The *Journal of Cotton Science 7:148–155 (2003)*
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AGRONOMY AND SOILS

Evaluation of Row Spacing and Mepiquat Chloride in Cotton

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ABSTRACT

Mepiquat chloride (1,1-dimethyl-piperidinium chloride) is a plant growth regulator that can be used by producers to manage crop development, uniformity, and maturity. Field experiments were conducted from 1998 to 2000 to evaluate the effect of row spacing and mepiquat chloride applications on cotton (*Gossypium hirsutum* L.). Four rates of mepiquat chloride (4 x 0.29 L ha^{-1}, 2 x 0.58 L ha^{-1}, 4 x 0.58 L ha^{-1}, and 4 x 0.88 L ha^{-1}) were evaluated for cotton grown in 19-, 38-, and 76-cm rows in 1998 and 25-, 38-, and 76-cm rows in 1999 and 2000. In 1999 and 2000, plant heights and number of total main stem nodes were different among row spacings and mepiquat chloride applications. The height-to-node ratio was highest in plots not receiving mepiquat chloride. Cotton grown in narrow rows had higher seed cotton yields than cotton produced in 76-cm rows, but reduced gin turnout in narrow row spacings negated any increase in seed cotton yield. As a result, lint yields among the different row spacings were not significantly different in 2 of 3 yr. In general, reduced row spacing and mepiquat chloride application did not lower fiber quality. In some cases, micronaire was reduced in narrow row spacings, but values were within the acceptable range for fiber grade standards to avoid discounts. Applications of mepiquat chloride increased lint yield only 1 of 3 yr, but is still considered a desirable management tool to control crop growth for efficient harvest, especially on fields with a history of excessive vegetative growth. Ultra-narrow row systems appeared to be a viable alternative to traditional wide-row systems for cotton production in the Mississippi Delta.

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Cotton farmers are faced with the difficult task of selecting management strategies under rising production costs and static or declining returns for their crop. One alternative method to combat these problems and to optimize profit is growing cotton in narrow rows. Ultra-narrow row systems require planting cotton in rows of 38 cm or less with plant populations of 173,000 to 297,000 plants ha^{-1}, and harvesting with a finger-type stripper harvester. Producing cotton in ultra-narrow rows requires careful consideration of several management components, which includes the use of plant growth regulators to control plant size and to reduce trash and grade discounts.

Stripper harvesting of narrow-row cotton typically increases trash and bark content of seed cotton. Strippers remove the entire boll, including the burs, as well as some of the peduncles and short limbs from the cotton plant. If any leaves remain on the plant, they also may be harvested adding trash to the cotton lint. In a study of several cultivars planted over the southeastern United States, up to 111 kg more trash and foreign matter was removed from seed cotton when producing a 218-kg bale of cotton grown in ultra-narrow rows compared with cotton grown in a wide-row spacing (Anthony et al., 1999). Anthony and Molin (2000) suggested that after ginning fiber quality characteristics were different for cultivars harvested with spindle pickers and strippers. Vories et al. (1999) reported only micronaire, which was consistently lower for ultra-narrow row cotton, was affected when comparing ultra-narrow row cotton with conventional systems. Current strippers for harvest of ultra-narrow row cotton require that plants be kept less than 76 cm tall for efficient and clean harvest. This can be achieved by selecting short-stature, early-maturing cultivars and by the use of plant growth regulators such as mepiquat chloride (1,1-dimethylpiperidinium).

Mepiquat chloride was introduced to the market in the late 1970's as a plant growth regulator to suppress excessive plant growth by decreasing plant height, number of nodes, branch lengths, and leaf area (Kerby et al., 1982; Reddy et al., 1990; Stuart et al., 1984; York, 1983a,b; Zummo et al., 1984). As a result of maximizing inputs for cotton production, under optimum growing conditions plants often become excessively tall and vegetative (Cathey and Luckett, 1980). Excessive vegetative growth may result in fruit shed (Gausman et al., 1979a; Walter et al., 1980), increased insect and disease problems, and reduced harvest efficiency, lint quality, and yield. Cotton plants treated with mepiquat chloride are typically more compact (Walter et al., 1980), have fewer nodes (Reddy et al., 1992), have shortened internodes (Heilman, 1981), and produce fewer reproductive branches. As a result, the effect of mepiquat chloride has been to decrease plant height (Heilman, 1981; Walter et al., 1980), increase earliness (Briggs, 1980), decrease boll rot (Snow et al., 1981), and facilitate insect management. Yield response to mepiquat chloride applications, however, has been inconsistent. Some researchers have found yield increases (Briggs, 1980; Schott and Schroeder, 1979; Walter et al., 1980; Williford, 1992) with the application of mepiquat chloride, whereas others have found yield decreases or no yield effects (Cathey and Meredith, 1988; Crawford, 1981; Feaster et al., 1980; Thomas, 1975). Yield responses to mepiquat chloride application appear to be related to environmental factors encountered by the plant throughout the growing season. Favorable yield responses are most typically associated with conditions that favor excessive vegetative growth such as high nitrogen rates, excessive rainfall, and thick stands.

Ultra-narrow row cotton production requires a uniform plant density without skips and control of excessive growth for efficient harvest, so the use of mepiquat chloride may be a good fit in ultra-narrow row management systems, particularly on fields with a history of excessive vegetative growth. Several researchers have evaluated the use of mepiquat chloride in ultra-narrow row systems in recent years. In a study near Scott, MS, on soils with high growth potential, Kerby (1998) reported that an early application is more important than high application rates. In a 1-yr study in Texas, the effects of 38- and 76-cm rows and mepiquat chloride rates on yield and fiber quality were investigated (Prince et al., 1998). Reductions in fiber quality were observed in the 38-cm rows compared with 76-cm rows. Application rate of mepiquat chloride did not affect lint yield in either row spacing, but the lack of differences was attributed to severe drought during the boll-filling period that masked any potential benefit of mepiquat chloride. Average lint yields were 7% higher for cotton produced in 25- and 51-cm rows treated with mepiquat chloride than without mepiquat chloride in a 4-yr study near Milan, TN (Gwathmey, 1998). Conversely, yields were reduced by mepiquat chloride applications for cotton grown in 19-cm rows in Arkansas (Allen et al., 1998). A 2-yr study in South Carolina consisting of four mepiquat chloride rates (4 x 0.29 L ha^{-1}, 2 x 0.58 L ha^{-1}, 4 x 0.58 L ha^{-1}, and 4 x 0.88 L ha^{-1}) and three row spacings (19-, 38-, and 76-cm) found no differences in seed cotton yield, gin turnout, or lint yield due to mepiquat chloride application (Jones, 2001).

As with conventional row spacings, the effect of mepiquat chloride on lint yields in ultra-narrow row cotton is erratic and inconsistent. Studies in the 1980's suggested these inconsistencies were due to environmental factors such as temperature, moisture, nutrient status (Briggs, 1980; Kerby, 1985; Kerby et al., 1986; York, 1983b) and planting date (Cathey and Meredith, 1988). In ultra-narrow row cotton systems, use of mepiquat chloride may be dependent on rainfall, fruit load, soil fertility, and other related factors. Wright et al. (2000) suggested internode length of the crop should be monitored and managed for 5 cm or less and mepiquat chloride used as needed.

The objective of this study was to evaluate the effectiveness of row spacings and mepiquat chloride management strategies on cotton growth, maturity, and lint yield.

MATERIALS AND METHODS

Field experiments were conducted from 1998 to 2000 to evaluate the growth of cotton cv. Paymaster 1220BR (Delta Pine and Land Company, Scott, MS) in three row spacings with five mepiquat chloride application strategies. Plots were located at the Delta Research and Extension Center near Stoneville, MS on a Bosket (fine-loamy, mixed, active, thermic Mollic Hapludalfs) very-fine, sandy loam soil. In 1998, row spacings consisted of 19-, 38-, and 76-cm rows. Row spacings of 25-, 38-, and 76-cm rows were evaluated in 1999 and 2000. Mepiquat chloride (Pix; BASF, Research Triangle Park, NC) treatments were the same for all 3 yr and consisted of an untreated check, four applications of 0.29 L ha^{-1}, two applications of 0.58 L ha^{-1}, four applications of 0.58 L ha^{-1}, and four applications of 0.88 L ha^{-1} (mepiquat chloride rates of 0.29, 0.58, 0.88 L ha^{-1} are equivalent to

12.2, 24.4, and 36.6 g ai ha^{-1}, respectively). Mepiquat chloride applications began at pinhead square and were applied over-the-top by a CO_2-pressurized backpack sprayer at a spray volume of 197 L ha^{-1}. Final applications were made at early bloom each year.

In all years, cotton was planted in a flat-row profile into adequate soil moisture. Planting dates were 6 May 1998, 25 May 1999, and 18 May 2000. Plant populations were approximately 247,000 plants ha^{-1} in the 25- and 38-cm plots and approximately 128,000 plants ha^{-1} in the 76-cm plots. In 1999 and 2000, 25-cm rows were planted with a Monosem precision vacuum planter and 38-cm rows were planted with a John Deere 1730 Max Emerge vacuum planter. Nitrogen was applied at 112 kg ha^{-1} in the form of 32% UAN (urea and ammonium nitrate solution) for all row spacings each year. Cultural inputs were performed to optimize yields for each row spacing and were consistent with local agronomic practices. Cotton was grown under non-irrigated conditions every year.

Data collected in 1999 and 2000 included plant height measurements at 2, 4, and 5 wk after pinhead square (phs). Total main stem nodes and height-to-node ratios were determined at 4 wk after phs from 10 plants plot^{-1}. Entire plots were machine-harvested by finger-type stripper for ultra-narrow rows (19 to 38 cm), and the center two rows by spindle-type picker for 76-cm rows, to determine total yield.

Yield variables evaluated included seed cotton yield, gin turnout, and lint yield. A laboratory gin was used to separate seed cotton samples into lint and seed. In 1999 and 2000, gin turnout, which takes into account trash and seed in harvested cotton, was calculated by dividing the weight of lint by the weight of a given sample and was expressed as a percentage. Fiber samples were subjected to high volume instrument (HVI) testing at Starlab (Starlab, Inc., Knoxville, TN). Fiber quality characteristics reported include micronaire, length, length uniformity, and strength.

Treatments were arranged as split plots in a randomized complete block design with main plots consisting of row spacings and five subplots consisting of mepiquat chloride treatments with four replications. Main plots were approximately 15.2 m long and 20 m wide. Subplots were 15.2 m long and 4.0 m long and the number of rows in each main plot varied depending on row spacing treatments. All data were subjected to analysis of variance. Means were separated using Fisher's protected least significant difference (LSD) test, a multiple comparison technique that requires a significant overall F value and involves standard t-tests between pairs of means. In all statistical tests, significance was determined at $P \leq 0.05$. Due to significant year x treatment interactions, each year was analyzed separately. Interactions between row spacing and mepiquat chloride level for the variables measured in each year of the study were not significant.

RESULTS AND DISCUSSION

Plant mapping. Plant measurements taken in 1999 and 2000 indicated mepiquat chloride treatments reduced plant height at 2 wk after phs compared with the untreated check (Table 1). Height reductions ranged from approximately 16 to 25% for the lowest to highest application rates of mepiquat chloride, respectively. At 4 wk after phs, height reductions were approximately 20 to 38% for the lowest to highest application rates (Table 1). Mepiquat chloride treatments reduced plant height at 5 wk after phs compared with the untreated check in 1999 and 2000. Row spacing did not affect plant height at 2 or 4 wk after phs in 1999, but plant height was reduced in 25-cm row spacings at these growth stages in 2000. Plant height at 5 wk after phs was reduced in 25-cm rows compared with the 76-cm row spacing in 1999 and 2000. The number of total main stem nodes at 4 wk after phs was greatest in 76-cm rows, averaging approximately one additional node compared with the narrower row spacings (Table 1). The height-to-node ratio at 4 wk after phs was highest in plots receiving no mepiquat chloride (data not shown). Row spacing did not affect height-to-node ratio in 1999 or 2000. Jost (2000) reported 2.5 fewer main stem nodes for cotton in 19-cm row spacings compared with 38-, 76-, and 101-cm row spacings. In another study, ultra-narrow rows had five fewer main stem nodes than wide row spacings at the end of the season (Kerby, 1998). In addition, plants not treated with mepiquat chloride had more main stem nodes than treated plants.

Yield data. Seed cotton yields were higher in the narrow row spacings compared with the 76-cm row spacing from 1998 to 2000 (Table 2). Mepiquat chloride applications had no effect on seed cotton yields in 1998 and 2000, but all mepiquat chloride treatments resulted in higher seed cotton yields compared with the untreated check in 1999. More than 15 cm of rain fell from June to August in 1998; however, after ad-

Table 1. Effect of mepiquat chloride application and row spacing on plant height at 2, 4, and 5 weeks after pinhead square (waphs) and number of total main stem nodes at 4 weeks after pinhead square on cotton in 1999 and 2000 at Stoneville, MS

Mepiquat chloride[z]	1999 Plant height (cm) 2 waphs	1999 Plant height (cm) 4 waphs	1999 Plant height (cm) 5 waphs	1999 Main stem nodes (#)	2000 Plant height (cm) 2 waphs	2000 Plant height (cm) 4 waphs	2000 Plant height (cm) 5 waphs	2000 Main stem nodes (#)
Untreated	69	86	87	14.6	71	91	92	14.0
Two - 0.58 L ha^{-1}	57	61	64	13.1	54	68	69	12.8
Four - 0.29 L ha^{-1}	58	64	68	13.4	58	73	72	12.9
Four - 0.58 L ha^{-1}	53	55	57	12.7	55	68	69	12.7
Four - 0.88 L ha^{-1}	53	53	54	12.6	53	64	66	12.5
LSD (*P* = 0.05)	4	4.5	4.1	0.6	3.6	3.8	3.9	0.6
Row spacing								
25 cm	57	59	63	13.0	54	69	70	12.7
38 cm	59	62	64	12.6	61	72	73	12.7
76 cm	58	70	70	14.3	60	78	79	13.5
SD (*P* = 0.05)	NS	NS	5.9	0.5	3.0	6.2	6.9	0.4

[z] Mepiquat chloride rates of 0.29, 0.58, 0.88 L ha^{-1} are equivalent to 12.2, 24.4, and 36.6 g ai ha^{-1}, respectively.

Table 2. Effect of mepiquat chloride application and row spacing on seed cotton yield, gin turnout, lint yield, and micronaire (MIC) on cotton from 1998 through 2000 at Stoneville, MS

Mepiquat chloride[y]	1998 Seed cotton (kg ha -1)	1998 Lint (kg ha-1)	1998 Mic	1999 Seed cotton (kg ha -1)	1999 Gin turnout (%)	1999 Lint (kg ha -1)	1999 Mic	2000 Seed cotton (kg ha -1)	2000 Gin turnout (%)	2000 Lint (kg ha -1)	2000 Mic
Untreated	3426	1109	4.9	2128	35.0	740	4.7	2083	31.7	699	3.8
Two - 0.58 L ha-1	3443	1103	5.0	2482	34.1	842	4.6	2043	31.8	679	3.9
Four - 0.29 L ha-1	3706	1209	4.9	2418	34.2	824	4.7	2039	31.8	679	3.8
Four - 0.58 L ha-1	3400	1095	5.0	2355	34.2	800	4.7	2092	31.8	697	3.9
Four - 0.88 L ha-1	3403	1123	5.0	2406	33.7	805	4.6	2013	31.3	660	4.0
SD (*P* = 0.05)	NS	NS	NS	177	0.8	56	NS	NS	NS	NS	NS
Row spacing											
25 cm (19 cm[z])	3827	1191	4.9	2412	32.9	792	4.6	2159	30.3	697	3.8
38 cm	3530	1051	4.9	2565	32.6	835	4.5	2341	30.5	759	3.8
76 cm	3071	1141	5.1	2098	37.1	779	4.8	1661	34.3	593	4.0
SD (*P* = 0.05)	260	NS	0.2	310	0.8	NS	0.2	268	0.9	93	NS

[y] Mepiquat chloride rates of 0.29, 0.58, 0.88 L ha^{-1} are equivalent to 12.2, 24.4, and 36.6 g ai ha^{-1}, respectively

[z] In 1998, row spacing was 19 cm.

equate moisture early in the growing season, less than 5 cm were received in July and August, 1999, and less than 2.5 cm during the same time period in 2000. Average day and night air temperatures were similar for all years (Table 3). Highest seed cotton yields were produced in 1998 when there was a better distribution of available moisture during the summer months. There was no apparent relationship between response to mepiquat chloride and rainfall.

Any evaluation of seed cotton yields between narrow and wide row spacings should take into account differences due to method of harvest. The amount of foreign matter in seed cotton is typically higher for ultra-narrow row cotton compared with cotton in wide rows, averaging 20 and 8% for stripper and spindle-harvested cotton, respectively (Valco et al., 2001). Gin turnout, which takes into account trash and is usually several percentage points below lint percentage, was evaluated in 1999 and 2000 (Table 2). In 1999, plots not treated with mepiquat chloride had higher gin turnout than plots receiving the three highest rates; however, in 2000, gin turnout was not affected by mepiquat chloride treatment. Gin turnout in 76-cm rows was approximately 4% higher than cotton grown in narrow rows in both 1999 and 2000. These findings are similar to those of Atwell et al. (1996) who reported an average of 28 and 32% gin turnout for ultra-narrow row cotton and conventional cotton, respectively. In this study, differences in gin turnout between narrow rows and wide rows were most likely attributable to the effect of machine efficiency of the stripper versus the spindle-picker used for harvest. In a broad study across the Cotton Belt, Valco et al. (2001) concluded that the difference in harvest method explained why ultra-narrow row cotton had over three times the foreign matter of cotton grown conventionally, resulting in a 5% reduction in lint turnout. Jost and Cothren (2001) observed that when cotton was hand-harvested, thus removing the effect of machine efficiency and reducing the possibility of introducing bark and leaf trash in the samples, lint percentage was greater in narrow rows compared to conventional row spacings. Engineering advances should continue to improve harvest efficiency of stripper-type harvest machinery.

The effects of row spacing and mepiquat chloride application on lint yield were inconsistent over the 3-yr study (Table 2). There were no differences in lint yield due to row spacing or mepiquat chloride application in 1998. Increases in seed cotton yield in narrow-row cotton were negated by reduced gin turnout, which in turn resulted in no significant differences in lint yields due to row spacing. In 1999, row spacing did not affect lint yield, but mepiquat chloride increased lint yield for all treatments compared with the untreated check by an average of 74 kg ha^{-1}. In 2000, yields were higher in 25- and 38-cm row spacings than 76-cm row spacing, while mepiquat chloride application did not affect lint yield. Overall, neither row spacing nor mepiquat chloride application had a significant effect on lint yield in 2 of 3 yr. Prince et al. (1998) also showed row spacing and mepiquat chloride application rate did not affect lint yield in 38- and 76-cm row spacings. Yield was not affected by application of mepiquat in three row spacings evaluated in South Carolina (Jones, 2001).

Lint Quality. Cotton produced in 76-cm rows had higher micronaire values compared with cotton produced in narrow row spacings when averaged across mepiquat chloride treatments in 1998 and 1999 (Table 2). In 1998, micronaire values in 76-cm rows were in

Table 3. Minimum and maximum air temperature and precipitation recorded from 1998 through 2000 at Stoneville, MS

	1998			1999			2000		
	Air temperature (°C)		Precipitation (cm)	Air temperature (°C)		Precipitation (cm)	Air temperature (°C)		Precipitation (cm)
	Min	Max		Min	Max		Min	Max	
April	**11.2**	**23.4**	**11.0**	**14.9**	**25.7**	**16.1**	**11.1**	**22.4**	**28.2**
May	**19.1**	**30.5**	**11.7**	**17.1**	**29.1**	**14.5**	**18.9**	**29.4**	**17.6**
June	**22.8**	**33.2**	**4.0**	**21.5**	**31.8**	**7.1**	**21.1**	**32.0**	**15.6**
July	**24.0**	**34.3**	**14.5**	**22.9**	**34.1**	**2.6**	**22.2**	**34.6**	**1.6**
August	**22.4**	**34.2**	**1.8**	**21.2**	**35.7**	**0.6**	**22.2**	**36.7**	**0.0**
September	**20.2**	**33.4**	**7.4**	**16.2**	**31.7**	**4.4**	**17.4**	**31.2**	**6.6**
Average	**20.0**	**31.5**	**13.6**	**19.0**	**31.4**	**7.5**	**18.8**	**31.1**	**11.6**

the discount range with a mean value of 5.1. These findings are similar to those of Vories et al. (1999) who reported a decrease in micronaire in 2 of 3 yr for cotton grown in ultra-narrow rows compared with conventionally-grown cotton. Jost (2000) found no differences in micronaire due to row spacing. Applications of mepiquat chloride did not affect micronaire in any year of the study. The range of micronaire values was similar for 1998 and 1999, but was much lower for all treatments in 2000.

Row spacing did not affect fiber length in any of the 3 yr, and mepiquat chloride application did not affect fiber length 2 of 3 yr (data not shown). Other studies (Baker, 1976; Howard et al., 2001; Vories et al., 1999) have reported similar results; however, Jost (2000) found ultra-narrow rows reduced length compared with conventional row spacing in 2 of 3 yr. Fiber lengths ranged from 2.77 to 2.87, 2.69 to 2.79, and 2.74 to 2.84 cm $fiber^{-1}$ in 1998, 1999, and 2000, respectively (data not shown).

Row spacing had no effect on fiber uniformity in 2 of 3 yr (data not shown). Fiber uniformity was higher in 76-cm rows compared with 25- and 38-cm rows in 2000. Mepiquat chloride application did not affect fiber uniformity in any year of the study. Means for all row spacings and mepiquat chloride applications were in the average (80% to 82%) to high (83% to 85%) range. These findings are similar to those reported by Jost (2000) and Valco et al. (2001) who found no differences in uniformity due to row spacing.

Neither row spacing nor mepiquat chloride application had a significant effect on fiber strength from 1998 to 2000 (data not shown). More importantly, values for fiber strength for each year were in the average to high range regardless of row spacing or mepiquat chloride treatment. In 1999 and 2000, fiber strength was above 29.5 g tex^{-1} and in the premium range in most cases. Heitholt et al. (1993) reported no differences in fiber strength due to row spacing. Fiber strength is largely determined by genotype such that cultivars with the highest strength tend to produce longer cellulose molecules providing fewer break points in the lint and greater cross linkages between fibers (Jordan, 2001).

CONCLUSIONS

Plant height and the number of plant nodes were reduced by applications of mepiquat chloride. The height-to-node ratio was highest in plots receiving no mepiquat chloride. Cotton grown in narrow rows had higher seed cotton yields than cotton produced in 76-cm rows; however, gin turnout was lower in narrow row spacings, thus negating any seed cotton yield advantage. As a result, lint yields were similar for the various row spacings. Overall, reduced row spacing and mepiquat chloride application did not lower fiber quality. In some years, micronaire was reduced in narrow row spacings; however, values were in the typical ranges and did not warrant discounts or premiums for grade. Although mepiquat chloride applications did not increase yield in most years, its use is desirable in ultra-narrow row cotton production to control crop growth for efficient harvest, especially on fields with a history of excessive vegetative growth. Data from this study suggest mepiquat chloride applied at 0.58 L ha^{-1} during pinhead square followed by a second application at the same rate approximately two weeks later was effective in controlling excessive vegetative growth and increased yield in one year out of three. In regard to lint yield and fiber quality, ultra-narrow row systems appeared to be a viable alternative for cotton production in the Mississippi Delta.

ACKNOWLEDGMENT

This research was supported by Cotton Incorporated project 98-568MS.

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