-till, was there a significant increase in yield gained by use of a legume cover crop, compared to the rye cover traditionally used in the area. However, lint yields were also not decreased by the use of legumes, so that cotton producers could use whichever system that the economics of seed costs and purchased N inputs favored.

Since lint quality was little affected by the UNR system, with the exception of an increase in bark grades in one year, and lint yields were increased by 50% in one year and 15% in another, it appears that cotton producers should closely examine the UNR system for use on drought prone soils. The consistency of increased or at least lint yields for the UNR system observed in each year, could lower the risk potential for cotton producers in southeast Alabama if they chose to adopt the system.

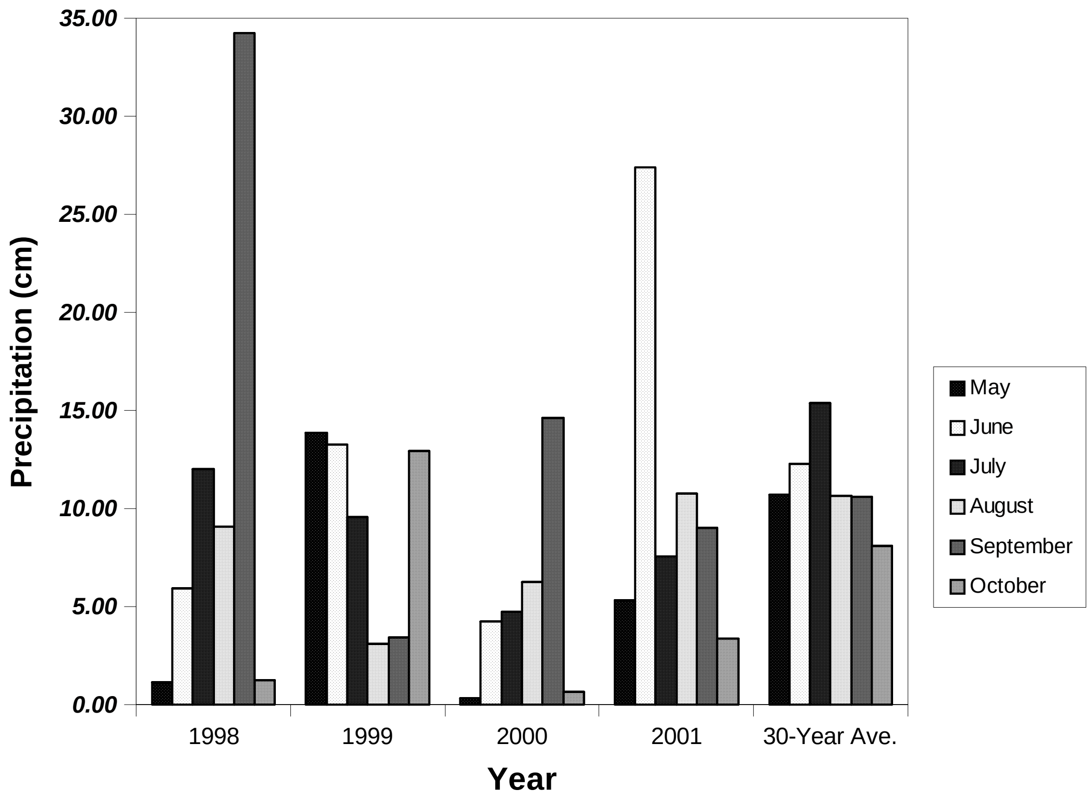


**Fig. 2.** Monthly Rainfall Totals at Wiregrass RREC During Cotton Growing Season, 1998 - 2001

Table 22. Plant Populations for Cover Crops and Tillage Combinations for Wide and Ultra Narrow Row Cotton at Wiregrass RREC in 2001, in 1000 plants $ha^{-1}$

| Treatment combination | Wide | UNR | LSD(0.10) |
|---|---|---|---|
| Legume/Conventional | 77 | 326 | 116 |
| Rye Conventional | 82 | 454 | 116 |
| Legume/No-till | 69 | 277 | 116 |
| Rye/No-till | 136 | 210 | 116 |

Table 23. Leaf Area Index (LAI) at Early Bloom for Cover Crops and Tillage Combinations for Wide and Ultra Narrow Row Cotton at Wiregrass RREC in 1998

| Treatment combination | Wide | UNR | LSD(0.10) |
|---|---|---|---|
| Legume/Conventional | 1.7 | 2.2 | 1.1 |
| Rye Conventional | 1.1 | 2.9 | 1.1 |
| Legume/No-till | 1.0 | 3.3 | 1.1 |
| Rye/No-till | 1.2 | 2.5 | 1.1 |

Table 24. Leaf Area Index (LAI) at Early Bloom for Cover Crops and Tillage Combinations for Wide and Ultra Narrow Row Cotton at Wiregrass RREC in 2001

| Treatment combination | Wide | UNR | LSD(0.10) |
|---|---|---|---|
| Legume/Conventional | 1.67 | 1.44 | 0.09 |
| Rye/Conventional | 1.14 | 1.57 | 0.09 |
| Legume/No-till | 0.85 | 1.29 | 0.09 |
| Rye/No-till | 0.82 | 1.10 | 0.09 |

## CONCLUSIONS

The results of these studies confirm that Ultra Narrow Row (UNR) cotton can be successfully managed in the southeast United States. Consistently high yields were noted in almost all trials and combinations, with more stability than normally encountered with traditional wide row cotton production, although side-by-side comparisons were not always available. These studies also show that many techniques proven for use for wide row cotton, such as use of no-till techniques, cover crops, and growth regulators can be successfully adapted for use with UNR cotton production systems.

Based on results from the Planting Date and Plant Population experiments, it appears that producers can successfully plant UNR cotton until early June with acceptable yields, although May plantings yielded significantly higher in two of the three years of the study. July planted cotton lint yields were too low for economical returns in two of three years, averaging only 125 kg $ha^{-1}$ in 1998 and 507 kg $ha^{-1}$ in 1999. Delaying planting of UNR cotton into June would allow producers more options for cropping systems, including allowing winter cover crops to reach more mature growth stages, cool season grazing opportunities, and for double cropping after small grain harvest. Returns from the harvest of a cool season crop before planting cotton could offset loss of revenue from reduced yields with June planted cotton in some years.

Producers should consider increasing plant populations for May plantings to between 296 000 and 395 000 plants $ha^{-1}$, while 198 000 plants $ha^{-1}$ appears to be sufficient for maximum yields of June plantings of UNR cotton. This compares to recommended plant populations for wide row cotton of 86 500 to 123 500 plants $ha^{-1}$ (Monks et al., 1997). Plant populations above these levels may have excessive plant-to-plant competition under certain weather conditions that can reduce yield. Acceptable lint quality was always obtained with May plantings, while June and July plantings sometimes had micronaire values that were too low or too high, and the lint price would have been discounted. While many other factors were studied, weather conditions affecting each Planting Date within a year had the greatest effect. Varying Plant Populations, while being statistically significant and interacting with Planting Dates, had relatively less effect on plant growth and lint quality factors studied.

The Growth Regulator Methods experiments showed that the method and rate of mepiquat chloride applications had surprisingly little effect on UNR cotton yields. However, in one of three years, application of mepiquat chloride did significantly increase yield. Height was sufficiently controlled by most combinations and decision methods, with dry summer weather and plant-to-plant competition keeping cotton plant height less than the recommended maximum height in most situations. Even in the year when untreated cotton plants grew above the desired height (1999), all decision methods tested kept cotton short enough for efficient harvest. All methods prescribed at least 0.0493 kg a.i. $ha^{-1}$ of mepiquat chloride in that year. The 5.1 cm internode method offered the best combination of minimizing mepiquat chloride rates and costs, while avoiding the risk of excessive plant height, yield decreases, and other negative factors. The choice of a plant-growth responsive method such as this one can save cotton producers a significant cost, while preventing unnecessary sprays in the crop environment.

Conclusions from the Cover Crops and Tillage experiments on a very drought prone soil, marginal for cotton production, showed great promise for increasing productivity on these soils. It appears that UNR cotton, with closer between-row spacing and higher plant populations, took advantage of higher early season intercepted sunlight (LAI) to yield over 50% more than Wide Row cotton in a year (1998) with delayed planting and a dry early summer. In a year with a relatively wet early spring and dry late summer (1999), Wide Row cotton plant growth was not limited by available soil moisture and continued vegetative growth through late bloom to produce yields equal to UNR systems. In the third year (2001) with limited early season rainfall, UNR yielded 15% more lint than Wide Row systems.

Tillage did not affect cotton yields in 1998, while conventional tillage increased cotton yields in 1999, particularly with a rye cover crop. The increase in yields with conventional tillage was likely due to better stands and the difficulty in accurate seed placement in heavy crop residue. Conventional tillage also increased yields in 2001, again due primarily to the difficulties of seed placement.

Cover crops had little effects on lint yields or other parameters measured with the exception of plant populations. Only in 1999 with no-till was there a significant increase in yield gained by the legume cover crop, compared to the rye cover traditionally used in the area. However, lint yields were also not decreased by the use of legumes, so that cotton producers could use whichever system that the economics of seed costs and purchased nitrogen inputs favored.

Since lint quality was little affected by the UNR system, with the exception of some bark grades in one year, and lint yields were increased by 50% in one year and 15% in another, it appears that cotton producers should closely examine the UNR system for use on drought prone soils. The consistency of yield increases for the UNR system, with no yield decreases observed, could lower the risk potential for cotton production in southeast Alabama if they chose to adopt the system.

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