PIX MANAGEMENT STRATEGIES FOR *BT* CULTIVARS IN THE COASTAL PLAINS OF TEXAS

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Abstract

In 1996, cotton (*Gossypium hirsutum* L.) cultivars expressing the *Bacillus thuringiensis* (*Bt*) toxin gene were introduced commercially. These transgenic varieties revolutionized crop production by controlling some lepidopteran pests with limited additional pesticide applications. However, these transgenic plants also experience rank vegetative growth. Crop simulation models currently estimate the effects of mepiquat chloride (MC) [1,1-dimethylpiperidinium chloride], tradename Pix, on main stem elongation and leaf area expansion rates for non-transgenic varieties. Transgenic plants, such as *Bt* cultivars, may behave differently to applications of mepiquat chloride than their non-transgenic counterparts. In addition, more MC may be required to control the excess vegetative growth of these varieties. To test these hypotheses, a field study was performed involving variable MC application rates. Pix (4.2 % mepiquat chloride) was applied near match-head square in a single application at the following rates: 5, 10, 15, and 20 oz/A. Data collected included the following weekly measurements: plant height, number of main stem nodes, average top 5 internode length, and total plant dry weight. Significant differences in plant height were observed between MC application rates. In addition, a regression model (R^2=0.80) was developed relating plant height to the calculated MC concentration of the plant tissue. The model developed for the *Bt* cultivar NuCOTN 33^B is similar to the MC height model devised for a non-transgenic variety (DPL 50). Therefore, we concluded that transgenic and non-transgenic cotton plants respond similarly to mepiquat chloride.

Introduction

In 1996, the *Bacillus thuringiensis* (*Bt*) toxin gene revolutionized the cotton industry by providing an alternative to producers for lepidopteran pest control. The *Bt* cultivar proved especially important in controlling tobacco budworm (*Heliothis virescens*), cotton bollworm (*Helicoverpo zea*), and pink bollworm (*Pectinophora gossypiella*) (Deaton 1995). Transgenic plants are formed by transferring genes from one organism to another. In cotton, Coker 312 is crossed with DPL 15 and Coker 100 W for transforming genes (Trolinder 1996). Coker 312 is a highly embryonic variety. Furthermore, all of the previously mentioned varieties exhibit rank vegetative growth. The transformed cotton behaves similarly to its parents with respect to vegetative growth. *Bt* varieties grown on fertile, irrigated soils require higher mepiquat chloride application rates due to their vigor (Jones, et al. 1996). Mitchener (1996) reported that NuCOTN 33^B, a commercial *Bt* cultivar, tended to grow too tall and used energy stolen from the fruit. He also stated that MC should be used judiciously in order to keep internode length below 3 inches. In 1997, a panel of experts gathered to organize *Bt* management strategies. They recommend the following MC application schedule: 6 to 8 oz/A at pinhead square; 10 to 12 oz/A at first bloom depending on growth rate; and 10 to 12 oz/A 10 to 14 days later, if needed (Wrona, et al. 1997).

For non-transgenic varieties, Pix has been used commercially to control excess vegetative growth. The active ingredient of Pix which provides the height control is mepiquat chloride (1,1-dimethylpiperidinium chloride). Landivar, et. al (1995) developed a regression model relating plant height to the internal plant mepiquat chloride concentration for DPL 50. They discovered that reduced plant height caused by MC diminishes at concentrations lower than 5 ppm. In addition, the effect of MC on height is negligible for concentrations in excess of 20 ppm. The optimum range of mepiquat chloride for height control lies between 10 and 12 ppm. Reddy, et al. (1995) proposed another model relating elongation rate to mepiquat chloride concentration. They reported an inverse linear relationship between the elongation rate and MC concentration.

Because *Bt* cultivars exhibit excess vegetative growth similar to their parents, the models developed for non-transgenic varieties may not express the relationship between height and MC concentration for transformed plants. Perhaps concentrations above the 10 to 12 optimum range will be necessary to control the rank vegetative growth of transgenic cultivars, such as *Bt* cotton. The objective of this study is to determine a relationship between mepiquat chloride concentration and main stem elongation in order to test the effects of variable application rates of mepiquat chloride on the *Bt* cultivar. In addition, the results of this experiment will be compared to a previous model for a non-transgenic variety.

Materials and Methods

To test the response of *Bt* cotton (*Gossypium hirsutum* L.) to variable applications of mepiquat chloride, a field experiment was conducted at the Texas A&M Agricultural Research and Experiment Station in Corpus Christi, Texas during the 1997 growing season. The cultivar NuCOTN 33^B was planted at a 38 in. row spacing and a density of 5 plants per ft. Plots were fertilized and drip irrigated to prevent water and nutrient stress.

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Five treatments were established based on the application rate of mepiquat chloride (1,1-dimethylpiperidinium chloride). The plots were arranged in a completely randomized block design. Each treatment was replicated four times. A week after matchhead square, Pix (4.2% MC) was applied to the plots with a backpack sprayer. The application rates for the treatments included the following: 5, 10, 15, and 20 oz/A. In addition to these four application rates, a control which did not receive mepiquat chloride was established.

Data collection for this experiment consisted of weekly measurements of height, number of main stem nodes, and the top 5 internode length (ALT 5). These measurements were collected for 6 weeks. In addition to these measurements, 6 plants were analyzed for dry weight every 7 days for 6 weeks. Samples were separated into leaves, stem, and fruit, and placed in a 45°C oven to dry.

To determine the effect of variable application rates of MC on height, the MC concentration in ppm (g/A MC per 10^6 g/A biomass) was calculated. Root weight was estimated to be approximately equal to the stem dry weight. The total plant dry weight was equivalent to the sum of the shoot dry weight and the root estimate. The plant MC concentration was calculated by dividing the total plant weight into the amount of MC applied per acre on a broadcast basis. Finally, the response to MC concentration on height was compared to the height of the control. Data for this field experiment were analyzed using ANOVA, Fisher LSD, and non-linear regression.

Results and Discussion

Data analyzed in this experiment indicate that the *Bt* cultivar, NuCOTN 33[B], responded similarly to mepiquat chloride as non-transgenic varieties. According to the analysis, the appplication rate of MC significantly affected the plant height. The greatest plant height was observed in the control treatment. These plants reached heights approaching 110 cm 28 days after the single MC application. Seven days after the application, the control was significantly taller than all other treatment groups. Within 14 days, the 5 oz/A MC treatment was significantly taller than the lower MC concentrations, but shorter than the control. On Day 21, the final effect of mepiquat chloride concentration on the height of plants was observed. A decline in height was observed between the control and the 15 oz/A MC. However, the 15 and 20 oz/A MC rates were not significantly different. This indicates that the maximum height reduction is achieved with 15 oz/A MC. Plant height data is summarized in Table 1.

Similar to height, the application rate also significantly influenced the average length of the top five internodes. This value, commonly called the ALT 5, demonstrates the growth rate of the plants. On day 7, all plants showed similar ALT 5 values. Fourteen days after the application, significantly higher average internode length was observed with the control; all other treatments yielded ALT 5 values close to 1.7. A week later, a significant increase between the 5 oz/A MC rate and the other treatments was observed. The final ALT 5 measurement showed that the control and 5 oz/A MC rate were similar. In addition, the 20 and 15 oz/A MC application rates were identical. This pattern is reminiscent of the height pattern observed in Table 1. By day 28, the treatment groups all exhibited a rapid increase in internode length from the previous week. This rapid increase in growth rate is attributed to the decline in internal MC concentration. The average length for the top 5 internodes is illustrated in Table 2.

Figure 1 shows the concentration curves for mepiquat chloride over the course of the experiment. Concentrations were determined by dividing the grams of MC applied per acre by million grams of biomass per acre. On the day of the application, concentrations ranged from 0 (the control) to approximately 60 ppm (20 oz/A). Concentrations declined over time for each of the treatments. By 28 days after the mepiquat chloride application, all treatments showed concentrations close to 5 ppm. Research has shown that MC concentrations below 5 ppm do not reduce main stem elongation rates. The rapid increase in growth rate indicated by the rise in ALT 5 for day 28 is probably an effect of the low (< 5 ppm) MC concentration at that time.

The model describing the effect of mepiquat chloride on the height is illustrated in Figure 2. The dependent variable is the ratio of the height observed for the treatment compared to the height of the control. Increasing the mepiquat chloride concentration from 0 to 5 ppm resulted in plants which were 65% as tall as the control. An MC concentration of 10 ppm reduced height to approximately 45% of the control; meanwhile, a 12 ppm MC concentration produced plants approximately 44% as tall as the control. In addition, the model is relatively flat when mepiquat chloride concentrations exceed 15 ppm. This indicates that concentrations above 15 ppm do not reduce growth below the 34% level. The regression model developed for the *Bt* cultivar is very similar to a previous model developed for DPL 50 by Landivar, et al. in 1995 (Figure 3). Because the two models are very similar, mepiquat chloride management strategies for the *Bt* cultivar are not different from the non-transgenic DPL 50.

Conclusions

According to the regression model, *Bacillus thuringiensis* (*Bt*) cotton cultivars respond similarly to mepiquat chloride as non-transformed varieties. The optimum MC level required for cost effective height reduction lies within the 10 to 12 ppm range. The maximum height reduction from MC is achieved with concentrations less than 15 ppm. Furthermore, the effects of mepiquat chloride on height diminish for internal concentrations less than 5 ppm. The results of this experiment verify earlier regression equations describing the effect of MC on main stem elongation. *Bt* cultivars exhibit the rank growth habits of the Coker 312 parent; however, they respond to a mepiquat chloride regression model similarly to a non-transgenic variety. The results of this field test illustrate that vegetative management through mepiquat chloride applications is not different for transgenic cotton varieties. Current management techniques for height reduction are practical for transgenic cultivars; however, closer monitoring of these varieties may be required. The results of this experiment should be verified with additional field tests across the Cotton Belt. Specifically, a side-by-side comparison of transgenic and non-transgenic cultivars should be studied.

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Table 1. Plant height (cm) as influenced by mepiquat chloride application rate.

OZ/A	DAY 0	DAY 7	DAY 14	DAY 21	DAY 28
0	44.6 b*	62.6 a	78.1 a	95.2 a	109.3 a
5	46.1 b	56.9 b	66.5 b	79.1 b	92.9 b
10	47.7 ab	55.0 b	62.8 c	75.4 c	85.4 c
15	50.0 a	56.5 b	60.6 c	69.4 d	76.8 d
20	49.8 a	55.5 b	60.1 c	68.6 d	80.3 d

*Means followed by the same letter are not significantly different. LSD = 0.05

Table 2. Average length of the top 5 internodes (ALT 5) as influenced by mepiquat chloride application rate.

OZ/A	DAY 7	DAY 14	DAY 21	DAY 28
0	2.1	2.2 a*	2.3 a	2.3 a
5	2.1	1.7 b	1.6 b	2.3 a
10	2.0	1.7 b	1.4 c	1.8 b
15	2.2	1.7 b	1.3 c	1.5 c
20	2.1	1.8 b	1.2 d	1.5 c

*Means followed by the same letter are not significantly different. LSD = 0.05

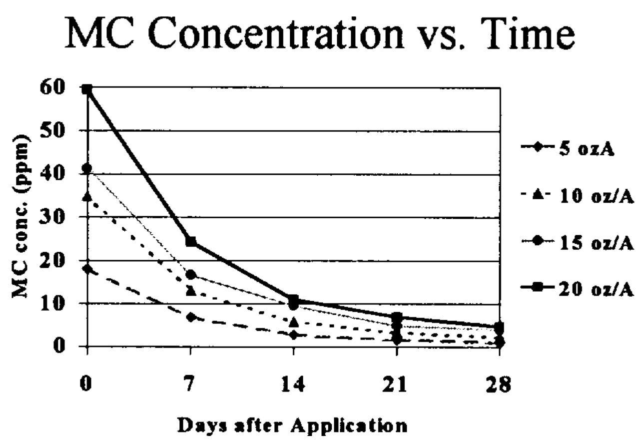

Figure 1. Calculated MC concentration of plant tissue based on the application rate.

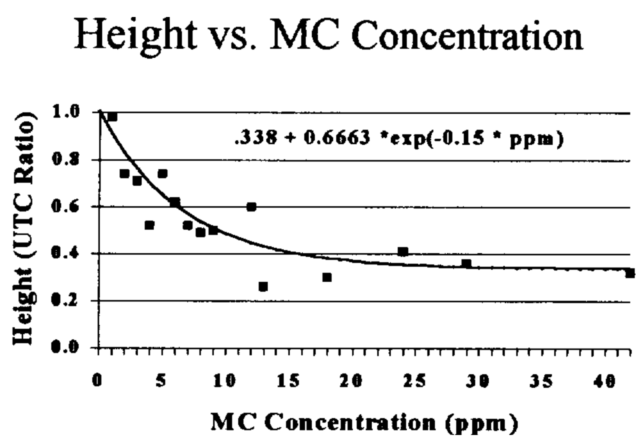

Figure 2. Regression model for height as influenced by the MC concentration.

R^2=0.80

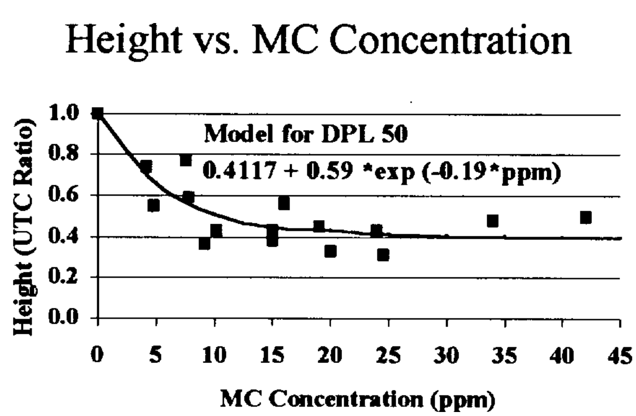

Figure 3. Regression model for height as influenced by the MC concentration.

Landivar, et al. 1995.
R^2=0.82