The *Journal of Cotton Science 9:189–198 (2005)*
http://journal.cotton.org, © The Cotton Foundation 2005

AGRONOMY AND SOILS

Effects of Different Seeding Rates and Plant Growth Regulators on Early-planted Cotton

W.T. Pettigrew* and J.T. Johnson

ABSTRACT

Although the early-planted cotton production system offers the potential of improved lint yield, production techniques need to be optimized to ensure consistent yield enhancement. The objectives of this study were to determine how different seeding rates and application rates of mepiquat-type plant growth regulator compounds (PGR) affected cotton growth and production under early planting conditions. A field study was conducted under early planting conditions from 2001 through 2004 using four cotton cultivars (PM 1218BR, STV 4691B, STV 4892BR, and DPL 555BR) and four seeding rates (7, 9, 11, and 13 plants m^{-2}). Depending on the year, half the plots were treated with either mepiquat chloride or mepiquat pentaborate (plus PGR), while the remaining plots were untreated (no PGR). Dry matter partitioning, canopy light interception, bloom counts, lint yield, yield components, and fiber quality data were collected throughout the experiment. When PGR was not applied, leaf area index (LAI) increased as the seeding rate increased, but the LAI plateaued at 11 plants m^{-2} when a PGR was applied. When a PGR was applied to the crop, plant height was reduced 9% and specific leaf weight was increased 4%. Plants treated with a PGR produced more flowers early in the season, and the untreated control plants produced more blooms later in the season. The potential for earlier maturity of plants treated with a PGR was also reflected in the reduced nodes above white bloom (NAWB) data relative to the control plants. No yield response was observed from PGR application, but the lowest seeding rate (7 plants m^{-2}) had 5% lower yield than any of the other seeding rates. Few fiber quality differences were detected among PGR application rates or seeding rates. The longer growing season associated with the early planting system allowed late season flowers on the control plants to develop into mature open bolls and resulted in equivalent yields between the control and plants treated with a PGR.

Since the introduction of transgenic crops, producers have had to deal with the additional input costs associated with technology fees. Fees for each transgenic trait are generally assessed on a cost per seed basis, which allows producers a measure of control over their expenses for the use of a transgenic trait. Reducing seeding rates, as a means to minimize this technology fee, while still taking advantage of the transgenic trait and potentially maximizing profit margins, is a temptation for many cotton producers.

Numerous plant population density studies have been conducted in cotton to determine the optimal plant densities for maximum yield (Buxton et al., 1977; Smith et al., 1979; Mohamad et al.,1982; Kerby et al., 1990a,b; Jadhao et al., 1993; Sawan et al., 1993; Bednarz et al., 2005). Optimal plant densities across multiple row widths ranged from 5 plants m^{-2} for normal-leaf cultivars to 10-15 plants m^{-2} for okra-leaf cultivars (Heitholt, 1994). Final population densities in a production field are dependent on the seeding rate, germination, emergence, and survival of the planted seed. For producers hoping to reduce the technology fee expense, the challenge is to optimize seeding rates with the germination rate of the given seed lot and the anticipated environmental conditions during planting and emergence (temperature; moisture; fungicide and insecticide applications; seedling disease, and insect pressure) that affect plant survival to achieve final population densities near the lower end of the optimum plant population range. Properly performed, this scenario would allow producers to minimize technology fee assessments without overly compromising yield potential. The use of the new higher yield potential early-planted cotton production system (Pettigrew, 2002) complicates this seeding rate decision, because obtaining an adequate stand is a key to the success of the system,

W.T. Pettigrew and J. T. Johnson, USDA-ARS, Crop Genetics and Production Research Unit, P.O. Box 345, Stoneville, MS 38776
*Corresponding author email: bpettigrew@ars.usda.gov

and early planted seed is placed in a potentially more stressful planting environment.

Another input decision for producers is whether to apply plant growth regulator compounds to the crop. The use of mepiquat chloride and the related compound mepiquat pentaborate to control excessive vegetative growth in cotton has become almost ubiquitous across the U.S. Cotton Belt, but the perceived benefits may not justify the expense of this input. While a reduction in plant height is a relatively consistent response to the mepiquat compounds, the yield response is inconsistent at best (York, 1983a,b; Kerby, 1985; Cathey and Meredith, 1988; Cook and Kennedy, 2000; Biles and Cothren, 2001). Cathey and Meredith (1988) reported that mepiquat chloride produced an increase in lint yield for late-planted (mid-May) cotton but caused a yield decrease in early-planted (mid-April) cotton. It was concluded that environmental conditions favoring excessive vegetative growth, such as late planting, would most likely provide a positive yield response to mepiquat chloride. The cooler temperature-induced reductions in early season growth observed with earlier planted (April 1) untreated cotton (Pettigrew, 2002) raises questions about the need for and response to these mepiquat compounds on early-planted cotton plants.

Increasing plant populations that would tend to promote excessive vegetative growth led to a greater response in lint yield to mepiquat chloride (York, 1983b). Much of the yield increase was attributed to the earlier maturity of the plants treated with mepiquat chloride rather than to control of vegetative growth. None of the previous mepiquat chloride or plant density studies were conducted under the very early-planted conditions used with the cotton early planting production system (Pettigrew, 2002). Because of this, there is uncertainty about the response of early-planted cotton to mepiquat chloride-type compounds and different seeding rates. In addition, the optimal seeding rate for early-planted cotton, which will allow the producer to minimize technology fee, remains uncertain. The objectives of this study were to determine how early-planted cotton responds to different levels of mepiquat compounds and to different seeding rates.

MATERIALS AND METHODS

Field studies were conducted on a Dubbs silt loam soil (fine-silty, mixed, active, thermic Typic Hapludalfs) near Stoneville, MS during 2001 through 2004, to determine the effects of mepiquat-type growth regulators and different seeding rates on early-planted cotton. Mepiquat chloride (Pix; BASF Corp.; Research Triangle Park, NC) was applied at 49 g a.i. ha^{-1} (plus PGR) or not applied (no PGR) in 2001 through 2003. In 2004, mepiquat pentaborate (Pentia; BASF Corp.) was substituted for mepiquat chloride and was applied at 115 g a.i. ha^{-1} (plus PGR) or not applied (no PGR). Each year, half of the plus PGR treatment was applied in early June during the squaring stage, with the remaining half applied 2 to 3 wk later when the plants were in early bloom. Two cotton genotypes were grown each year. In 2001 and 2002, Stoneville 4691B (STV 4691B; Stoneville Pedigreed Seed; Memphis, TN) and Paymaster 1218 BR (PM 1218BR; Delta Pine and Land Co.; Scott, MS) were grown. Deltapine 555BR (DPL 555BR; Delta Pine and Land Co.) was grown instead of PM 1218BR in 2003 and 2004. Although STV 4691B was still grown in 2003, Stoneville 4892BR (STV 4892BR; Stoneville Pedigreed Seed) was substituted for STV 4691B in 2004.

Four seeding rates were used in this study. The goal of the seeding rates was to achieve final plant densities of 7 plants m^{-2}, 9 plants m^{-2}, 11 plants m^{-2}, and 13 plants m^{-2}. Seeding rates were adjusted to achieve the desired final population densities by assuming survival of 75% of the planted seeds under the conditions encountered with early planting.

The size of the individual experimental plots was 4 rows spaced 1.02 m apart and 18.3 m in length. Plots were planted on 2 April in 2001, 4 April in 2002, 31 March in 2003, and 31 March in 2004. The experimental design was a randomized complete block with a split plot arrangement of treatments and six replications. Main plots consisted of the different rates of the plant growth regulators and subplots were the cotton genotypes and seeding rates. The subplots were arranged as a factorial.

Dry matter harvests were taken between 116 and 119 d after planting (DAP) in 2002; from 84 thru 86 DAP in 2003, and from 82 thru 85 DAP in 2004. The early harvest dates in 2003 and 2004 occurred approximately during the early blooming period, while the later harvest date in 2002 approximately corresponded to a cut-out harvest date. Cut-out refers to a period of slowing vegetative growth and flowering due to a strong demand for assimilates by the existing boll load. On each harvest date, the above ground portions of plants from 0.3 m of row were harvested from one of the outside rows of each plot and separated into leaves, stems and petioles, squares, and blooms and bolls. Leaves were passed through a LI-3100 leaf area meter (LI-COR, Lincoln, NE[1]) to determine leaf area index (LAI), and main-stem nodes were counted. Samples were dried for at least 48 h at 60 °C, and dry weights were recorded.

In addition to the LAI determined by the destructive dry matter partitioning harvests, LAI was also quantified by use of the LAI-2000 plant canopy analyzer (LI-COR; Lincoln, NE) between 109 and 113 DAP in 2002, 105 and 109 DAP in 2003, and 103 and 107 DAP in 2004. All readings were taken between 0800 h to 1000 h (8:00 am and 10:00 am, CDT) using a 45° view cap. Due to the heterogeneous nature of some of the plot canopies, a minimum of 4 above-canopy readings and 16 below-canopy readings were taken per plot. Four transects were made with the orientation of the field of view changing between perpendicular and parallel to the row direction on alternate transects. During all readings, the sensor was shielded from direct sunlight using a 1.75-m diameter patio umbrella (Hicks and Lascano, 1995).

The number of white blooms (blooms at anthesis) per subplot was counted on a weekly basis to document the blooming rate throughout the growing season. These counts were taken on 6.1 m of row from one of the inner subplot rows and were initiated at first bloom and continued until production of blooms had virtually ceased. The number of main-stem nodes above a sympodial branch that had a white bloom at the first branch fruiting position (NAWB) was also counted weekly on three plants per plot to document the progression of reproductive development up the stem, as well as crop maturity. Bloom counts and NAWB data were collected every year of the study.

The percentage of photosynthetic photon flux density (PPFD) intercepted by the canopies of both experiments was determined with a LI 190SB point quantum sensor (LI-COR; Lincoln, NE) positioned above the canopy and a 1-m-long LI 191SB line quantum sensor placed on the ground perpendicular to and centered on the row. Two measurements were taken per plot with the average of those two measurements used for statistical analysis. All measurements were taken between 1230 h and 1430 h (12:30 pm and 2:30 pm, CDT) with all above canopy reading $\geq 1700\ \mu mol\ m^{-2}\ s^{-1}$. These PPFD interception data were collected on 71 and 98 d after planting (DAP) in 2001, 74 and 105 DAP in 2002, 85 and 106 DAP in 2003, and 103 DAP in 2004.

Cotton was defoliated using a mixture of tribufos and ethephon during early-to-mid September each year. Approximately 2 wk after defoliation, the two center rows of each subplot were harvested with a spindle picker and weighed. After defoliation, but prior to mechanical harvest, a 50-boll sample was collected from each subplot for use in determination of yield components. Boll mass was determined from these 50-boll samples by dividing the weight of seed cotton by the number of bolls harvested. These samples were then ginned and weighed to calculate lint percentage, which was used to calculate lint yield from the mechanically-harvested seed cotton. The number of bolls produced per unit ground area was calculated from the boll mass and total seed cotton weights per subplot. Average seed mass was determined from 100 non-delinted seeds per sample and reported as weight per individual seed. Lint samples from each subplot were sent to Starlab Inc. (Knoxville, TN) for fiber quality determinations. Fiber strength (T1) was determined with a stelometer. Span lengths were measured with a digital fibrograph. Fiber maturity, wall thickness, and perimeter were calculated from arealometer measurements.

Statistical analyses were performed using the PROC MIXED program of SAS (SAS Institute; Cary, NC). For traits in which there was a significant interaction between year and PGR rates or seeding rates, the results are presented by year. When PGR rate or seeding rate effects were consistent across years, then the PGR or seeding rate means were averaged across years, and the interactions between year and PGR rate or seeding rate were considered a random source of error. When the interactions were not significant, PGR rate and seeding rates were averaged across cotton genotypes. The use of different genotypes during different years of the study prevented averaging genotype means across years. Means were separated by a protected LSD at $P \leq 0.05$.

RESULTS AND DISCUSSION

Different climatic conditions following planting resulted in different final plant population densities for each year (Table 1). The desired survival of 75% of the planted seed in this early planting scenario was achieved only in 2001. Lower population densities were attained in 2002 through 2004, which indicated that the assumed survival percentage (75%) was too high, and that higher seeding rates would have been more appropriate to achieve the population density goals during those years.

Table 1. Actual cotton plant population density for each of the desired seeding rates for 2001 through 2004

Seeding rate[y]	Plant Population (plant m^{-2})[z]			
	2001	2002	2003	2004
7 plants m^{-2}	7.1	3.0	4.6	4.7
9 plants m^{-2}	9.0	4.1	5.5	6.1
11 plants m^{-2}	11.3	5.4	6.5	7.2
13 plants m^{-2}	13.1	6.6	7.5	8.7
LSD (*P* = 0.05)	0.4	0.4	0.5	0.4

[y]To achieved the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z]Plant populations counted approximately 30 d after planting.

No significant interactions were observed between seeding rate and PGR application rates for the dry matter partitioning components, so seeding rates were averaged across PGR rates and PGR rates were averaged across seeding rates. Except for specific leaf weights, there were few differences in the components of dry matter partitioning among the seeding rates (Table 2). The two highest seeding rates (11 and 13 plants m^{-2}) had approximately 3% lower specific leaf weights than the two lowest seeding rates (7 and 9 plants m^{-2}). The heterogeneous nature of the canopies and distribution of plants within the row for the lower seeding rates, coupled with the small sample size of the dry matter harvest may have been insufficient to detect potential differences among the seeding rates.

By using a sampling strategy designed for heterogeneous canopies, the LAI-2000 Plant Canopy Analyzer can compensate for the increased variability associated with a heterogeneous canopy structure. Utilizing this approach, a significant interaction was observed between seeding rates and PGR rates for the nondestructive leaf area index (LAI) measurements (Table 3). When PGR was not applied to the plots, the LAI was significantly different among seeding rates, with the LAI becoming progressively greater as the seeding rate increased. When the PGR was applied, the LAI increased with increasing seeding rate up to the 11 plant m^{-2} seeding rate. Increasing the seeding rate to 13 plants m^{-2} did not result in a further LAI increase. LAI did not differ between PGR rates for any of the seeding rates except for the 13 plants m^{-2} seeding rate where the application of PGR caused an 11% reduction in LAI compared with the untreated control. In previous research, Heitholt et al. (1996) were unable to detect LAI differences between plots treated with mepiquat chloride and untreated plots using the LAI-2000 Plant Canopy Analyzer.

Table 2. The effect of seeding rates and plant growth regulator (PGR) application rates averaged across cotton genotypes and years on cotton dry matter partitioning data

Variable	Height (cm)	Nodes plant^{-1}	Height:node	Leaf area index	Specific leaf weight (g m^{-2})	Vegetative weight (g m^{-2})	Reproductive weight (g m^{-2})	Harvest index
Seeding rate[y]								
7 plants m^{-2}	66	19.4	3.34	2.42	56.9	274.1	141.4	0.168
9 plants m^{-2}	67	19.6	3.36	2.32	57.0	265.2	130.7	0.172
11 plants m^{-2}	67	19.1	3.44	2.21	55.1	246.5	117.1	0.164
13 plants m^{-2}	67	19.1	3.44	2.37	55.0	262.1	104.8	0.157
LSD (*P* = 0.05)	ns	ns	ns	ns	1.8	ns	ns	ns
P > *F*	0.84	0.08	0.22	0.55	0.04	0.39	0.13	0.34
PGR application[z]								
No PGR	70	19.7	3.47	2.42	55.0	271.0	118.5	0.159
Plus PGR	64	18.9	3.32	2.23	57.0	252.9	128.5	0.171
LSD (*P* = 0.05)	3	0.4	0.13	ns	1.3	ns	ns	0.012
P > *F*	0.01	0.01	0.03	0.13	0.01	0.20	0.50	0.04

[y]To achieve the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z] PGR was mepiquat chloride at 49 g a.i. ha^{-1} in 2002 through 2003 and mepiquat pentaborate at 115 g a.i. ha^{-1} in 2004.

Table 3. The effect of seeding rates and plant growth regulator (PGR) application rates averaged across cotton genotypes and the years on cotton leaf area index measured nondestructively using a LAI-2000 Plant Canopy Analyzer

Seeding rate[y]	Cotton leaf area index		
	No PGR	Plus PGR[z]	Mean
7 plants m^{-2}	2.90	2.84	2.87
9 plants m^{-2}	3.08	3.09	3.09
11 plants m^{-2}	3.32	3.30	3.31
13 plants m^{-2}	3.71	3.32	3.52
			LSD (*P* = 0.05)
PGR rates within seeding rates			0.19
Seeding rates within PGR rates			0.15
Seeding rate mean averaged across PGR rates			0.15

[y]To achieve the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z]PGR was mepiquat chloride at 49 g a.i. ha^{-1} in 2002 through 2003 and mepiquat pentaborate at 115 g a.i. ha^{-1} in 2004.

PGR application altered the growth of the plants so that many of the dry matter partitioning components were affected (Table 2). It has been reported that these compounds reduced the plant stature relative to the untreated control plants (York, 1983a,b; Kerby, 1985; Cathey and Meredith, 1988; Cook and Kennedy, 2000; Biles and Cothren, 2001). PGR application reduced plant height by 9% and reduced both the number of main stem nodes and the height to node ratio by 4%. Although no differences were detected in LAI among PGR application rates from the destructive sampling, the plants treated with PGR had 4% greater specific leaf weight than the untreated control. Overall vegetative and reproductive weights did not differ between the treated or untreated plants, but the harvest index (ratio of reproductive weight to total weight) was 8% greater in the PGR-treated plants.

The canopy PPFD interception response to different seeding rates or PGR application rates was inconsistent across sampling dates (Table 4). Canopy PPFD interception among seeding rates was different on one of the measurement dates, while it was

Table 4. The effect of seeding rates and plant growth regulator (PGR) application rates averaged across cotton genotypes on cotton canopy photosynthetic photon flux density (PPFD) interception at various days after planting (DAP)

Variable	PPFD interception (%)						
	2001		2002		2003		2004
	163 DAP	190 DAP	168 DAP	199 DAP	175 DAP	196 DAP	194 DAP
Seeding rate[y]							
7 plants m^{-2}	53.2	97.0	89.3	86.0	57.0	77.8	71.8
9 plants m^{-2}	54.9	97.2	88.9	87.3	56.9	78.6	72.6
11 plants m^{-2}	56.7	98.1	88.9	88.9	58.7	76.6	74.0
13 plants m^{-2}	56.9	97.7	89.1	88.5	61.0	78.4	73.5
LSD (*P* = 0.05)	2.7	ns	ns	ns	ns	ns	ns
$P > F$	0.03	0.16	0.94	0.34	0.09	0.73	0.64
PGR application[z]							
No PGR	56.5	98.2	88.6	89.3	58.4	79.9	76.3
plus PGR	54.4	96.9	89.5	86.0	58.4	75.8	69.7
LSD (*P* = 0.05)	ns	ns	ns	2.8	ns	ns	3.2
$P > F$	0.36	0.10	0.45	0.03	0.97	0.06	0.01

[y]To achieve the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z]PGR was mepiquat chloride at 49 g a.i. ha^{-1} in 2002 through 2003 and mepiquat pentaborate at 115 g a.i. ha^{-1} in 2004.

different between the PGR application rates on two of the seven measurement dates. When significant differences were detected, the canopies of the lowest seeding rate (7 plants m^{-2}) intercepted less solar radiation than the other seeding rates, and the canopies of plants treated with a PGR intercepted less solar radiation relative to the untreated control canopies. Gwathmey et al. (1995) and Heitholt et al. (1996) also reported that cotton canopies treated with mepiquat chloride intercepted less solar radiation than the canopies of untreated cotton plants.

The flowering rate between PGR application rates was inconsistent among the years (Fig. 1 and 2). The flowering rate between the two rates of PGR application in 2002 or 2004 was not different. While the PGR-treated plants produced more early-season flowers in both 2001 and 2003, the untreated control plants exhibited a higher late season flowering rate in both of those years. This higher early season flowering induced by mepiquat compounds has previously been reported by Biles and Cothren (2001), but they did not observe the increased late season flowering in the untreated plants noted in this study. In general, differences were not observed in the rate of flowering among the seeding rates (data not shown), but when differences were observed, the higher seeding rates produced more blooms early in the season and the lower seeding rates produced more blooms late in the season. A similar pattern of flower production among divergent cotton population densities was also reported by Jones and Wells (1997). In addition, Heitholt (1995) reported no differences in total seasonal flower production among different plant densities ranging from 2 to 20 plants m^{-2} for normal-leaf cultivars.

This earlier reproductive development in the plants treated with PGR was also reflected in a reduced NAWB number relative to the control plants on most of the measurement dates (Fig. 3 and 4). This reduced NAWB for the PGR-treated plants was consistent during each year of the study. As blooms form on higher main-stem nodes, the NAWB decreases

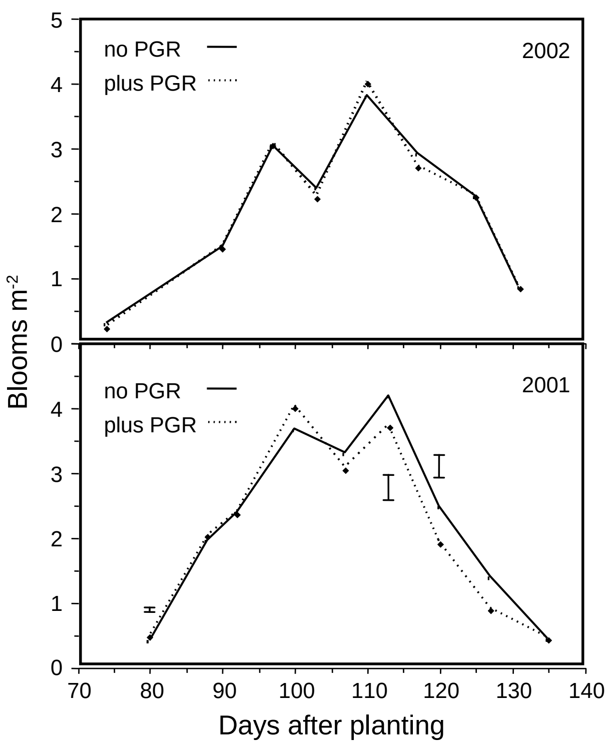

Fig. 1. White blooms (blooms at anthesis) m^{-2} of ground area of cotton at various days after planting (DAP) throughout the 2001 and 2002 growing seasons in plots either treated on not treated with plant growth regulator compounds (PGR). PGR application rate means were averaged across cotton genotypes and seeding rates. Vertical bars denote LSD values at *P* = 0.05 and are present only when the differences between soil moisture treatments are significant.

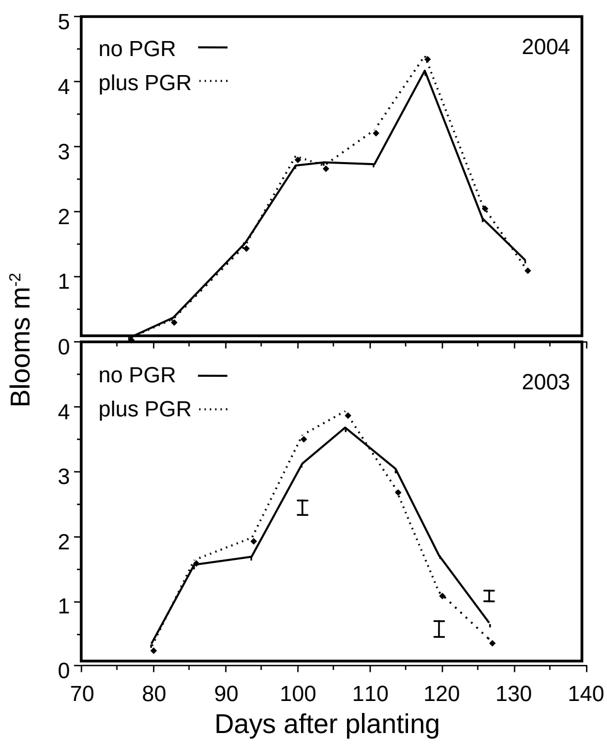

Fig. 2. White blooms (blooms at anthesis) m^{-2} of ground area of cotton at various days after planting (DAP) throughout the 2003 and 2004 growing seasons in plots either treated on not treated with plant growth regulator compounds (PGR). PGR application rate means were averaged across cotton genotypes and seeding rates. Vertical bars denote LSD values at *P* = 0.05 and are present only when the differences between soil moisture treatments are significant.

as the maturity of the plant progresses. Because the NAWB difference between PGR treatments is generally less than one node on all measurement dates, this maturity difference equates to less than 1 or 2 d, assuming a vertical blooming interval of 2.5 to 3 d (Bednarz and Nichols, 2005). When the NAWB decreases to 5, the crop is considered to be at cut-out (Bourland et al., 1992). Earlier maturity of PGR-treated plants has been reported by others (York, 1983a; Kerby, 1985).

There was no interaction between seeding rates and PGR application rates for lint yield or any of the components of yield, so seeding rates were averaged across PGR rates, and PGR application rates were averaged across seeding rates. Because these results were consistent across years, the seeding rate means and PGR means were also averaged across years. The lowest seeding rate (7 plants m^{-2}) averaged 5% lower lint yield than any of the other seeding rates (Table 5). Lint yield among the other seeding rates was not different. Production of fewer bolls per unit ground area was the yield component responsible for the reduction in lint yield observed with the 7 plants m^{-2} seeding rate. None of the other yield components were different among the seeding rates. Although applying a PGR did not affect lint yield, many of the yield components were altered by a PGR application. Bolls for the PGR-treated plants had 3% greater boll mass than bolls from the control plants due primarily to the 3% more seed per boll and 2% larger seed mass. Similar increases in boll and seed mass in response to mepiquat chloride were reported by York (1983a, 1983b), Cathey and Meredith (1988), and Biles and Cothren (2001). This larger boll mass for the PGR-treated plants was offset by the reduced lint percentage of the PGR-treated plants relative to the control plants, which explains the lack of yield response to the PGR application. York (1983a, 1983b), Cathey and Meredith (1988), and Biles and Cothren (2001) also found that mepiquat chloride reduced lint

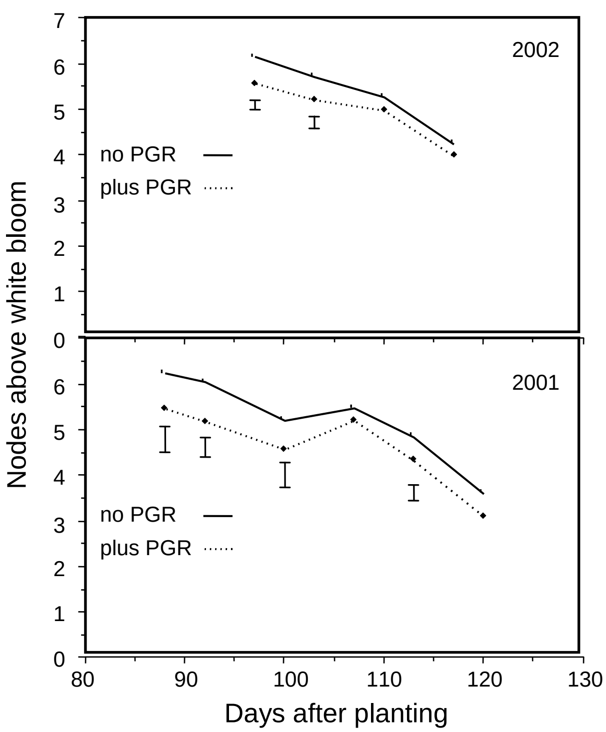

Fig. 3. Number of main-stem nodes of cotton above a sympodial branch with a first-position white bloom (bloom at anthesis) at various days after planting (DAP) throughout the 2001 and 2002 growing seasons in plots either treated on not treated with plant growth regulator compounds (PGR). PGR application rate means were averaged across cotton genotypes and seeding rates. Vertical bars denote LSD values at *P* = 0.05 and are present only when the differences between soil moisture treatments are significant.

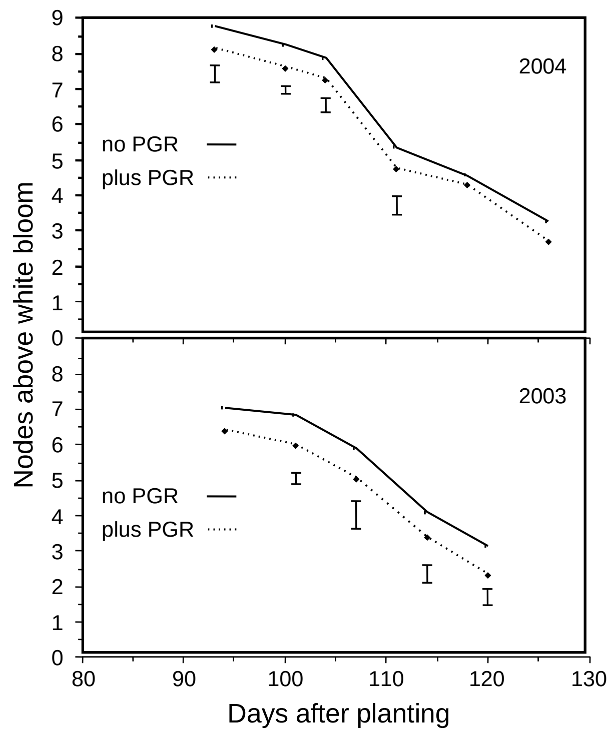

Figure 4. Number of main-stem nodes of cotton above a sympodial branch with a first-position white bloom (bloom at anthesis) at various days after planting (DAP) throughout the 2003 and 2004 growing seasons in plots either treated on not treated with plant growth regulator compounds (PGR). PGR application rate means were averaged across cotton genotypes and seeding rates. Vertical bars denote LSD values at *P* = 0.05 and are present only when the differences between soil moisture treatments are significant.

percentage. Neither the number of bolls produced per unit ground area nor the lint index was different among the PGR application rates.

There few differences in the fiber quality traits among seeding rates (Table 6). Although the micronaire with the 11 plants m^{-2} seeding rate was significantly lower than either the 9 plants m^{-2} or 13 plants m^{-2} seeding rates, there was no discernable trend for a seeding rate effect on micronaire. Fiber perimeter, a component of micronaire, for the 11 plants m^{-2} seeding rate was also significantly lower than the other seeding rates. The only fiber traits affected by applying PGR were fiber elongation and the span lengths. A 1% reduction in fiber elongation

Table 5. The effect of seeding rates and plant growth regulator (PGR) application rates averaged across cotton genotypes and the years on cotton lint yield and yield components

Variable	Lint yield (kg ha^{-1})	Boll number (bolls m^{-2})	Boll mass (g)	Seed number ($boll^{-1}$)	Seed mass (mg)	Lint percentage (%)	Lint index (mg $seed^{-1}$)
Seeding rate[y]							
7 plants m^{-2}	1393	69	5.00	30	99	41.5	70
9 plants m^{-2}	1441	71	5.04	30	100	41.5	71
11 plants m^{2}	1471	73	4.95	29	99	41.5	70
13 plants m^{-2}	1465	73	4.95	30	99	41.6	70
LSD (*P* = 0.05)	46	2	ns	ns	ns	ns	ns
P > *F*	0.01	0.01	0.16	0.89	0.16	0.90	0.50
PGR application[z]							
no PGR	1431	72	4.91	29	98	41.7	70
Plus PGR	1455	71	5.06	30	100	41.3	70
LSD (*P* = 0.05)	ns	ns	0.11	0.6	1	0.3	ns
P > *F*	0.15	0.52	0.01	0.01	0.01	0.01	0.95

[y]To achieve the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z]PGR was mepiquat chloride at 49 g a.i. ha^{-1} in 2002 through 2003 and mepiquat pentaborate at 115 g a.i. ha^{-1} in 2004.

Table 6. The effect of seeding rates and plant growth regulator (PGR) application rates averaged across cotton genotypes and the years on cotton fiber quality traits

Variable	Fiber strength (kN m kg^{-1})	Fiber elongation (%)	Span length (cm)		Length uniformity (%)[x]	Micronaire	Fiber maturity (%)	Fiber perimeter (μm)
			2.5 %	50 %				
Seeding rate[y]								
7 plants m^{-2}	188	7.4	2.85	1.41	48.8	4.84	85.8	51.4
9 plants m^{-2}	186	7.4	2.84	1.41	48.9	4.90	86.6	51.2
11 plants m^{2}	187	7.4	2.86	1.41	48.7	4.79	86.4	50.5
13 plants m^{-2}	189	7.4	2.85	1.41	48.9	4.88	86.7	51.0
LSD (*P* = 0.05)	ns	ns	ns	ns	ns	0.07	ns	0.6
P > *F*	0.07	0.90	0.30	0.87	0.81	0.01	0.43	0.03
PGR application[z]								
no PGR	187	7.4	2.84	1.40	0.49	4.84	86.4	50.89
plus PGR	188	7.3	2.86	1.42	.049	4.86	86.3	51.19
LSD (*P* = 0.05)	ns	0.1	0.01	0.01	ns	ns	ns	ns
P > *F*	0.47	0.05	0.01	0.01	0.79	0.47	0.84	0.19

[x]Length uniformity = (50 % span length / 2.5 % span length) X 100.

[y]To achieve the desired seeding rate, actual seeding rates are adjusted assuming 75% survival of planted seed.

[z]PGR was mepiquat chloride at 49 g a.i. ha^{-1} in 2002 through 2003 and mepiquat pentaborate at 115 g a.i. ha^{-1} in 2004.

occurred when a PGR was applied, but both the 2.5% and 50% span lengths were increased in response to PGR application. Although these differences may be statistically significant, biologically they may be of little consequence because they are so small. Cathey and Meredith (1988) also reported similar fiber elongation reductions and 2.5% span length increases in response to mepiquat chloride application. A slight increase in the fiber length upper half mean caused by treatment with mepiquat chloride was reported by (York, 1983a).

No lint yield advantage was attained from applying the mepiquat compounds to the cotton crop under these early planted conditions, although PGR application may have slightly accelerated the crop maturity as demonstrated by the reduced NAWB numbers. Although the PGR-treated plants had enhanced flowering early in the season, the longer growing season provided by the early planting production system allowed the control plants to continue flowering and setting bolls later in the season. These flowering trends appear to have cancelled each other out, resulting in no yield differences between the PGR-treated and control plants. When production circumstances, such as late planting, planting a late maturing cultivar, or an early frost, conspire separately or in combination to curtail the time available for later boll set and maturation, a PGR application may provide a yield boost over the untreated cotton by an acceleration of the reproductive growth. Cathey and Meredith (1988) found mepiquat chloride produced a yield increase when the cotton was planted later in the growing season. Furthermore, York (1983b) indicated that for the two lowest plant populations in his study, no yield response to mepiquat chloride would have been observed if the growing season had been long enough for all the bolls set to mature and open.

While Heitholt (1994) identified 5 plants m^{-2} as the optimal population density for normal-leaf cotton, the final mean plant density produced by the 7 plants m^{-2} seeding rate goal in this study was essentially equal to the 5 plants m^{-2} density (4.85 plants m^{-2}) and produced a yield reduction relative to the higher rates. This difference is probably because the within row plant distribution with this study contained more gaps and was less uniform than what occurred in the Heitholt (1994) study. Assuming that the 5 plants m^{-2} density is optimal, the seeding rate must be increased accordingly under early planting conditions to achieve that final plant density. Based on the data from this study, for most years one should assume a survival rate lower than the 75% level used in this study when adjusting seeding rates for early planting conditions.

In conclusion, although crop maturity may have been slightly accelerated and some yield components were affected, the application of the mepiquat compounds did not significantly improve yield. This situation is partially attributed to the longer growing season afforded by early planting, which allowed the late flower production from the control plants to set bolls that opened in time for harvest. Yield responses from mepiquat compounds have been notoriously inconsistent across many studies. It is questionable whether these plant growth regulating compounds are necessary in an early planting situation. In addition, a higher seeding rate is needed with the early planting production system to achieve optimal plant densities because of the lower level of seedling survival level, and the potential for a non-uniform distribution of plants within row.

DISCLAIMER

Trade names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product or service, and the use of the name by USDA implies no approval of the product or service to the exclusion of others that may also be suitable.

REFERENCES

Bednarz, C.W., and R.L. Nichols. 2005. Phenological and morphological components of cotton crop maturity. Crop Sci. 45:1497-1503.

Bednarz, C.W., W.D. Shurley, W.S. Athony, and R.L. Nichols. 2005. Yield, quality, and profitability of cotton produced at varying plant densities. Agron. J. 97:235-240.

Biles, S.P., and J.T. Cothren. 2001. Flowering and yield response of cotton to application of mepiquat chloride and PGR-IV. Crop Sci. 41:1834-1837.

Bourland, F.M., D.M. Oosterhuuis, and N.P. Tugwell. 1992. Concept for monitoring the growth and development of cotton plants using main stem counts. J. Prod. Agric. 5:532-538.

Buxton, D.R., R.E. Briggs, L.L. Patterson, and S.D. Watkins. 1977. Canopy characteristics of narrow-row cotton as influenced by plant density. Agron. J. 69:929-933.

Cathey, G.W, and W.R. Meredith, Jr. 1988. Cotton response to planting date and mepiquat chloride. Agron. J. 80:463-466.

Cook, D.R., and C.W. Kennedy. 2000. Early flower bud loss and mepiquat chloride effects on cotton yield distribution. Crop Sci. 40:1678-1684

Gwathmey, C.O., O.M. Wassel, and C.E. Michaud. 1995. Pix effects on canopy light interception by contrasting cotton varieties. p. 1153-1154. *In* Proc. Beltwide Cotton Conf., 4-7 Jan. 1995, San Antonio, TX. Natl. Cotton Counc. Am., Memphis, TN.

Heitholt, J.J. 1994. Canopy characteristics associated with deficient and excessive cotton plant population densities. Crop Sci. 34:1291-1297.

Heitholt, J.J. 1995. Cotton flowering and boll retention in different planting configurations and leaf shapes. Agron. J. 87:994-998.

Heitholt, J.J., W.R. Meredith, Jr., and J.R. Williford. 1996. Comparison of cotton genotypes varying in canopy characteristics in 76-cm vs. 102-cm rows. Crop Sci. 36:955-960.

Hicks, S.K., and R.J. Lascano. 1995. Estimation of leaf area index for cotton canopies using the LI-COR LAI-2000 Plant Canopy Analyzer. Agron. J. 87:458-464.

Jadhao, J.K., A.M. Degaonkar, and W.N. Narkhede. 1993. Performance of hybrid cotton cultivars at different plant densities and nitrogen levels under rainfed conditions. Ind. J. Agron. 38:340-341.

Jones, M.A., and R.Wells. 1997. Dry matter allocation and fruiting patterns of cotton grown at two divergent plant populations. Crop Sci. 37:797-802.

Kerby, T.A. 1985. Cotton response to mepiquat chloride. Agron. J. 77:515-518.

Kerby, T.A., K.G. Cassman, and M. Keeley. 1990a. Genotypes and plant densities for narrow-row cotton systems. I. Height, nodes earliness, and location of yield. Crop Sci. 30:644-649.

Kerby, T.A., K.G. Cassman, and M. Keeley. 1990b. Genotypes and plant densities for narrow-row cotton systems. II. Leaf area and dry-matter partitioning. Crop Sci. 30:649-653.

Mohamad, K.B., W.P. Sappenfield, and J.M. Poehlman. 1982. Cotton cultivar response to plant population in a short-season, narrow-row cultural system. Agron. J. 74:619-625.

Pettigrew, W.T. 2002. Improved yield potential with an early planting cotton production system. Agron. J. 94:997-1003.

Sawan, Z.M., A.E. Basyony, W.L. McCuistion, and A.H.A. El Farra. 1993. Effect of plant population densities and application of growth retardants on cottonseed yield and quality. J. Am. Soc. Oil Chem. 70:313-317.

Smith, C.W., B. A. Waddle, and H.H. Ramey. 1979. Plant spacings with irrigated cotton. J. Agron. 71:858-860.

York, A.C. 1983a. Cotton cultivar response to mepiquat chloride. Agron. J. 75:663-667.

York, A.C. 1983b. Response of cotton to mepiquat chloride with varying N rates and plant populations. Agron. J. 75:667-672.