Effects of 1,1-Dimethylpiperidinium Chloride on the Yields, Agronomic Traits, and Allelochemicals of Cotton (*Gossypium hirsutum* L.), a Nine Year Study

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The synthetic plant growth regulator 1,1-dimethylpiperdinium chloride (mepiquat chloride, PIX) has been used worldwide to control plant height in cereals and other crops such as cotton (*Gossypium hirsutum* L.) over the past 15 years. In cotton, its major effect is to shorten internodes, and the result is a more compact, darker green plant. Its effect on yield has varied from season to season with small decreases as the norm. However, its continued use may still be indicated because of decreased exposure of the crop to insects and enhanced maturity (earliness). During the study period at Mississippi State from 1982 through 1992 on three different varieties, yield was reduced by 6.6 and 17.0% at the low and high application rates, respectively. Lint percent was reduced by 1.7%, while boll size and seed index were increased by 5.7 and 6.1%, respectively. Several established cotton insect allelochemicals were analyzed each year. During the period, bud (square) gossypol was increased by 10.9 and 13.7%, tannins were decreased by 1.4 and 2.6%, and flavonoids were decreased by 1.0 and 6.0% at the low and high levels, respectively.

Keywords: *PIX; plant growth regulator; mepiquat chloride; cotton yield*

INTRODUCTION

Since the early 1960s, the use of "onium" compounds, beginning with the lead structure (2-chloroethyl)trimethylammonium chloride (CCC) and its progression to 1,1-dimethylpiperdinium chloride (mepiquat chloride, PIX; BASF, Ludwigshafen, Germany), has been of great importance in controlling plant height in cereals and other crops such as cotton (*Gossypium hirsutum* L.) (Sauter, 1984; Jung, 1984). PIX has been tested extensively on cotton over the past 15 years by us and others (Zummo et al., 1983; Ganyard, 1982; Hedin et al., 1984, 1988a,b) and is now widely used commercially. Its major effect is to induce internode shortening, which is visibly apparent, and the result is a more compact, darker green plant (Namken and Gausman, 1978). Its effect on yield has varied from season to season with both increases and decreases observed, in part, evidently, because of differences in environment (Zummo et al., 1983; Hedin et al., 1984, 1988a,b). There have been a number of reports about the effects of PIX on insect pests of cotton. Zummo et al. (1983) reported less damage, decreased bollworm [*Helicoverpa zea* (Boddie)] growth, and 10–20% increased terpenoids, tannins, and astringency in a Texas field plot test. Ganyard (1982) in North Carolina observed a 23% decrease in bollworm damage in PIX-treated cotton.

Since 1982, we have conducted field tests with PIX and a number of other candidate plant growth regulators each year, recording yield of cotton, agronomic traits, and the content of known allelochemicals to cotton insect pests (Hedin et al., 1984, 1988a,b; Hedin and McCarty, 1991; McCarty et al., 1987; McCarty and Hedin, 1989; Graham et al., 1987; Jenkins et al., 1987; Mulrooney et al., 1985). We have continued these tests since the above-noted reports through the 1992 crop year. Because the treatments with PIX appeared to have a slightly adverse effect on yield over the years, it was believed of interest to summarize both the previously reported data and the recent data to obtain more quantitative information about yield. The data obtained from analysis of leaves, squares (buds), and seed for the major allelochemicals, gossypol, flavonoids, condensed tannins, and anthocyanin, are also reported. These allelochemicals have been shown to be toxic to the tobacco budworm [*Heliothis virescens* (F.)], a major pest of cotton, and therefore could be associated with yield (Hedin et al., 1984, 1988a,b).

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MATERIALS AND METHODS

1982–1992 Bioregulator Field Tests. The commercial cotton cultivars Stoneville 213 (ST-213), Deltapine 50 (DPL-50), and DES-119, well adapted for the study area, were grown each year on the North Farm at Mississippi State University. The cotton was planted each year on or about May 1 in single-row [0.97 × 12.8 m (W × L)] plots. Insects were controlled all season with fenvalerate (DuPont Agricultural Products, Wilmington, DE) and Cythion (American Cyanamid, Princeton, NJ). The growth regulator formulations were applied at three rates (zero, low, high; see Table 1 for rates) to plants whose squares were "match head" in size and 2 weeks later (about the first and third weeks of July each year). In some instances, three or four applications were made. The experimental design was a randomized complete block with five replications.

The timing of applications and rates were in general those recommended by previous investigators or the manufacturer (Hedin et al., 1988a,b). Two rates, with the second application generally 3-fold higher, were used to improve the likelihood that a response would be elicited. The PIX formulation (a gift from BASF) was measured and dissolved in 5–10 mL of H_2O. One milliliter each of Span 80 and Tween 80 was then added. The solutions were made up to 1.25 L with water just before use. The PIX was applied with a CO_2-pressurized backpack sprayer delivering 203 L/ha at 207 kPa of pressure. For allelochemical analyses, plant material (terminal leaves and squares) was collected 2 and 4 weeks after the first application (about July 31 and August 14) in an attempt to observe greatest effects and placed in the freezer (−20 °C) until processed.

Table 1. Changes in Yields, Lint Percent, Boll Size, and Seed Index of Cotton Plants Treated with PIX[a–d]

year	cultivar	yield of control, kg/ha	yield, % low	yield, % high	lint % low	lint % high	boll size low	boll size high	seed index low	seed index high
1984–1985	ST-213	1858	+0.6	−2.8	−0.5	−1.0	0.0	−1.6	0.0	+0.9
1986	ST-213	1441	−17.1	−36.4						
1987	DPL-50	1623	−12.9	−5.3	−1.2	−1.1	+1.9	+7.5	+1.0	+5.1
1988	DPL-50	1386	+16.7	+7.6	−0.8	−0.7	−1.8	+5.4	+5.9	+6.9
1989	DPL-50	1212	+3.6	−7.7	−0.6	−2.0	+7.0	+5.3	+5.7	+6.7
1990 (2 applications)	DPL-50	1528	−4.8	−12.3	−0.2	−1.0	+4.3	+4.3	+5.5	+11.0
1990 (3 applications)	DPL-50	1269	−7.5	−21.5	−1.9	−2.9	+8.3	+12.5		
1991 (2 applications)	DES-119	1447	−17.6	−25.0	−1.0	−1.7	−9.8	−3.9		
1991 (4 applications)	DPL-50	1939	−6.6	−12.3	−0.8	−1.5	+3.5	+7.0		
1992	DPL-50	1150	−4.4	−26.0	−0.8	−2.3	+8.3	+10.4		
1992	DES-119	1084	−16.8	−45.1	−2.2	−2.8	−2.1	0.0		
av		1400	−6.6	−17.0	−1.0	−1.7	+1.8	+5.7	+3.6	+6.1

[a] Percent changes of yield, boll size, and seed index were from the control. Change in Lint percent is reported as numerical change. [b] Over the 1984–1992 period, the average Lint percent, boll size, and seed index were 39.2, 5.3, and 10.1, respectively. [c] Rates and numbers of applications: 1984–1986, 50 × 2 and 100 × 2 g ha^{-1} ai; 1987–1992, 14.9 × 2 and 46.7 × 2 g ha^{-1} ai; 1990 (one test), 14.9 × 3 and 46.7 × 3 g ha^{-1} ai; 1992 (one test), 7.5 × 4 and 23.4 × 4 g ha^{-1} ai. [d] Boll size is expressed as grams per boll, lint percentage is the percent of seed cotton that is lint, and seed index is the weight in grams of 100 fuzzy seeds.

Table 2. Percent Changes in Bud Allelochemicals of PIX-Treated Cottons[a,b]

year	cultivar	gossypol, % low	gossypol, % high	tannins, % low	tannins, % high	flavonoids, % low	flavonoids, % high
1982	ST-213	+14.3	+42.9	+0.9	−10.5	−11.1	−18.3
1986	ST-213	+44.4	+48.1	−10.0	−9.4	−2.7	−11.8
1987	DPL-50	+16.7	+11.1				
1988	DPL-50	+2.0	+4.1	+14.3	+16.9	+9.2	+6.0
1989	DPL-50	0.0	+11.7	+6.9	+1.7	+1.4	−5.1
1990 (2 applications)	DPL-50	+16.2	+11.6	−7.1	−12.8	+12.2	+3.0
1990 (3 applications)	DPL-50	+5.7	+2.9	+1.9	+5.0	+1.0	−2.0
1991 (2 applications)	DES-119	−6.2	−6.2			−9.7	−9.0
1991 (4 applications)	DPL-50	+5.4	−2.7	−16.4	−9.3	−8.1	−10.8
1992	DPL-50						
1992	DPL-50						
1992	DES-119						
av change		+10.9	+13.7	−1.4	−2.6	−1.0	−6.0

[a] Average content of controls, 1982–1992: gossypol, 0.32%; tannins, 11.99%; flavonoids, 1.78%. [b] See Table 1 for rates and number of applications.

The plots were machine harvested one time for yield determination on about September 30. A defoliant (in recent years, Dropp, NOR-AM Chemical Co., Wilmington, DE) was applied if required for efficient harvesting. Prior to machine harvest, 25 open bolls were hand harvested from each plot, weighed, and ginned to determine boll size, lint percentage, and seed index. Boll size is expressed as grams per boll, lint percentage is the percent of seed cotton that is lint, and seed index is the weight in grams of 100 fuzzy seeds. The lint percentage determined was used in calculating lint yields.

Analysis of Allelochemicals. Plant tissue [ca. 25 terminal leaves and 25 squares (buds)] from each replication was collected, freeze-dried, and ground prior to allelochemical analysis. Analysis of allelochemicals (gossypol, tannin, anthocyanin, flavonoid) was conducted following the procedures described by Hedin et al. (1988a).

Statistical Procedures. Data obtained from the various analyses and measurements were subjected to the analysis of variance, and (lsd) values were calculated according to SAS (1985) methods.

RESULTS AND DISCUSSION

Table 1 presents a summary of changes in yields and agronomic traits of cotton treated with PIX from 1984 through 1992. Table 2 presents a summary of changes of three cotton plant allelochemicals for insects (gossypol, condensed tannins, and flavonoids) in the cottons treated with PIX from 1982 through 1991. This information was compiled from statistically analyzed data. It must be conceded that experimental conditions (i.e., rate, number of applications, cultivars, climate) varied over the 9 year period. While this may limit our ability to make rigorous comparisons, obvious efficacy would nevertheless be apparent.

Over the study period, the average yield of controls was 1400 kg ha^{-1}, and the average lint percent, boll size, and seed index were 39.2, 5.3, and 10.1, respectively (see Table 1). The average contents of bud allelochemicals for the controls during the period were as follows: gossypol, 0.32%; tannins, 11.99%; and flavonoids, 1.78%. Perhaps the most pertinent information obtained from the study (Table 1) is that yields were decreased in most years as a result of treatment with PIX and that higher levels of treatment caused greater yield decreases (17%) than did the lower levels (6.6%). Other information provided in Table 1 shows that lint percent was decreased by 1.7% on average, while boll size and seed index were increased by 4.7 and 6.1%, respectively.

The gossypol content of squares was increased over the period by an average of 10.9 and 13.7% at the low and high levels, while condensed tannins were decreased by 1.4 and 2.6% and the flavonoids were decreased by 1.0 and 6.0% over the period (Table 2). Except for the large increases in gossypol in 1982 and 1986, the overall effect of PIX on gossypol appears to have been minimal. Percent changes of allelochemicals in leaves were generally small and parallel to those of squares; consequently, they are not listed.

The major plant growth responses to PIX are decreased plant height, decreased leaf area index, early maturation, and generally higher boll load on low branches (Hayes, 1993). Excessive vegetative growth is not a problem in all environments, and early maturation is not a benefit in some environments. Therefore, no uniform response to PIX across the entire cotton belt is observed. The full-season cotton yield response to PIX has been variable; however, during short growing seasons, the maturity enhancement alone may justify the application of PIX. Hayes (1993) reported about 5 days of earliness due to treatment with PIX. Earliness can be important in a pest management system since insects do not have to be controlled as long. Earliness also is important if it allows the harvest of the crop to begin sooner, usually under more favorable environmental conditions. Tracy and Sappenfield (1992) reported that it was beneficial to irrigate and apply PIX to cotton grown in Missouri in 2 years of 3. On the basis of their results, they encouraged Missouri cotton growers to use PIX. In summary, our results suggest that the several cultural advantages of PIX have a yield cost, so cotton should be treated at the lowest effective level (variable across environments) that will give adequate internode shortening while conserving yield.

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