RED EDGE DETECTION OF COTTON GROWTH AND N STATUS

Tyson B. Raper
Jac J. Varco
Ken J. Hubbard
Brennan C. Booker
Mississippi State University
Mississippi State, Mississippi

Abstract

Cotton reflectance collected using a tractor mounted sensor has the potential to direct fertilizer N applications. However, there is a need for a more precise definition of the relationship between sensor-observed reflectance, cotton plant height, and cotton N status. The objective of this study was to examine NDVI, GNDVI and REIP calculated from data acquired with the YARA N Sensor (Yara International ASA, Oslo, Norway) for their effectiveness in differentiating cotton (*Gossypium hirsutum* L.) plant height and leaf N. Field trials were conducted in 2009 and 2010 at the Plant Science Research Farm, Mississippi State, MS. Fertilizer N rates of 0, 40, 80, and 120 lb N/acre were applied to establish wide growth differences. The Yara N Sensor was used to collect canopy reflectance across 20 visible and near-infrared wavelengths at several physiological stages. Plant height and leaf N were also determined at these stages. NDVI, GNDVI, and REIP were analyzed relative to sensitivity of cotton N status. Derivative analysis of the spectral reflectance signatures showed consistent shifts in red edge inflection point (REIP) across N rates, suggesting REIP to be an indicator of early season cotton N status. Strong relationships for GNDVI and NDVI occurred at later physiological stages which would be less ideal for applying side dress fertilizer N. First week of square GNDVI and NDVI relationships with leaf N were weaker than REIP relationships with leaf N at the same sampling date in both years. Although GNDVI and NDVI readings may be restricted to directing sampling or N applications in the following growing season, REIP has the potential to be an indicator of cotton N status early enough for efficient use of side dress applied fertilizer N.

Introduction

Although sensor derived NDVI is commonly utilized, correlations between cotton N status and NDVI have been observed as weak (Bronson et al., 2005). Recent work has suggested that calculation of the red edge inflection point (REIP) could be a more accurate method of determining cotton canopy stress (Buscaglia et al., 2002; Fridgen et al., 2004) and several accurate methods for deriving REIP exist in forestry applications (Pu et al., 2003; Dawson et al., 1998). Most research in cotton has concluded the red edge region correlates well with cotton N status, but the only aspect of the red edge region examined was the magnitude of reflectance (Tarpley et al., 2000; Read et al., 2002). A Gaussian derived REIP should be examined for it's potential to predicting cotton N status. The objective of this study was to determine relationships between plant height, leaf N, and derived reflectance indices NDVI, GNDVI, and REIP using the YARA N Sensor.

Methods

Data was collected in 2009 and 2010. The trial was conducted at the Mississippi Agricultural and Forestry Experiment Station, in Starkville, Mississippi both years. Each of 16 plots was comprised of 12 rows by 125 ft with treatments arranged in a randomized complete block design. Delta and Pine Land BG/RR 445 was planted in 2009 and Deltapine BG/RR 1028 was planted in 2010 at a row spacing of 38 in and 4.3 seed/ft. Treatments consisted of a split (50% at planting / 50% at early square) application of UAN 32% N solution for total applied rates of 0, 40, 80, and 120 lb N/acre during the growing season.

Reflectance values were acquired on clear sunny days between 11 a.m. and 12 p.m. using the Yara N Sensor (tec5Hellma, Inc. Plainview, NY) tractor mounted 76 in above the ground. The Yara N Sensor is a passive spectrometer which has four fiber optic inputs feeding to one central spectrometer and an irradiance sensor. Two fiber optic inputs are located on each end of the sensor unit and each senses the crop between 58º and 70º at an off-nadir view. The tractor was driven at 3.5 mph above rows 6 and 7 allowing the Yara N Sensor to sense rows 2, 3, 4, 9, 10, and 11. Wavelengths recorded were 450, 500, 550, 570, 600, 620, 640, 650, 660, 670, 680, 700, 710, 720, 740, 760, 780, 800, 840, and 850 nm. The bandwidth was + or – 5nm. GNDVI and NDVI were calculated by the following equations:

$$GNDVI= (R_{840} – R_{550}) / (R_{840} + R_{550})$$

$$NDVI= (R_{840} – R_{650}) / (R_{840} + R_{650})$$

where R_{840} is the reflectance at 840 nm, R_{650} is the reflectance at 650 nm, and R_{550} is the reflectance at 550 nm.

A reflectance signature was constructed with the Yara N Sensor reflectance data from each plot. The first derivative was calculated from each plot and four derivative values from the wavelengths 700, 710, 720, and 740 nm in the red edge region were applied to a Gaussian for parameter equation to define peak or Red Edge Inflection Point (REIP).

GPS locations for each index were acquired by a Trimble Pro XR Receiver (Sunnydale, CA). Five plant measurements were taken from each of four marked sub-locations corresponding to sensed rows in each plot. Leaf samples were obtained on the same dates as canopy reflectance data collection. Five recently matured leaves were obtained 5 to 6 nodes from the terminal on the main stem at each of the four marked sub-locations in each plot. Leaves were oven dried at 65°C and ground through a 20 mesh sieve in a Wiley Mill. Leaf N concentration was determined on 4 to 6 mg of ground leaf samples by a Carlo Erba N/C 1500 dry combustion analyzer (Carlo Erba, Milan, Italy).

Results and Discussion

NDVI and LEAF N, %

The NDVI values at early square in 2009 (Fig. 1) appeared to be a good estimator of leaf N across N status. The relationship was linear, strong (r^2= 0.635), and covered a wide range of NDVI and leaf N values. The NDVI values at early square in 2010 (Fig. 2) did not appear to be a good estimator of leaf N across N status. The relationship was curvilinear, weak (r^2=0.270) and did not cover as wide of a range of NDVI and leaf N values as in 2009.

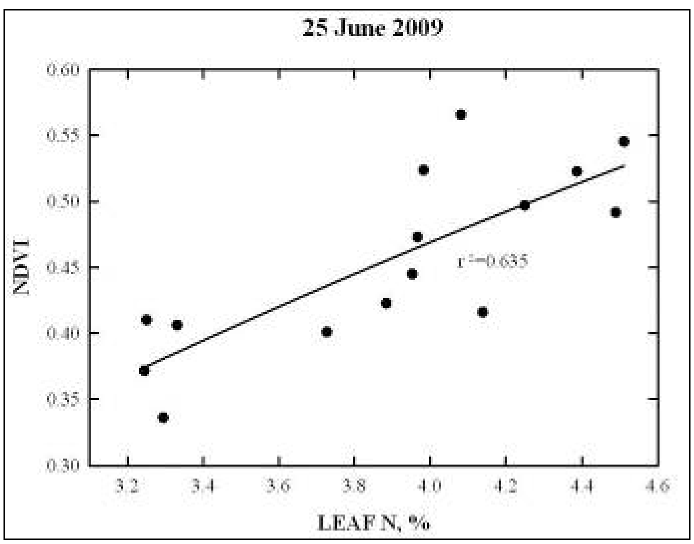

Figure 1: 2009 Early Square.

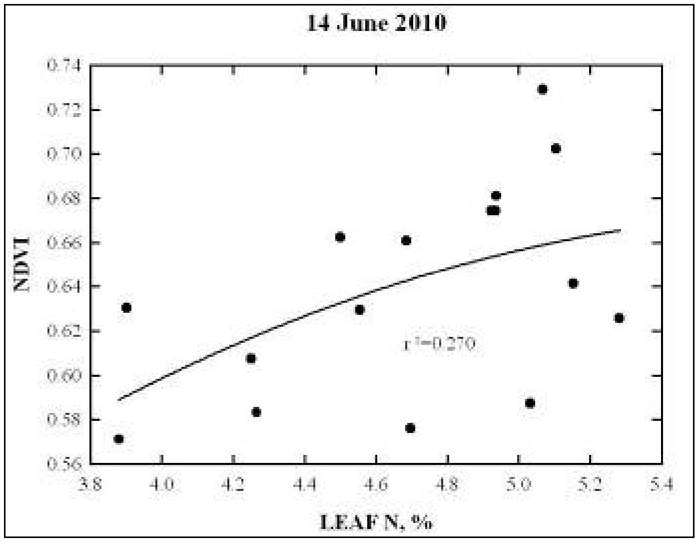

Figure 2: 2010 Early Square.

NDVI and PLANT HEIGHT, cm

The NDVI values at early square in 2009 (Fig. 3) appeared to be a good estimator of plant height across N status. The relationship was curvilinear, strong (r^2= 0.670), and covered a wide range of NDVI and plant height values. The NDVI values at early square in 2010 (Fig. 4) were not as strong an estimator of plant height across N status. The relationship was curvilinear, moderate (r^2=0.473) and covered a wide range of NDVI and leaf N values.

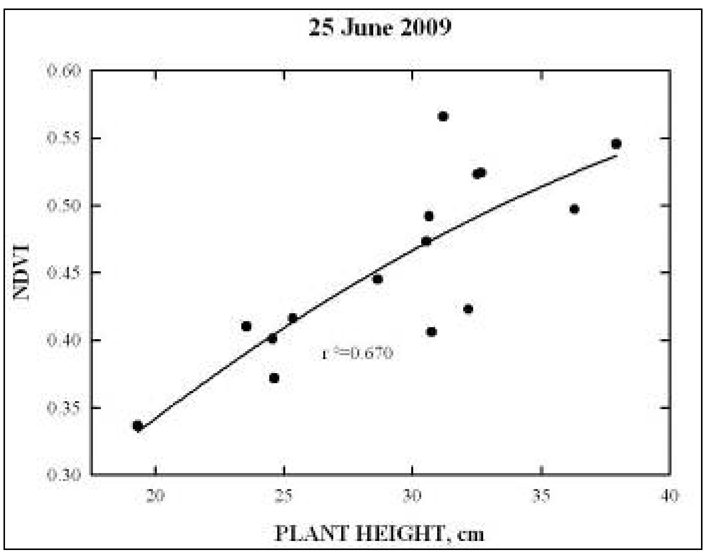

Figure 3: 2009 Early Square.

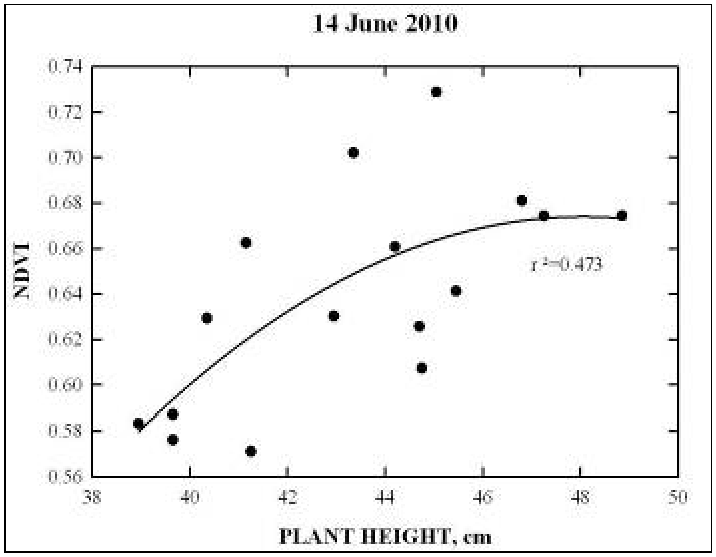

Figure 4: 2010 Early Square.

GNDVI and LEAF N, %

The GNDVI values at early square in 2009 (Fig. 5) appeared to be a good estimator of leaf N across N status. The relationship was linear, strong (r^2= 0.671), and covered a wide range of GNDVI and leaf N values. The GNDVI values at early square in 2010 (Fig. 6) did not appear to be a good estimator of leaf N across N status. The relationship was linear, moderately weak (r^2=0.333) and although it covered a wide range of leaf N, it did not cover a wide range of GNDVI values.

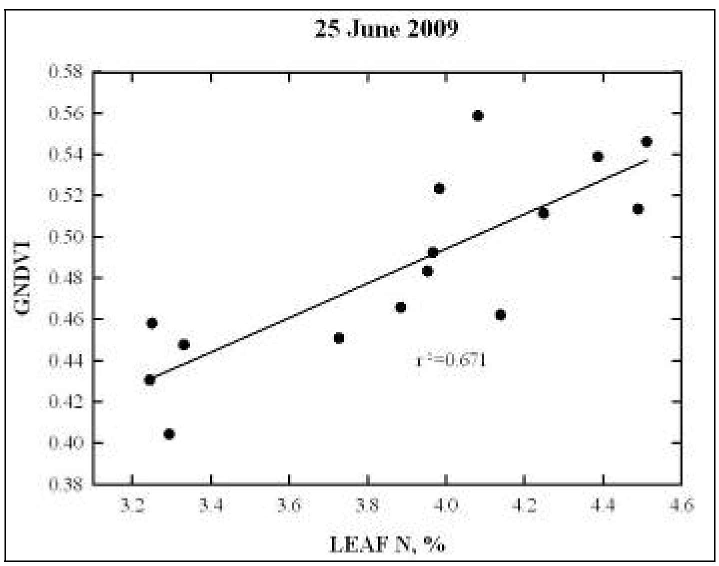

Figure 5: 2009 Early Square.

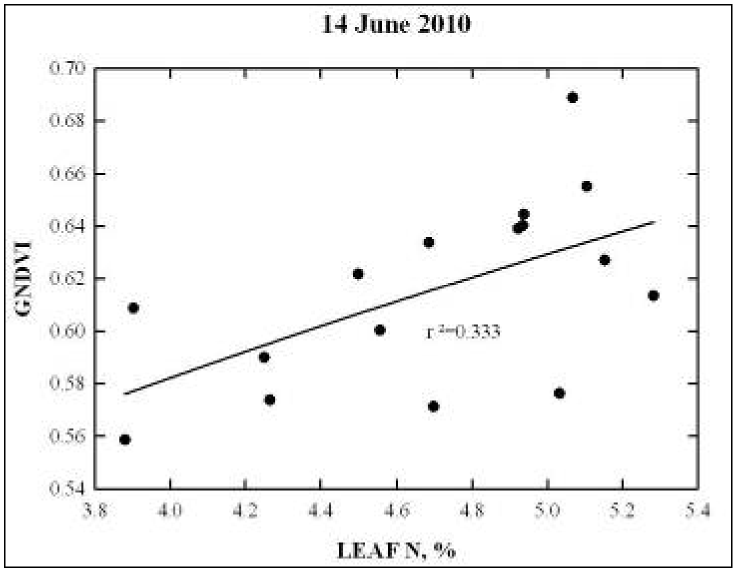

Figure 6: 2010 Early Square.

GNDVI and PLANT HEIGHT, cm

The GNDVI values at early square in 2009 (Fig. 7) appeared to be a good estimator of plant height across N status. The relationship was curvilinear, strong (r^2= 0.651), and covered a wide range of GNDVI and plant height values. The GNDVI values at early square in 2010 (Fig. 8) did not predict plant height across N status as well as in 2009 (Fig. 7). The relationship was curvilinear, moderate (r^2=0.=526) and although it covered a wide range of plant height values, it did not cover a wide range of GNDVI values.

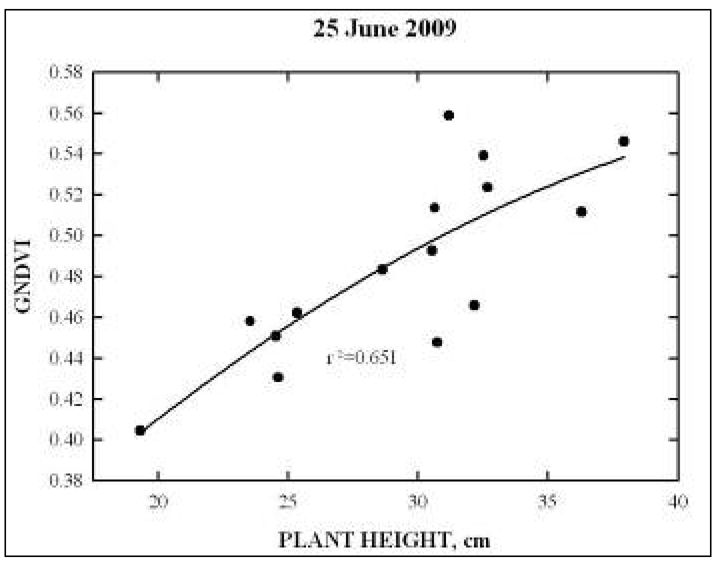

Figure 7: 2009 Early Square.

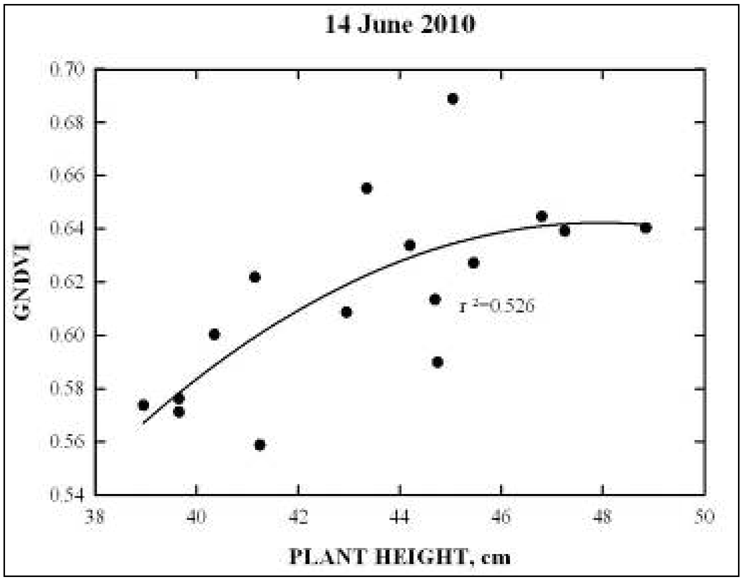

Figure 8: 2010 Early Square.

<u>REIP and LEAF N, %</u>

The REIP values at early square in 2009 (Fig. 9) appeared to be a very good estimator of leaf N across N status. The relationship was curvilinear, strong (r^2= 0.830), and covered a wide range of REIP and leaf N values. The REIP values at early square in 2010 (Fig.10) also appeared to be a good estimator of leaf N across N status. The relationship was curvilinear, strong(r^2=0.698) and covered a wide range of REIP and leaf N values.

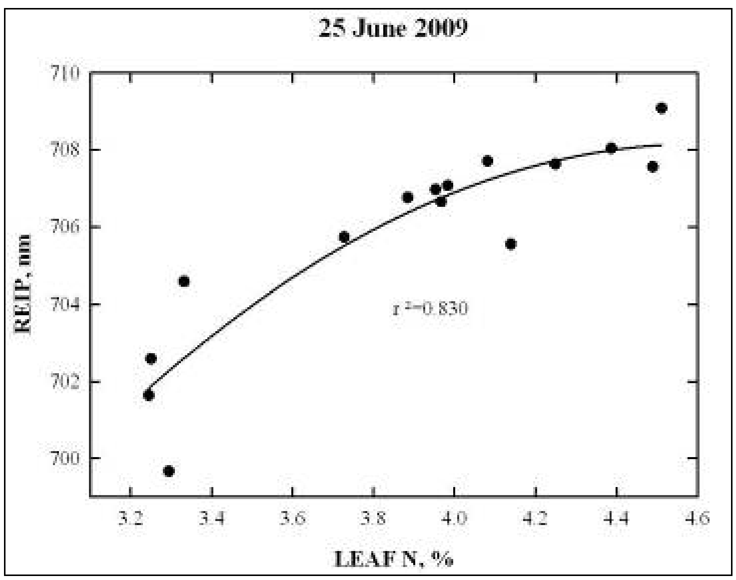

Figure 9: 2009 Early Square.

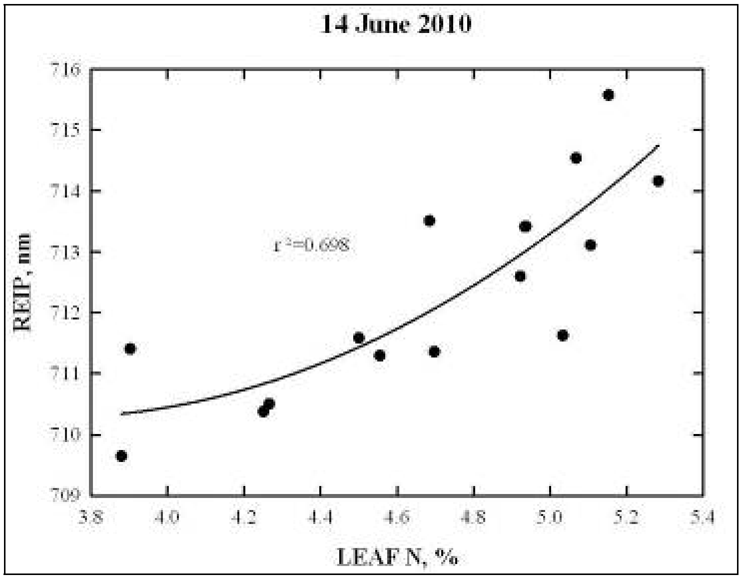

Figure 10: 2010 Early Square.

REIP and PLANT HEIGHT, cm

The REIP values at early square in 2009 (Fig. 11) appeared to be a very good estimator of plant height across N status. The relationship was curvilinear, strong (r2= 0.800), and covered a wide range of REIP and plant height values. The REIP values at early square in 2010 (Fig.12) did not predict plant height across N status as well as in 2009 (Fig. 11). The relationship was curvilinear, moderate (r2=0.427) and covered a wide range of REIP and plant height values.

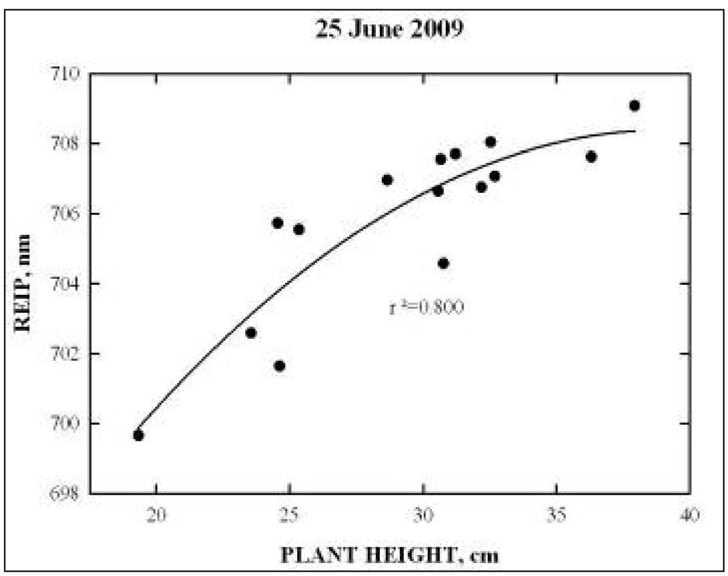

Figure 11: 2009 Early Square.

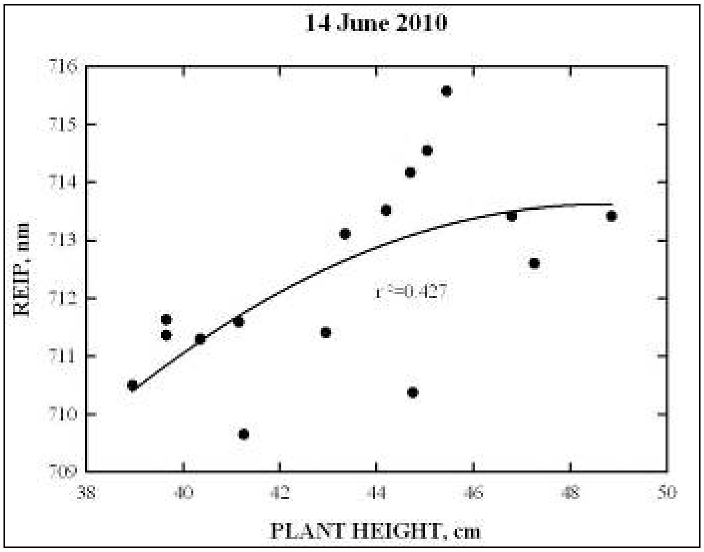

Figure 12: 2010 Early Square.

Discussion

First week of square GNDVI and NDVI relationships with leaf N were similar in both years (Figs. 1, 2, 5, and 6). The relationship between GNDVI and leaf N tended to be slightly stronger than the relationship between NDVI and leaf N in both years. REIP relationships with leaf N were much stronger than either NDVI or GNDVI relationships with leaf N at first week of square in both years (Figs. 1, 2, 5, 6, 9, and 10).

First week of square GNDVI and NDVI relationships with plant height were similar in both years (Figs. 3, 4, 7 and 8). First week of square REIP relationships with plant height were strong in 2009 (Fig. 11), but were much weaker in 2010 (Fig. 12). In 2009, REIP had a stronger relationship with plant height than either GNDVI or NDVI (Fig. 3, 7, and 11). In 2010, however, REIP had a weaker relationship with plant height than either GNDVI or NDVI (Fig. 4, 8, and 12).

Conclusions

Although REIP relationships with leaf N were stronger than for NDVI or GNDVI in both years, REIP relationships with plant height were not. These results suggest that REIP may be more sensitive to cotton N status and less sensitive to cotton biomass than GNDVI or NDVI. Both GNDVI and NDVI have the potential to be effective measurements of late season N status in cotton; however, REIP has the potential to be an effective early season measurement of cotton N status. Further research is needed to incorporate reflectance magnitude in the red edge region and REIP into one reflectance index.

Acknowledgements

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