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CROP REFLECTANCE AS AN INDICATOR OF COTTON GROWTH AND NITROGEN AVAILABILITY

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Abstract

Utilizing canopy reflectance to determine leaf N concentrations and plant height could be a useful tool in improving N use efficiency. The objectives of this research were to establish relationships between canopy reflectance and leaf N concentrations and plant height using an on-the-go tractor mounted spectrometer. A field experiment consisting of four fertilizer N rates to establish differences in plant height, leaf N concentrations, and yield was conducted in the summer of 2004. Plant height was measured in conjunction with canopy reflectance and leaf N was measured at early square, early bloom, and late bloom. The Green Normalized Vegetation Index (GNDVI) was used to determine relationships between reflectance data and cotton growth. On-the-go sensing of crop reflectance accurately detected cotton growth differences. Results also showed GNDVI correlated strongly to leaf N concentrations at peak bloom and reflectance data acquired at or after peak bloom could be useful in predicting yield.

Introduction

Utilization and efficiency of fertilizer N as well as other agrichemicals could be increased through spatial applications directed by on-the-go sensing of cotton canopy reflectance. Leaf N prediction based on leaf reflectance has been demonstrated under greenhouse (Buscaglia and Varco, 2002) and field conditions (Fridgen and Varco, 2004). Strongest correlations were found within the green (550 nm) spectral band and at what is known as the red edge (700 nm). Past research also demonstrated the strongest relationship occurs near peak bloom (Buscaglia and Varco, 2002; Emerine 2004; Fridgen and Varco, 2004). Vegetation indices utilizing reflectance measurements within selected spectral bands have been developed to detect crop growth, greenness, and various stress induced changes. The GNDVI has been shown to correlate well with cotton growth and response to varying levels of N availability (Peterson, 2002). Since N availability strongly influences biomass, leaf area, and greenness, the objective of this study was to determine the effects of varying N availability on the relationship of crop reflectance to leaf N, plant height, and yield.

Materials and Methods

A study of crop reflectance as an indicator of cotton growth and N availability was conducted at the Mississippi State Plant Science Research Center, Mississippi State, MS. Data for this study was collected in 2004. The experimental site was on a Marietta fine sandy loam (fine-loamy, siliceous, thermic Fluvaquentic Eutrochrept). Cotton was planted on 6 May 2004 with a row spacing of 38 in. Cotton variety Deltapine 444 BG/RR was planted at a rate of 4 seed/ft. Sixteen plots were used; each plot 120 ft. long and 12 rows wide. Fertilizer N was applied using a urea ammonium nitrate solution (32% N) on 20 May and 11 June. The UAN solution was banded 8 in to the side of the row and 4 in deep. Fertilizer N rates of 0, 40, 80, and 120 lbs N/acre were applied 50% after planting and 50% at early square. Treatments were replicated four times and were arranged in a randomized compete block design.

Ten recently matured leaves from the main stem (4 to 5 nodes from terminal) were collected from each plot at 35 DAP (early square), 62 DAP (early bloom), and 76 DAP (peak bloom). The leaves were then oven dried at 65^{o}C. Dried samples were ground to pass a 20-mesh sieve in a Wiley Mill. Leaf N concentrations were determined on 4 to 6 mg of oven dried samples using a Carlo Erba N/C 1500 dry combustion analyzer (Carlo Erba, Milan, Italy).

Plant height data was measured at 35 DAP (early square), 46 DAP (pre-bloom), 62 DAP (1st bloom), 70 DAP (2nd week bloom), 76 DAP (3rd week bloom), 83 DAP (4th week bloom), and 92 DAP (5th week bloom). Three plants were measured at ten different locations within each plot. Measurements were taken at the same locations throughout the season, although the exact same three plants may not have been measured each sampling.

Canopy reflectance was measured using a Hydro N Sensor (Hydro-Agri, Dulmen, Germany). The sensor was tractor mounted on a three-point hitch. The sensor consisted of two spectrometers with a wavelength range of 450-

900 nm. The two spectrometers were spaced 210 cm to record data on each side of the tractor. Two optical inputs were connected to each spectrometer and were directed at 90° from each other. The viewing direction was 64° from nadir. The initial height from the ground to the sensor windows was 64 in. to capture principally rows 2 and 3 and 10 and 11 and was adjusted accordingly to compensate for increasing plant height as the season progressed. Tractor speed was 3.5 mph and data was recorded in one-second intervals. Data was collected at 35 DAP (early square), 46 DAP (pre-bloom), 62 DAP (1st bloom), 70 DAP (2nd week bloom), 83 DAP (4th week bloom), and 92 DAP (5th week bloom). The data was collected on predominately sunny days between 11 a.m. and 2 p.m. Wavelengths recorded were 550 nm, 650 nm, 700 nm, 710 nm, and 840 nm. Coincident GPS data was recorded using a Trimble Pro XR Receiver (Sunnydale, CA) connected to the Hydro N Sensor.

Yield data was collected by using a modified spindle type picker equipped with load sensors (Rice Lake Scales, Greenwood, MS). The picker harvested rows 2 and 3 and 10 and 11 to match rows used for plant height, leaf N sampling, and canopy reflectance. Fifty boll samples from each plot were hand picked and ginned to establish lint percentage.

Results and Discussion

Plant height differences induced by varying fertilizer rates and their effects on GNDVI throughout the growing season are shown in Fig. 1. Within each date, a linear relationship was observed, except at early bloom on 7 July 2004 where the relationship was the weakest. With time there was a tendency for decreasing slope which is likely the result of a decline in ground cover differences. Prediction of plant height for each sampled date using GNDVI is shown in Fig. 2. An increase in slope was observed as the season progressed implying the most accurate prediction would result using time dependent models. Given the strength of the relationships as evidenced by each r^2, on-the-go sensing of relative plant height differences is plausible.

The relationship between GNDVI and leaf N concentration is shown in Figs. 3-5. Little correlation existed at early squaring and blooming, while a strong relationship was observed at peak bloom. These results suggest that sufficient canopy development and N usage must occur for accurate prediction of leaf N from remote sensing of the crop canopy. This effect has been observed in previous studies (Fridgen and Varco, 2004; Peterson, 2003).

The relationship between GNDVI on 6 Aug. 2004 and lint yield is shown in Fig. 6. Good relationships were observed from peak bloom and later, while reflectance at earlier sampling dates was not able to differentiate potential yield. As a demonstration of the range in available N in this study, the effects of fertilizer N rate are shown in Fig. 7.

In conclusion, on-the-go sensing of crop reflectance accurately detected cotton growth differences. Crop greenness relative to leaf tissue N was most accurately detected at peak bloom. Adaptation of on-the-go crop reflectance for spatial application of agrichemicals including fertilizer N, growth regulators, insecticides, and defoliants appears to be a viable option.

References

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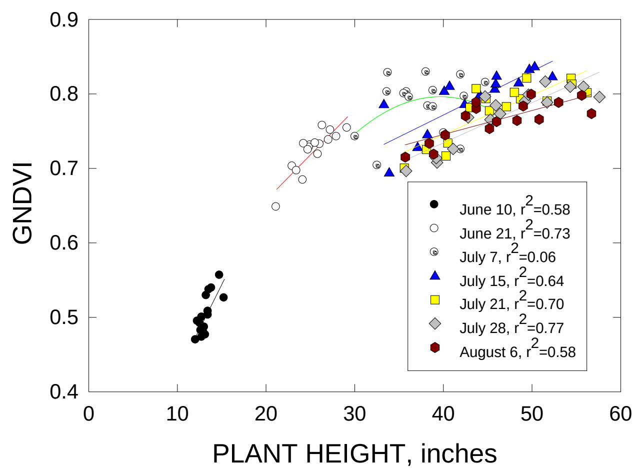

Fig. 1. Detection of plant height differences induced by varying fertilizer N supply by GNDVI.

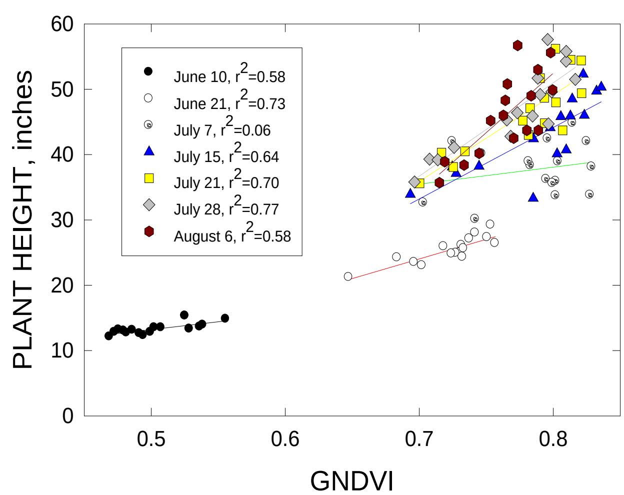

Fig. 2. Prediction of cotton plant height at various dates throughout the growing season using GNDVI.

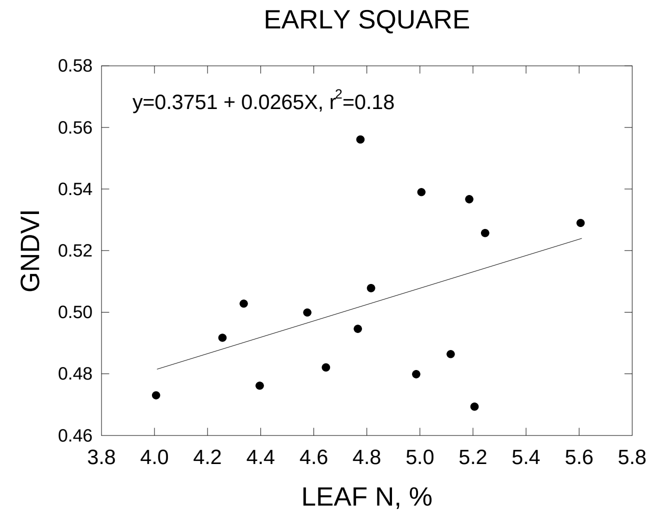

Fig. 3. Varying leaf N content effects on GNDVI at early square.

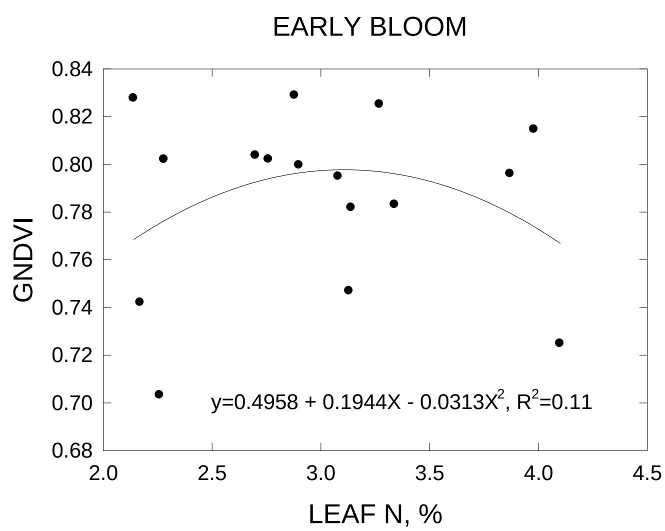

Fig. 4. Varying leaf N content effects on GNDVI at early bloom.

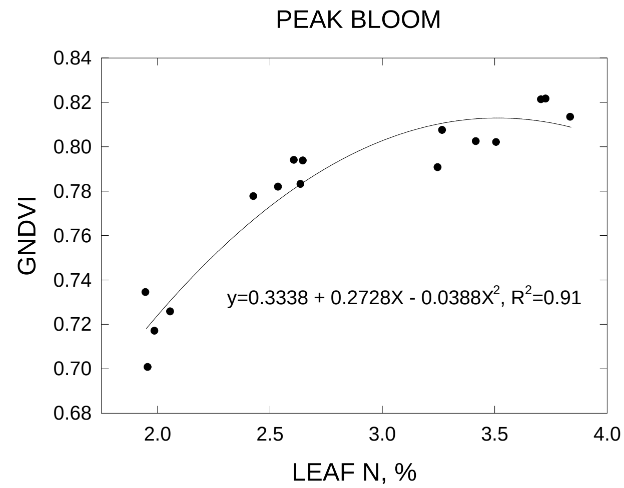

Fig. 5. Varying leaf N content effects on GNDVI at peak bloom.

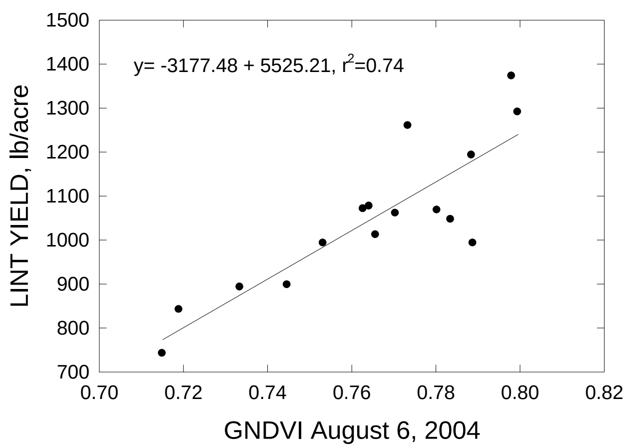

Fig. 6. Relationship between lint yield and GNDVI derived from reflectance acquired Aug. 6, 2004.

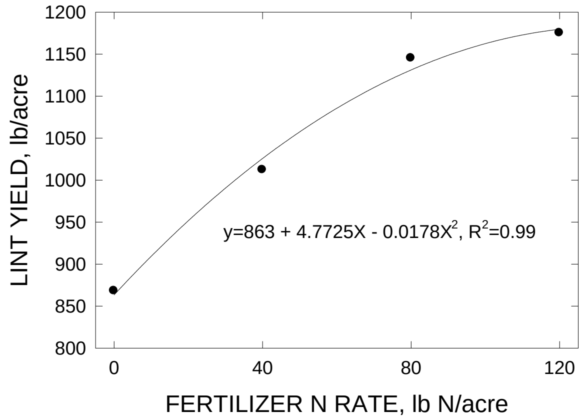

Fig. 7. Lint yield response to varying fertilizer N rates.