SENSOR BASED VARIABLE RATE HARVEST AIDS

Randy Taylor
Biosystems and Agricultural Engineering - Oklahoma State University
Stillwater, OK
Shane Osborne
J.C. Banks
Plant and Soil Sciences - Oklahoma State University
Altus, OK

Abstract

Variable rate application of harvest aids could be a cost cutting means for cotton producers in the southern Great Plains. One method that has been proposed for variable rate application is using crop sensors to estimate percent open bolls and current defoliation level. Small plots were used to determine the relationship between the normalized difference vegetative index (NDVI) measured with sensors and the percentage of open bolls and nodes above cracked boll (NACB). This relationship was the basis for a variable rate prescription used in field trials. A cotton field in southwest Oklahoma was divided into three replications of four plots. This was a 2x2 factorial experiment with application method (uniform/variable) and input (PGR/DEF) as the treatments. This combination resulted in four test plots and allowed possible interaction of variable rate PGR and defoliant. This study was conducted on one field in 2008 and two fields in 2009. There was no significant difference in yield for any site/year. Averaged across the three site/years, the variable rate treatment resulted in 7 percent less PGR and 8 percent less DEF being prescribed. Though no measurements were made, there was no discernable difference in the efficacy of uniform and variable applications.

Introduction

Cotton is a perennial plant and unique in nature. For cotton, vegetative and reproductive growth occurs simultaneously. Although vegetative growth is necessary to support reproductive growth, excessive vegetative growth may result in low lint yield and many other problems. The cotton plant has aggressive growth habits which depend upon water and nutrient uptake. Plant growth regulators (PGRs) are used to reduce vegetative growth and cause reproductive growth. Application of cotton growth regulators depends upon crop growth status. Crop growth status is indicated by different crop parameters called crop structural indices. Height to node ratio (HNR), fruit retention (FR), growth rate (GR), nodes above white flower (NAWF), main stem node number (MSN), nodes above cracked boll (NACB), percent open bolls, and plant height are the structural indices being used for cotton crop mapping (Kerby et al., 1997; Kerby et al., 1998; Bourland et al., 1992). Various researchers have used plant structural indices to define cotton growth status. Munier et al. (1993) related plant height with plant vigor and early fruit retention and considered plant height as a good indicator for use of PGRs. Kerby et al. (1990) also considered plant height as an important deciding for PGR application.

Several studies have been conducted to measure cotton physiological parameters to define cotton growth status at different growth stages for estimation of growth regulator application rate. Different methods that have been used to measure growth parameters are remote sensing using aircrafts and satellites, in field machine vision, and by manually mapping plant structure from different field locations (Reddy et al, 2003; Plant et al, 2000; Goel et al, 2003; Kataoka et al., 2003; Jenkins and McCarty, 1995). Reflectance data collected in visible, infrared, near infrared and microwave region is correlated with physically measured cotton growth and structural indices. Several studies have shown correlation between growth parameters and reflectance data. Some researchers have also used hyper and multi spectral data to measure yield and plant growth physiological parameters (Zarco-Tejada et al., 2005; Plant et al., 2000).

Though many vegetative indices exist, the most common and highly correlated index is Normalized Difference Vegetative Index (NDVI) (Tucker et al., 1980; Plant et al., 2000). Many studies have shown strong correlations between NDVI and different growth parameters for cotton. In addition, strong correlations have also been observed between NDVI and height of the top five nodes in cotton plants (Kirkpatrick et al., 2005). Plant et al., (2000) found strong correlation between NDVI and NACB ($r^2 > 0.80$) using multi spectral imagery. Also a weak correlation was observed between NDVI and NAFB (R^2= 0.51-0.65).

The objective of this research was to evaluate sensor based variable rate prescriptions for plant growth regulators and harvest aids (defoliant/boll opener) in a field scale experiment.

Materials and Methods

This experiment was a 2x2 factorial with application method and product as the factors. The application methods were uniform (U) and variable (V) and the products were plant growth regulators (PGR) and a defoliant/boll opener tank mix (DEF). Plots were randomized with three replications on a production cotton field near Altus, OK in 2008 and 2009 and on a bulk production block at the SWREC in 2009. Plots ran the entire length of the fields and were at least 26.7 feet wide. The wide varied on each field/year due to available equipment. Due to the field shape, plot length varied between 1250 and 2550 feet.

In 2008 the plant growth regulator was applied with a John Deere 6500 sprayer with a 60 foot boom. The sprayer was equipped with a Mid-Tech TASC 6300 rate controller and Trimble RTK Auto Pilot system, and Greenleaf Technologies TDVR 015 variable orifice nozzles. In 2008, the defoliant/boll opener was applied with a Big John sprayer with a 30 foot boom. This sprayer was equipped with a Raven SCS440 controller, Outback S2 guidance system, and SharpShooter™ nozzle control system. Both sprayers were equipped with GreenSeeker RT220 application and mapping systems to measure NDVI and send target application rates to the controllers. The Big John sprayer was used for all applications in 2009. The boom was reduced to 26.7 feet to match row spacing.

Plots were harvested with the cooperating farmer's John Deere 9965 cotton picker equipped with an Ag Leader yield monitor. The harvest width was four rows resulting in four passes per plot. Since plots were 18 rows wide, some picker passes contained data from two plots. Data from these passes were deleted from the file. The yield monitor data were "cleaned" to eliminate points where picker speed (<1.5 mph) or mass flow (<0.5 lbs/s) were abnormally low. Yield data were imported into ArcView 3.2 and assigned to plots by joining tables. The resulting data were averaged to obtain a single yield value for each plot.

Greenseeker® sensors were used to measure normalized difference vegetative index (NDVI) on small plot studies at the Southwest Research and Extension Center (SWREC) in Altus, OK. These data were correlated with plant mapping data to develop relationships for prescription applications. A hand held GreenSeeker® sensor was used to field validate the prescription at the time of application. Minor adjustments to the prescription were made as deemed necessary. Prescriptions are shown in figures 1 and 2 for the two years.

The PGR was applied to the production field on July 28, 2008. Pentia was mixed to apply 12 oz/ac of product at a 10 gpa application rate. The application rate was then adjusted based on NDVI and the prescription. Regardless of NDVI the application rate was held between 5 and 10 gpa resulting in a range of 6 and 12 oz/ac of Pentia. In 2009 PGR was applied to both fields on July 23 using the same product mix, but the new prescription. The maximum rate was the same, but the lowest rate in 2009 was 2.5 gpa resulting in 3 oz/ac of Pentia.

Defoliation occurred on October 11, 2008. The target application rate for the defoliant/boll opener tank mix was 12 gpa. This application rate consisted of 1.5 pints/ac of Finish and 1.1 pints/ac of DEF. Like the PGR, the application rate was then adjusted based on NDIV and the prescription. Regardless of NDVI the application rate was held between 8 and 16 gpa. This range kept the Finish rate between 1 and 2 pints/ac and the DEF rate between 0.7 and 1.5 pints/ac. Defoliation in 2009 occurred on October 2 on the production field and October 19 on the station. The tank mix for 2009 was the same as 2008, but the maximum rate was reduced to 12 gpa while the minimum rate stayed at 8 gpa. This kept the Finish rate between 1.0 and 1.5 pints/ac and the DEF rate between 0.7 and 1.1 pints/ac.

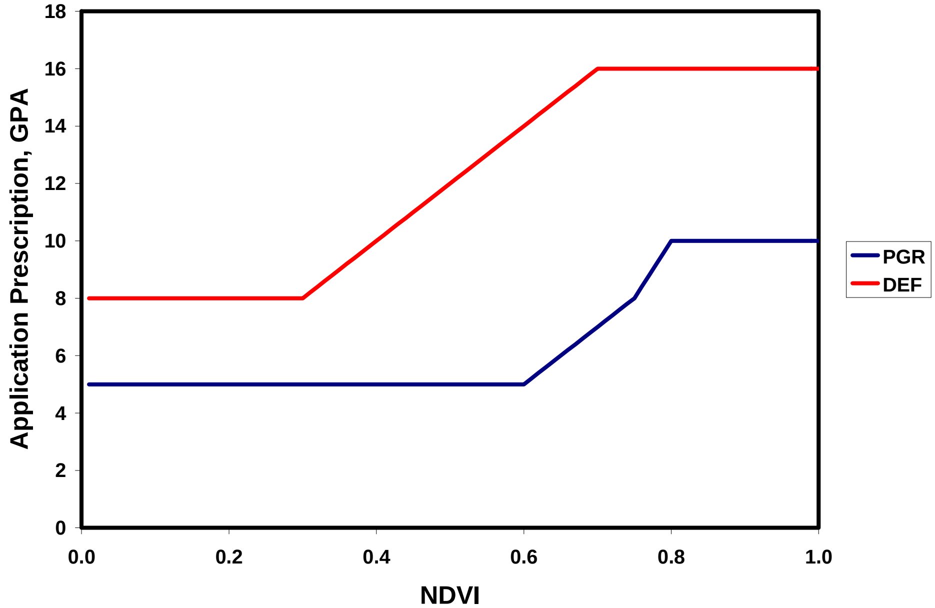

Figure 1. 2008 variable rate prescriptions for plant growth regulator (PGR) and a defoliant/boll opener (DEF) tank mix based on NDVI.

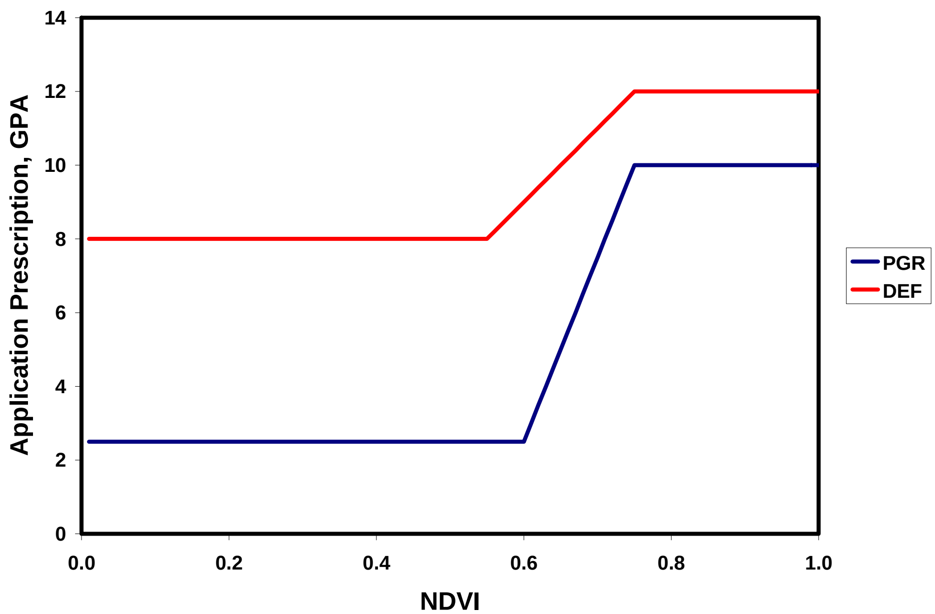

Figure 2. 2009 variable rate prescriptions for plant growth regulator (PGR) and a defoliant/boll opener (DEF) tank mix based on NDVI.

Results and Discussion

Average seed cotton yield in 2008 for the production field was 4220 lbs ac^{-1}. Yield variability independent of the treatment structure was evident in the yield map (figure 3). Generally yield was greater on the east side of the field. Low yield at the south end of the field was likely due to water. Salinity caused the low yielding areas in the center of the field. The replicated plots were used to account for some of this variability. Treatment mean yields are shown in Table 1. There was no significant yield difference and no interaction between treatments.

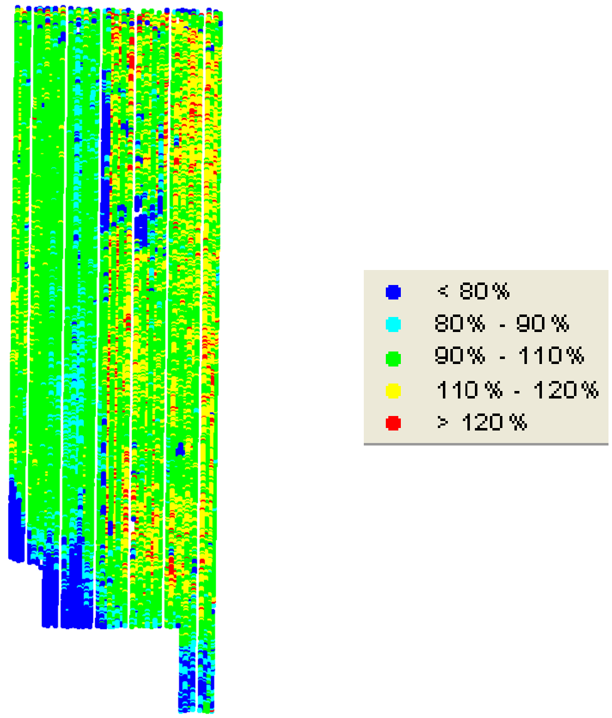

Figure 3. Normalized seed cotton yield map for the plot area of the production field in 2008. Average yield is 100%.

The prescription for variable rate PGR resulted in less product being used (Table 1). The variable rate PGR plots required about 9 percent less PGR than the uniform rate. However, the spray equipment was not able to apply the target rate as effectively as desired. The resulting PGR application was about 15 percent greater about than prescribed in the variable rate plots. Thus the actual PGR savings was closer to 6 percent.

However, the defoliant/boll opener variable rate prescription called for a higher average application rate than uniform (Table 1). The prescription rate was about 3 percent greater than the uniform rate. The sprayer used for the defoliant/boll opener application was better equipped for variable rate application and did a much better job of applying the desired rate. The difference in prescribed rate was due to the philosophy used in developing the prescription. The PGR prescription assumed that the uniform rate would be sufficient as the maximum variable rate whereas the DEF prescription assumed the uniform rate was adequate for the average condition. The philosophy used for the DEF prescription assumes the uniform rate was too low the high NDVI areas of the field.

Average seed cotton yield in 2009 for the production field was 4406 lbs ac^{-1}. Treatment mean yields are shown in Table 2. There was no significant yield difference and no interaction between treatments. Though not statistically significant, the variable rate PGR prescription called for 5 percent less product than the uniform rate. However, there was a significant difference in the prescribed defoliant application rate for variable and uniform treatments. However, the 2.5 percent difference was of little practical significance.

Average seed cotton yield in 2009 for the station field was 2750 lbs ac^{-1}. Treatment mean yields are shown in Table 3. There was no significant yield difference and no interaction between treatments. However, the prescribed defoliant for the variable rate defoliant treatment was significantly lower (25%) than the uniform treatment. Though not statistically significant, the variable rate PGR prescription called for 7 percent less product than the uniform rate.

While no data were collected to quantify efficacy of the products applied, there were no visible differences between treatments for all site-years, thus applications were considered effective.

Table 1. 2008 production field treatment means.

TRT	PGR	DEF	Yield	PGR R_x	PGR AR	DEF R_x	DEF AR
1	U	U	4213	10.0	10.0	12.0	12.0
2	U	V	4137	10.0	10.0	12.4	12.4
3	V	U	4340	9.0	9.4	12.0	12.0
4	V	V	4170	9.3	9.4	12.3	12.3

Table 2. 2009 production field treatment means.

TRT	PGR	DEF	Yield	PGR R_x	PGR AR	DEF R_x	DEF AR
1	U	U	4378	10.0	10.0	12.0	12.0
2	U	V	4356	10.0	9.9	11.8	11.6
3	V	U	4470	9.4	9.2	12.0	11.7
4	V	V	4421	9.6	8.9	11.7	11.4

Table 3. 2009 station field treatment means.

TRT	PGR	DEF	Yield	PGR R_x	PGR AR	DEF R_x	DEF AR
1	U	U	2736	10.0	10.0	12.0	11.9
2	U	V	2741	10.0	10.2	9.7	9.7
3	V	U	2751	9.4	9.4	12.0	11.9
4	V	V	2773	9.2	9.3	8.4	8.3

Summary

Variable rate application had no significant affect on yield. While product efficacy was not quantified, there was no visible difference between treatments for all site-years; thus uniform and variable applications were considered effective.

Variable rate prescriptions were refined over the course of this experiment. Variable rate prescriptions in the second year were more focused on saving product. More effort should be directed at developing a robust prescription that is valid over a wider range of conditions. These prescriptions should also consider the limitations of application equipment.

Variable rate PGR resulted in an average 7 percent reduction in prescribed product. The PGR prescriptions were similar across the two years. The variable rate DEF prescriptions were much different for the two years. Averaged over the three site-years, variable rate application resulted in an 8% defoliant/boll opener reduction.

Acknowledgements

The authors would like to acknowledge Cotton, Inc. for providing funding to conduct this study and express appreciation to Keeff Felty for collaborating on this field study.

References

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

Goel, P.K., S.O. Prasher, J.A. Landry, R.M. Patel, A.A. Viau, and J.R. Miller. 2003. Estimation of crop biophysical parameters through airborne and field hyperspectral remote sensing. Transactions of ASAE 46(4):1235-1246.

Jenkins, J.N., and J.C. McCarty. 1995. End of season plant maps. Bulletin 1024. Mississippi State, Miss: Mississippi Agricultural and Forestry Experiment Station.

Kataoka,T, T. Kaneko, H. Okamoto, and S. Hata. 2003. Crop growth estimation system using machine vision. Proceedings of IEEE/ASME. International Conference on Advanced Intelligent Mechatronics (AIM 2003).2:1079-1083

Kerby, T., D. Plant, W. Hofmann, and D. Horrocks. 1990. Predicting Pix response using the expert system Calex/Cotton. Proceedings Beltwide Cotton Conferences, pp. 658-659.

Kerby, T.A., R.E. Plant, and R.D. Horrocks. 1997. Height to node ratio as an index of early season cotton growth. J. Prod. Agric. 10:80-83.

Kerby, T.A., R.E. Plant, S. Johnson-Hake, and R.D. Horrocks. 1998. Environmental and cultivar effects on height-to-node ratio and growth rate in Acala cotton. J. Prod. Agric. 11:420-427.

Kirkpatrick, M.T., J.J. Walton, D.M. Dodds, D.B. Reynolds, and C.G. O'Hara. 2005. Site-specific plant growth regulator applications based on aerial imagery. Proceedings Beltwide Cotton Conferences, pp..

Munier, D.J., B.L. Weir , S.D. Wright and T.A Kerby. 1993. Applying Pix at variable Rates When Plant Height Varies in A Cotton Field. Proceedings Beltwide Cotton Conferences, pp. 1206-1207.

Plant, R.E., D.S Munk, B.R. Roberts, R.L. Vargas, D.W. Rains, R.L. Travis and R.B. Hutmacher. 2000. Relationships between remotely sensed reflectance data and cotton growth and yield. Transactions of ASAE. 43(3):535-546

Reddy, K.R., D. Zhao, V.G. Kakani, J.J. Read, and K. Sailaja. 2003. Estimating cotton growth and developmental parameters through remote sensing. Proceedings of SPIE-The International Society for Optical Engineering. 5153:277-288

Tucker, C.J., J.H. Elgin, Jr., and J.E. McMurtrey III. 1980. Relationship of spectral data to grain yield variation. Photogrammetric Engineering and Remote Sensing. 46(5):657-666.

Zarco-Tejada, P.J., S.L. Ustin, and M.L. Whiting. 2005. Temporal and spatial relationships between within-field variability in cotton and high-spatial hyperspectral remote sensing imagery. Agron. J. 97:641-653.