ON-THE-GO SENSOR SYSTEM FOR COTTON MANAGEMENT

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Abstract

Seven Greenseeker sensors were mounted on a mobile platform to measure cotton NDVI. These sensors were connected to a CAN bus along with a data logger and DGPS. Two ultrasonic sensors were also mounted on the platform to measure crop height. The ultrasonic sensors were not connected to the CAN bus, but were connected to the data logger. Four of the Greenseeker sensors were mounted directly over the crop row and three were mounted to sense the area between the rows. This system was used to measure NDVI and plant height on several cotton studies involving nitrogen rates and plant growth regulator applications. Though this research did not conclusively define the ability to conduct real-time, sensor-based, variable rate applications for cotton, it did provide encouragement and direction for continuing research. Based on these results a midseason (60 days after planting) NDVI measured over the row was moderately related (r^2=0.22) to height/node ratio in one study. The NDVI measured in row middles with GreenSeeker® sensors correlates (r^2=0.56) with plant height in two studies. These two relationships give hope to the ability to variably apply PGRs with sensors in real time. The NDVI measured with a GreenSeeker sensor over the plants was somewhat related (r^2=0.17) to percent open bolls in an N rate study. It is expected that this relationship could be used to define a variable rate prescription for boll opener or defoliant.

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. Cotton plant has aggressive growth habits which depend upon the 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. Recording of such crop structural indices is known as plant mapping (Jenkins and McCarty, 1995). Height to node ratio (HNR), fruit retention (FR), growth rate (GR), nodes above white flower (NAWF), main stem node number (MSN) 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 rate and quantity of growth regulators. Different methods that have been used to measure growth parameters are remote sensing using aircrafts and satellites, in field machine vision, and by manually taking samples from different sites (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 of the 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, 1979; Plant et al., 2000). Many studies have shown strong correlations between NDVI and different growth parameters for cotton crop. In addition, strong correlations have also been observed between NDVI and height of top five nodes in cotton plant (Kirkpatrick et al., 2005). Plant et al., (2000) had found strong correlation between NDVI and nodes above cracked boll (NACB) ($r^2 > 0.80$) using multi spectral imagery. Also a weak correlation was observed between NDVI and nodes above white flower (NAFB) (R^2= 0.51-0.65).

Commercially available reflectance sensors are currently used to collect data and drive variable rate prescriptions. The objectives of this research were to assemble a data acquisition system to measure cotton physiological characteristics with sensors and determine potential relationships between sensor measurements and cotton plant properties to create prescriptions for real-time sensor based variable rate application.

Materials and Methods

A sensor system was assembled using seven GreenSeeker® sensors, two Massa ultrasonic sensors, a potentiometer (10K, 5 turns), and a Trimble AgGPS 132. Data from these sensors were recorded with a SOMAT E-Daq Data Logger. GreenSeeker® and GPS data were connected on a controller area network (CAN) bus and data were recorded from the bus. The analog signal from the ultrasonic sensors and potentiometer were logged directly with the SOMAT. The data aquisistion system and sensors were mounted on a small spot sprayer to create a mobile platform.

The seven GreenSeeker® sensors were configured such that four were mounted directly over the crop row and three were mounted between the crop rows (Figure 1). The ultrasonic sensors were positioned in front of the third and fifth GreenSeeker® sensors where there was a clear view of the crop. Sensor data were collected on multiple research studies near Altus, OK. A nitrogen rate (0, 40, 80, and 120 lbs N/ac) experiment was used to create growth differences for sensor measurement. Other studies included a long term (30+ years) fertility study and a Beltwide PGR study. Plots varied in size, but were at least four rows wide with 40 inch row spacing. All studies were furrow irrigated. Sensor data were collected multiple times throughout the season as ground conditions permitted. Plant measurements were taken at five locations within each individual plot to coincide with sensor data collection. These measurements varied depending on the growth stage and included plant height, nodes, NAWF, NACB, and percent open bolls.

Figure 1. GreenSeeker® sensors and Ultrasonic sensors mounted on a boom

Sensor data were collected by driving the spot sprayer through plots and logging data. The data were stored as SIF files which were then converted to Excel files using Infield software (SOMAT) and then preprocessed using MATLAB and ArcView. Heading, latitude, and longitude were used from the GPS to georeference individual sensors and their corresponding measurements using a program developed in MATLAB. Data from the individual GreenSeeker® sensors were coded based on the sensor location relative to the row. The georeferenced data were then imported and plotted in ArcView. The individual plots and their corresponding data were then extracted visually in ArcView for each field. The data were then labeled according to different plot numbers and treatments. This extracted data of each plot were averaged in MATLAB, to yield single values for measured parameters for each plot. The average values of cotton physiological parameters were also calculated for each plot from manually measured data. Sensed data was then correlated with the manually measured cotton mapping data with respect to different treatments given to the plots and also with respect to different growth stages.

Results and Discussion

The primary data reported here is based on the nitrogen rate study. Some of these results include data from the Beltwide PGR study. A moderate relationship between NDVI measured over the top of plants and the height/node ratio was found in the nitrogen rate study on the July 18 and August 13 sampling dates. There was no correlation found at other sampling dates. The correlation at the latter date is of little value since PGR applications would likely not be made that late in the growing season. However, the relationship for the July 18 (60 days after planting) sampling could provide guidance for PGR applications. There was no correlation at the earliest sampling date (July 12).

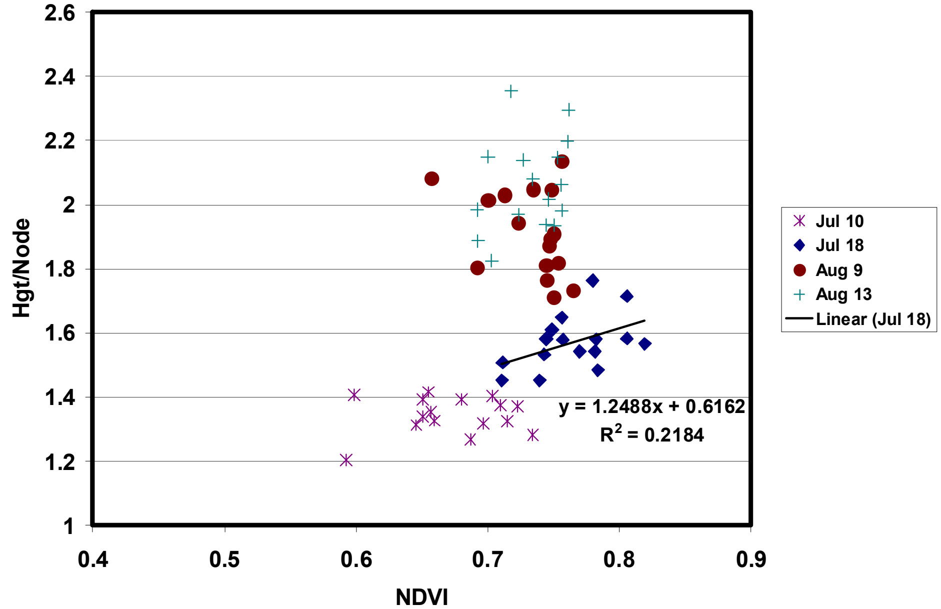

Figure 2. Relationship of NDVI and height/node ratio by sampling date for the nitrogen rate study.

The NDVI measured with GreenSeeker® sensors mounted between the rows was a good proxy for crop height (figure 3). When compared across all sampling, the r^2 was 0.91. However, in season decisions require the ability to detect differences at the same time. The r^2 for the July 18 date only was 0.37. Again, this is a time when PGRs could be applied. If plant height is a good indicator of PGR need, then NDVI measured between the rows may provide input to a prescription. It is believed that the NDVI measured between the rows is actually indicating canopy closure and that this is related to plant height. As shown in Figure 4, combining data gathered from plots in a Beltwide PGR study with data from the nitrogen rate study improves the relationship of NDVI measured between rows and plant height (r^2=0.56). The crop was at the same stage in both studies. Combining the data changes the slope of the equation relative to analyzing the studies independently, but it strengthens the overall relationship.

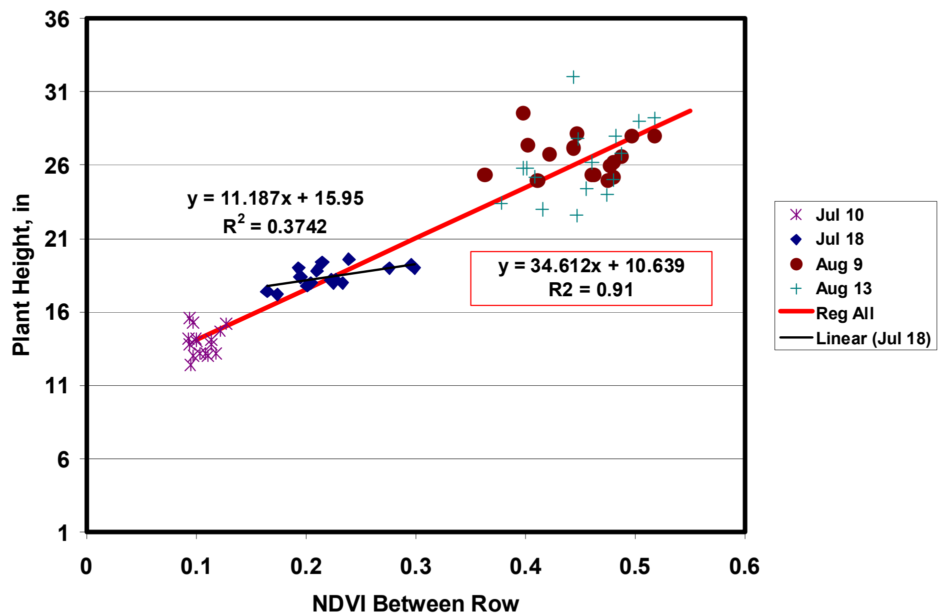

Figure 3. Plant height as a function of NDVI measured between the rows. The red line is the regression for all data (equation in the red box) and the other regression is for the July 18 data only.

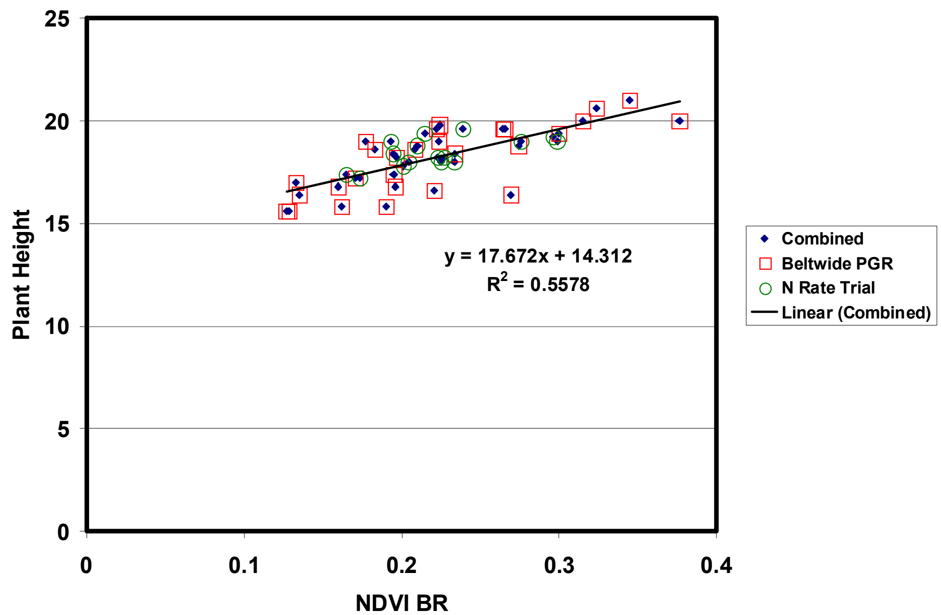

Figure 4. Plant height as a function of NDVI measured between the rows for the nitrogen rate and Beltwide PGR trials. The regression is for the combined data.

Percent open bolls were measured on the nitrogen rate study in late September. Though this data had a weak correlation (r^2=0.17) with NDVI measured over the row, the relationship was as expected (Figure 5). The check plot had begun to senesce and change color. This coincided with more open bolls.

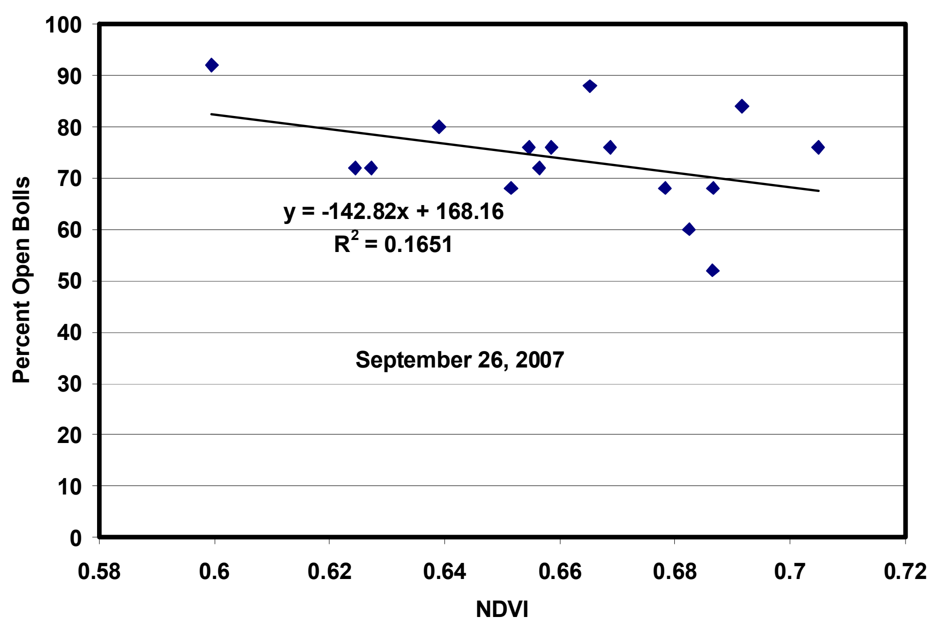

Figure 5. Percent open bolls as a function of NDVI measured over the row.

Conclusions

Though this research did not conclusively define the ability to conduct real-time, sensor-based, variable rate applications for cotton, it did provide encouragement and direction for continuing research. Based on these results a midseason (60 days after planting) NDVI measured over the row was moderately related to height/node ratio in one study. The NDVI measured in row middles with GreenSeeker® sensors correlates with plant height in two studies. These two relationships give hope to the ability to variably apply PGRs with sensors in real time. The NDVI measured with a GreenSeeker sensor over the plants was related to percent open bolls in an N rate study. This relationship could be used to define a variable rate prescription for boll opener or defoliant.

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