REAL TIME VARIABLE RATE PIX APPLICATION

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Abstract

A real-time variable rate Pix application system that integrated an optical plant height sensor, the MEPRT (**MEP**iquat Chloride **R**ate and **T**iming) relationships, and a chemical rate controller was developed. The height sensor used an array of light beams that were either blocked or unblocked by the plants. The height estimate was calculated from the histogram of the blocked beams. The height estimate along with the operator supplied average plant density and number of nodes was used in the MEPRT relationships to predict the optimal Pix application rate. The desired rate for an area of the field was transmitted to the chemical rate controller for application to the measured plants.

Pix was applied using a paired observation design of alternating variable and uniform application rates in two 20-acre fields. The variable application rate was based on the developed system and the uniform application rate was calculated using the operator observed average plant height. The average application rate from the variable blocks were greater than the uniform blocks in Field A, but lower in Field B. At the time of variable application, the plant height throughout the field was systematically overestimated by 7 cm, resulting in over-application of Pix.

Four rows received no Pix application the entire season. These rows were used as a control to compare the treatments. Yield differences between the treatment and control were calculated for seed cotton yields in Field B and lint and seed in Field A. No statistical difference was observed between the treatment blocks.

Introduction

Cotton is a plant that requires many decisions to produce a crop. From planting until harvest time, chemicals are applied to aid and regulate the growth of the plants. In a conventionally farmed field, uniform application rates of all chemicals are usually applied to the entire field based on average field conditions. Unfortunately, considerable variability in plant development and size can occur in many agricultural fields. Minimizing this variability can be advantageous especially with insect management, crop termination (Cothren and Oosterhuis, 1993) and final harvest.

Mepiquat chloride (Pix®) is a growth regulator commonly used in cotton production to control the vegetative growth in cotton plants. The effect of Pix on plant growth and yield has been studied extensively. Studies have shown that vegetative growth is suppressed but the effect on yield is inconsistent. Landivar (1998) suggests that one reason for the inconsistent yield response is the unpredictable nature of weather conditions. Weather conditions after Pix application has a large influence on final lint yield. Dry and/or cool weather conditions often results in excessive inhibition of vegetative growth, whereas wet and/or warm weather conditions may require additional applications to obtain the desired plant size. In either scenario, lint yields are often reduced. However, York (1983) found a positive yield response to Pix in North Carolina when weather conditions favored excessive vegetative growth.

Research has recently been conducted to determine if variable rate application of Pix will produce more consistent yield results than a standard, uniform application. Comparison studies showed mixed results. Thurman and Heiniger (1998) conducted intensive grid sampling of a cotton field in North Carolina at two resolutions (0.75 ac/sample and 0.25 ac/sample). They found that random sampling, as practiced by crop consultants, underestimated the variability of plant height within the field. They concluded that plant height variability was great enough to justify variable rate application of Pix. Munier et al. (1994) compared variable applications to fixed rates on California cotton fields and found a fixed rate to provide a better economic return. A sprayer operator who judged the plant size and turned on appropriate nozzles determined the variable application. Thurman and Heiniger (1999) used aerial photography, soil surveys and field history to determine areas of slow and fast growing plants. Pix was applied in uniform and soil-specific rates. They found that the variable treatments had a 45.3-65.8 lb/ac yield advantage over the uniform treatment. The uniform application resulted in an undesirable height variability increase.

Research conducted at the Texas Agricultural Experiment Station in Corpus Christi showed that maintaining the plant concentration of Pix in the 10-12 ppm range resulted in an adequate regulation of vegetative growth (Landivar et al., 1992, Landivar et al., 1995). Empirical relationships, such as those in the MEPRT (**MEP**iquat Chloride **R**ate and **T**iming) software, use plant density, number of mainstem nodes and plant height to estimate plant biomass. Knowing the plant biomass, the optimal Pix application rate can be calculated for the plant. One limitation of using the MEPRT relationships is the period for which the Pix application rate estimations are true. The linear relationships between plant height and biomass is only accurate from the time of square initiation until the development of fruit load. Attempting to use these relationships outside of this time range will result in incorrect application rates (Landivar, 1998).

Stewart (1998) began work using an optical height sensor for variable rate Pix application at Texas A&M. The original system recorded the light curtain status throughout the field, and compared the output to hand measurements of plant height. An equation based on the top sensor beam blocked and the days after emergence was developed to predict the plant height. This sensor height map was used to create a variable rate Pix application map. Using the Rockwell Vision System and a variable rate controller, Pix was applied according to the application map. This initial system required two passes through the field to accomplish the Pix application, one for measuring the height, and another for applying the Pix from the map that was developed from the height map. Integrating the system to require only one pass through the field would reduce time spent in the field and costs for fuel.

Objectives

1. Design a real-time variable rate Pix application system.
2. Evaluate the effect of Pix in uniform and variable applications in two fields.

Materials and Methods

Variable Rate Application System

The variable rate application system incorporated a plant height sensor, the MEPRT relationships, and a chemical rate controller. The system program was loaded and executed on a Wag Vision Control Device (VCD). The communication of the instrumentation with VCD was performed through serial communication. The plant height sensor data was an input into the VCD and the desired and actual application rates of the rate controller were transmitted and received, respectively. The program running on the VCD included the height estimation algorithm, MEPRT relationships and determination of the necessary chemical flow rate. Data from all the instruments was recorded on a PCMCIA card.

The plant height sensor consisted of an array of infrared light beams, and was mounted on the front of a high-clearance sprayer (Figure 1). As the

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plants passed through the light curtain of beams, some beams were blocked. Figure 2 illustrates the application of the light curtain with a cotton plant. The transmitter and receiver bars of the sensor were positioned to scan across two rows of cotton. This setup reduced the sensitivity to the variations in a single row of cotton. The array was 40 beams spaced 0.75 inches apart, and was scanned 190 times per second. Each scan resulted in 40 values of 1 or 0, depending on if the beam was blocked or not. By summing these scans over the one-second period, a histogram was created where each bar represented the portion of time that beam was blocked. The histogram characterized the vegetative growth pattern of the cotton plants that were driven past during that period. Figure 3 is a theoretical example of the blocked beam histogram. Using this histogram, the beam with the maximum number of beams blocked was found (M). This beam indicated where the densest plant vegetation was present. The beam representing the plant height should always occur above beam M. The highest beam number (A) with more than 75% blocked transmissions and the lowest beam number (B) with less than 25% blocked transmissions are located. The average beam (H) between these two beams was used to estimate the height to the terminal bud of the plants. Figure 4 shows actual blocked beam histograms recorded in 1999.

Using the operator-provided plant density and number of nodes along with the measured plant height, the built-in MEPRT software predicts the desired Pix application rate for the section of row. The desired rate was communicated to the variable rate controller every second. The controller responds with the actual rate as it constantly adjusts to match the desired rate.

A Raven SCS 750 rate controller was used to regulate the flow of the main tank and five possible injection modules. Testing was conducted to determine the lag time when using one injection module to deliver the desired chemical. Driving 8.0 km/h (5 mi/h) and applying 15 gal/ac of carrier fluid, the delay before changing the concentration at the nozzle was 41 seconds, or 91.6 m (301 ft) of travel. This lengthy delay was clearly unacceptable. To avoid this delay, the Pix was mixed directly in the main tank.

Design and Experiments

Two fields at the Texas A&M University research farm in Burleson County were used to test the effect of variable and uniform Pix applications. Both fields were rectangular 20-acre fields. Field A was a production cotton field used for several years. Field B was planted in cotton for the first time in 2000. Both fields were first planted in early April. On May 1, a storm with hail, high winds, and heavy rainfall destroyed the cotton crop. All cotton was replanted again in mid-May. The majority of the rain for the season fell during May and tapered off as the summer progressed. Unfortunately, Field B was irrigated twice and Field A was only irrigated once all season. This contributed to less vegetative growth than in previous years.

The first Pix Plus application was at pinhead square growth stage, 41 days after emergence. Since no visible difference in plant height across the fields was noticed, both fields were applied a uniform 8-oz application. Four control rows per pass were not sprayed for future comparisons. Within 2-4 hours after the application, a heavy rainstorm passed over the farm. Based on the time elapsed, it was concluded that no Pix, or minimal Pix, had been absorbed by the plants. Four days later, another 8-oz application of Pix Plus was reapplied to both fields.

The second Pix application date was determined to be at first white flower growth stage. This stage occurred 57 days after emergence. Before the application, plant height was recorded twice across the fields. For every pass, height measurements were recorded for two rows that received Pix and two control rows. Every three feet down the pass, average plant height measurements to the terminal bud were estimated. Thirty readings were recorded to verify the accuracy of the optical height sensor.

The second Pix application used alternating variable and uniform application rates. The application rate for the variable passes was determined by the real-time variable rate system. The uniform passes were applied the average rate predicted within MEPRT using the sensed plant heights. The same four control rows were maintained in this application for continued comparison. Figure 5 shows the experimental design used in the two fields. With the row configuration in the fields, Field A had five paired blocks and Field B had seven paired blocks.

The fields were harvested in mid-September using a 4-row cotton picker. Field B was harvested first. After each pass in the field, the harvested cotton was measured with a weighing boll buggy. In addition, a sample bag from each pass in Field A were collected and ginned for seed and lint turn out percentages. These percentages were applied to the entire picked basket for analysis.

Plant mapping data was collected at the pinhead square and first white flower growth stages and immediately before harvest. Plants were removed from the field and mapped in the lab. Two locations in each block were sampled for both the Pix applied and control rows. However, this data has not been completely analyzed and is not included in this report.

Results

Variable Rate Application System

The real-time variable rate application system was only used during the second Pix application. Only the height sensor was tested two weeks before the second Pix application. The RMS errors in the sensor estimates of the height were between 2.4 – 6.5 cm (0.94 – 2.56 in). However, during all field measurements collected at first white bloom, the optical height sensor systematically overestimated the actual plant height for all passes (Figure 6); however, the trends down the pass were tracked. This includes the pass made while applying Pix Plus to the cotton. The RMS error was 7.0-14.0 cm for the entire data set. Since this error was consistent, a difference between two measurements could still be calculated. The first two field measurements provided a comparison of the difference in height between the rows applied with Pix and the control rows. Figures 7 and 8 show the plant heights in both fields were typically greater in the control rows than the Pix applied rows. The RMS difference for Field A was 11.9 cm and Field B was 14.7 cm.

Because of the overestimation, the Pix application was higher than desired; however, this inaccuracy was consistent for the uniform and variable blocks. The applied Pix application rates in the uniform blocks of Fields A and B were 4.8 oz/ac and 4.9 oz/ac, respectively (Table 1). Using the real-time variable rate system, the average application rate was desired to be near the uniform application rates. However, for this experiment the average variable application rates in Field A were 6.2-7.1 oz/ac, higher than the average. Average rates in Field B ranged from 4.2-4.7 oz/ac, lower than the uniform application rate. The unexpected application rates can be contributed to formulating an estimated average field height by monitoring the sensor measured heights during the first height measurement. The operator-judged average height was not accurate, even with the benefit of the height sensor.

Yield data was evaluated as paired comparisons. Each treatment replication had a 4 row control included, and the uniform and variable rates were adjacent. The difference in the measured yield between the treatments was calculated and analyzed statistically. The mean seed cotton difference between the treatment and the control in Field B was –47 and –14 lb/ac for the variable and uniform blocks, respectively (Table 2). There was no statistical difference between the paired data. Differences for each block are seen in Figure 9. Yield data for Field A was separated into lint and seed, since the gin turnout percentages were available. The mean lint yield difference was –46 and –10 lb/ac for the variable and uniform blocks, respectively (Table 2). Figure 10 shows the individual lint yield block differences. For the seed yield differences, the same pattern was noticed (Figure 11). The mean differences for the variable and uniform blocks were –82 and –17 lb/ac, respectively. No statistical difference can be determined from either data set. While there was no statistically significant difference in either field, all Pix applications resulted in reduced yield, and the trend was for variable rate application to have a greater reduction.

Summary

The real-time variable rate Pix application system performed as designed. Unfortunately, the plant height was systematically overestimated for the entire application. Over-application of Pix was a consequence of this inaccuracy. However, the Pix application in the variable and uniform blocks was consistent. Comparing the yield difference from each of the blocks, no statistical difference in the method of application was seen in the seed cotton, lint and seed yields.

Since a positive yield gain did not result from the Pix applications, the value of Pix could be questioned. Being a dry season and irrigation minimal, the plants did not grow to their full potential. Field A was also in cotton in 1999, and produced cotton with rank vegetative growth in some areas of the field because the Pix application was inadequate. 2000 was not a good year for evaluating the value of variable rate Pix applications. Further testing under a wider range of growing conditions is needed.

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Table 1. Block mean Pix application rates (oz/ac) for each treatment

Treatment	Field A	Field B
Variable	6.2 - 7.1	4.2 - 4.7
Uniform	4.8	4.9

Table 2. Mean difference between treatment and control yields.

	Field 2	Field 1	
Treatment - Control	Seed Cotton (lb/ac)	Lint (lb/ac)	Seed (lb/ac)
Variable	-47 a	-46 a	-82 a
Uniform	-14 a	-10 a	-17 a

Figure 1. Optical height sensor mounted in front of high-clearance sprayer

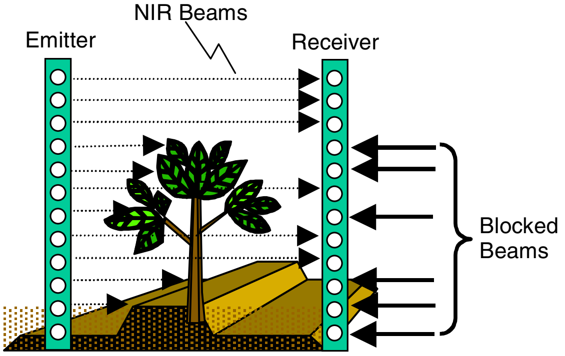

Figure 2. Light curtain with a cotton plant blocking some of the beams.

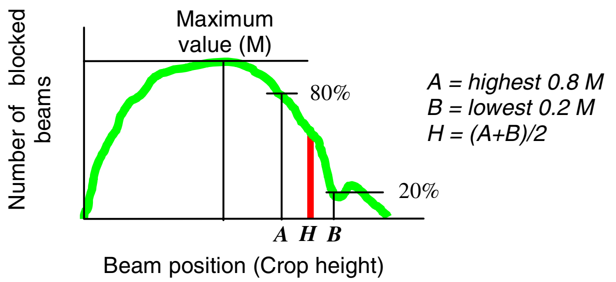

Figure 3. Hypothetical histogram of blocked beam frequency. A, B and H show the points used to estimate the plant height.

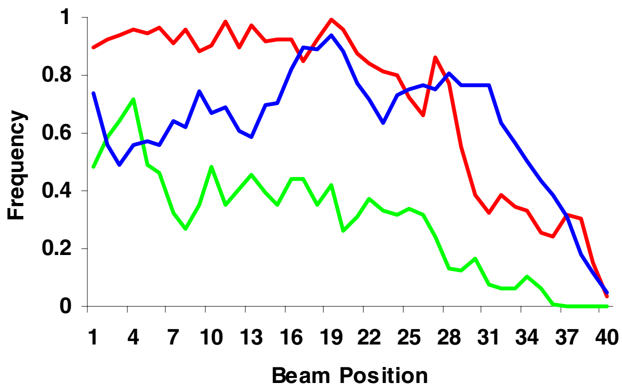

Figure 4. Actual blocked histograms from 1999 data. The histogram shape was not always the same throughout the crop.

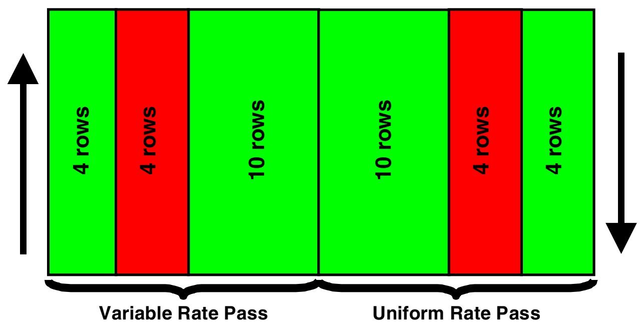

Figure 5. Experimental design used for comparison of treatments. Darker control rows received no Pix during entire season.

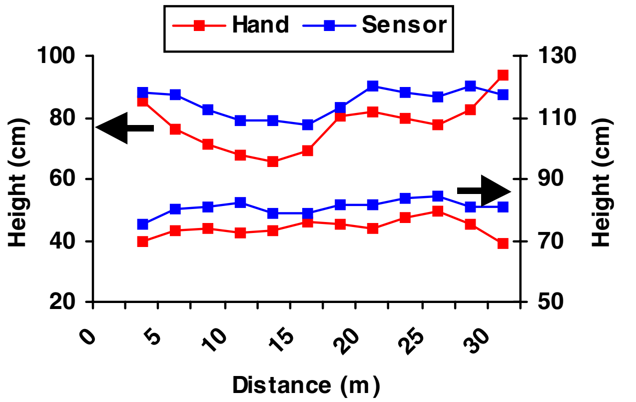

Figure 6. Height measured down the rows at first white flower. The sensor systematically overestimated the height, but continued to follow the trends in the field.

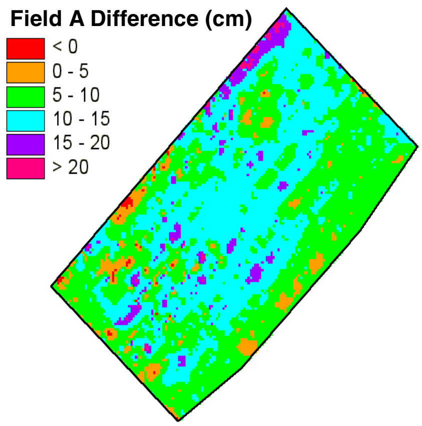

Figure 7. Difference in sensor measured plant height between control and Pix applied rows. The RMS difference was 11.9 cm.

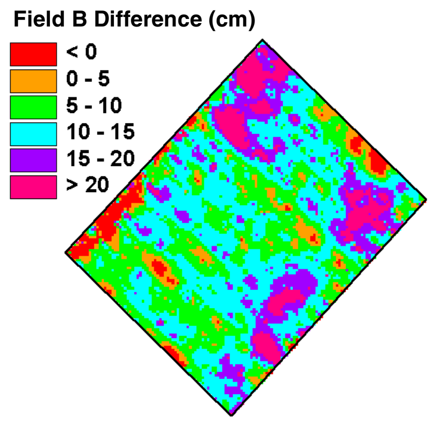

Figure 8. Difference in sensor measured plant height between control and Pix applied rows. The RMS difference was 14.7 cm.

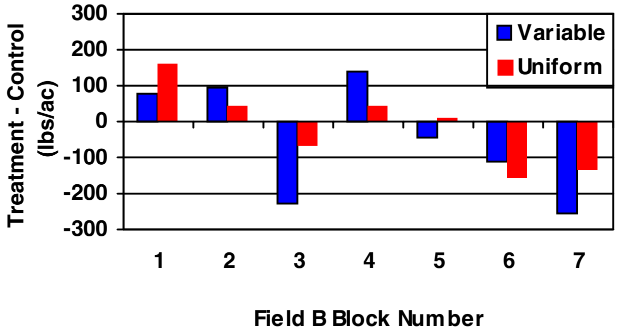

Figure 9. Difference in seed cotton yield for treatments within each block

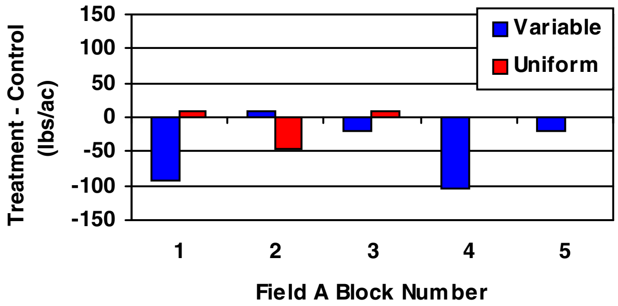

Figure 10. Difference in lint yield for treatments within each block

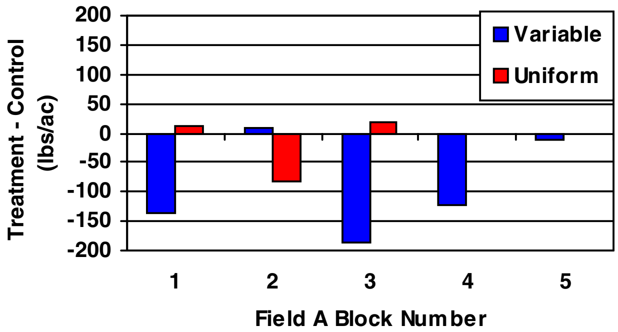

Figure 11. Difference in seed yield for treatments within each block