CROP REFLECTANCE AS AN INDICATOR OF NITROGEN AVAILABILITY AND FERTILIZER NEEDS TO MAXIMIZE PROFITABILITY IN COTTON PRODUCTION

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Abstract

Managing soil variability is a complex issue in cotton production, especially in dealing with N fertilization. Crop growth is a result of an integration of all factors influencing it, including the size of the available N pool and water relations. Spatial variances in crop reflectance are an indication of growth potential and at least a partial indication of the relative differences in the utilization of and/or size of the available N pool. Crop reflectance based variable rate N fertilization has the potential to improve profit maximization through improved N-use efficiency, reductions in spatial variability in growth, and reductions in year-to-year carryover of soil nitrate.

Introduction

Producers are faced with increasing fertilizer N costs which are linked to the costs of natural gas which comprises approximately 80% of the cost of manufacturing. It is well understood that a deficiency of N in cotton production will limit yield and lower quality. Excesses of N contribute to rank growth, boll rot, difficulty in harvesting, and an increased need for plant growth regulators, insecticides, and defoliants. University N fertilizer recommendations are based on response functions and recommendations are adjusted for various factors such as soil texture, landscape position, soil test N, tissue tests, in-season rainfall, irrigated vs. non-irrigated, variety selection, yield potential or history, previous crop, tillage, cover crop, and history of rank growth. Producers generally select fertilizer N rates based on field average response, while considering one or more of these factors and base level university recommendations.

Crop Reflectance Based N Fertilization

Soil N availability can be considered a determinant of crop biomass production, leaf area, greenness, physiological processes, and ultimately yield. Utilization of crop reflectance as a basis for fertilizer N management has great potential. Green band indices have been shown to be the most reliable for determining leaf N status in cotton (Buscaglia and Varco, 2002; Peterson, 2002; Bronson et al., 2003). Leaf N and K concentrations can be predicted utilizing crop reflectance, especially in the green and red edge spectral regions (Fridgen and Varco, 2004). Vegetative indices from aerial imagery have been shown to be most highly correlated with leaf N at peak bloom (Emerine, 2004). Structural indices (e.g. NDVI, SAVI, etc.) related to canopy scattering and growth are better indicators of field variability at earlier growth stages, while chlorophyll related indices are better related at later stages (Zarco-Tejada et al., 2005). As a theoretical basis for utilizing crop reflectance we can assume the following:

1. Crop growth is a result of an integration of all factors influencing it including the size of the available N pool and weather conditions.
2. Remote sensing/crop reflectance is an indicator of growth.
3. Selected crop reflectance indices can be used as surrogate measurements for total leaf N and N content.
4. Spatial variances in crop reflectance are an indication of growth potential and at least a partial indication of the relative differences in the utilization of and/or size of the available N pool.

Methods

A fertilizer N rate study at the Plant Science Research Unit from 2004 to 2009 at Mississippi State, MS was designed to represent a broad range in N availability which would influence leaf tissue N values, plant height, as well as canopy reflectance. Fertilizer rates included 0, 40, 80, and 120 lb N/acre applied in a 50/50 split at planting and early square. The fertilizer source was urea ammonium nitrate solution (32 %N) applied 9 in. to one side of each row 3 in. deep using no-till coulters equipped with a liquid knife. Treatments were replicated four times and plots were 125 ft long and 12 rows wide at 38 in. spacing. Cotton variety DPL BG/RR 445 was planted at a rate of 4.3 seed/ft. No growth regulators were used and weed and insect control were in response to scouting and university recommendations were followed. Reflectance values were acquired on clear days between 11 a.m. and 12 p.m. using the Yara N Sensor (tec5Hellma, Inc., Plainview, NY) tractor mounted 76 inches above the ground. The Yara N

Sensor is a passive spectrometer which has four reflectance sensors feeding to one central spectrometer and an irradiance sensor. Two reflectance sensors are located on each end of the Yara 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. The vegetative index GNDVI was calculated using the following equation:

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

Results

Lint yield trends for each year are shown in Fig. 1. All years except the first year showed a quadratic response with an agronomic maximum yield near 80 lb N/acre. The first year of the study, tillage consisted of forming rows with hipping disks and the seedbed preparation with a do-all. Yield appeared to respond up to the 120 lb N/acre rate. The 6-y average in Fig. 1 showed a definite peak near 80 lb N/acre and a decline in yield at the greatest rate of 120 lb N/acre. Typically it has been observed that the cotton grows taller in the 120 lb N/acre plots suggesting greater vegetative growth and less boll development.

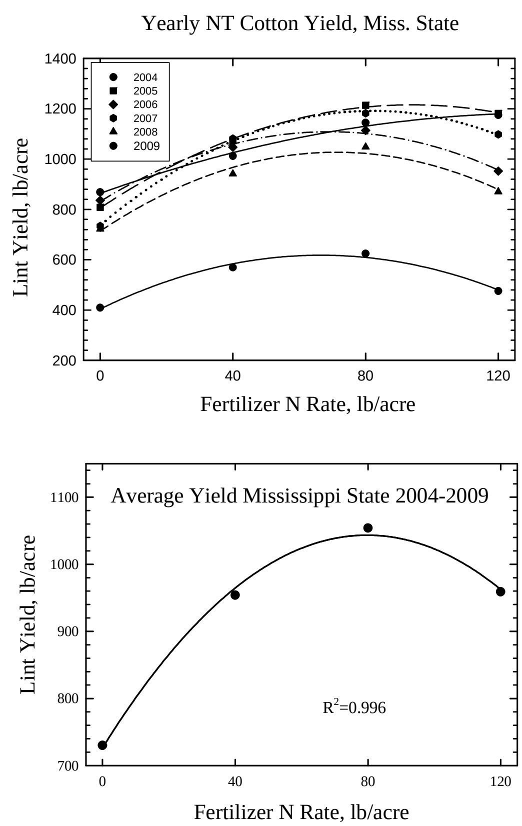

Fig. 1. Yearly cotton lint yield response to fertilizer N rates and the overall 6-y average response.

Fertilizer N rate effects on total N uptake in 2008 are shown in Fig. 2. This effect demonstrates a direct response in N accumulation by aboveground biomass and a proliferation of corresponding dry matter as well as chlorophyll. Both of these components strongly influence canopy reflectance. Given that 80 lb N/acre has produced the agronomic optimum lint yield, it appears that optimum N uptake is near 100 to 120 lb N/acre for a yield near 1000 lb lint/acre.

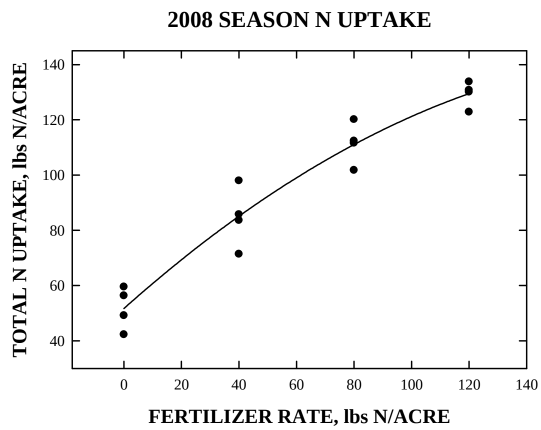

Fig. 2. Total N uptake response to fertilizer N rate in 2008 at Mississippi State.

Leaf tissue N trends as influenced by N availability or varying N rate are shown for 2008 (Fig. 3). Corresponding sampling times are for early square, 2nd week of squaring, 3rd week of squaring, 4th week of squaring, and early flowering. With no added N, leaf N values were generally a 0.5% lower than any of the fertilized treatments throughout the sampling period. All treatments declined drastically from the 3rd week of squaring to early flowering. Separation in treatments was most consistent during this same period.

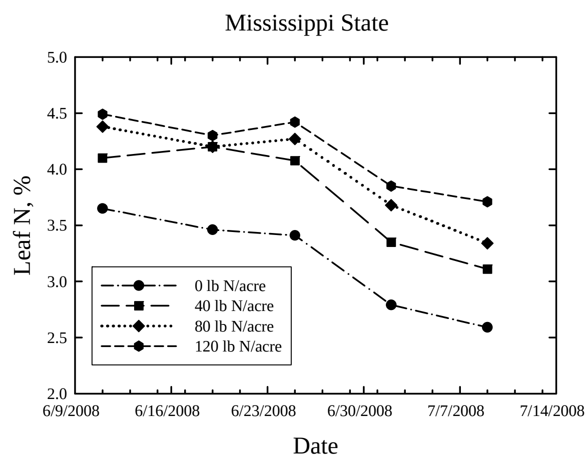

Fig. 3. Temporal changes in leaf tissue N as influenced by fertilizer N rate in 2008.

Leaf tissue N effects on GNDVI values for various growth stages is shown in Fig. 4. The variability in GNDVI was minimal at early square, but increased with later growth stages. It is obvious that as leaf tissue N declines throughout the season, GNDVI increases due to the increase in green biomass.

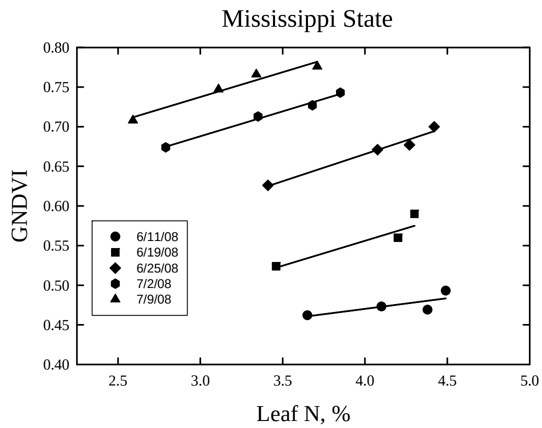

Fig. 4. Response in GNDVI to differing leaf tissue N values for physiological growth stages from early square through to early flowering in 2008.

The response in GNDVI as a result of growth and leaf greenness differences induced by fertilizer N treatments and its relationship to plant height is shown in Fig. 5 for three sampling dates. Although a moderately strong relationship was observed in 2008 at early square, the relationship improved by early flowering and maintained through to peak flowering.

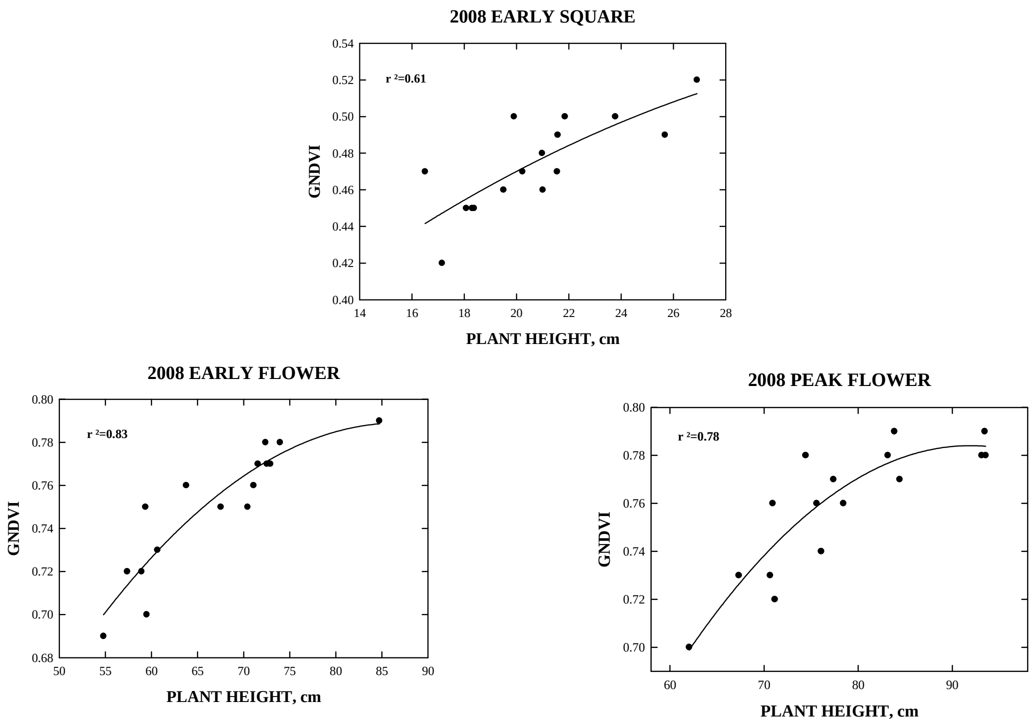

Fig. 5. Relationships between plant height at various physiological growth stages in 2008 to GNDVI.

A four year average response in leaf N to fertilizer N rates at early square and early flowering is shown in Fig. 6. Given that 80 lb N/acre is the agronomically optimum N rate, leaf N values which would optimize N utilization would occur in a range encompassed by the drawn circle. Thus, 4.5% leaf would be a target at early squaring and would decline to around 3.8% at early flowering. This period represents when sidedress N applications are made, beginning at early square and hopefully completed by early flowering.

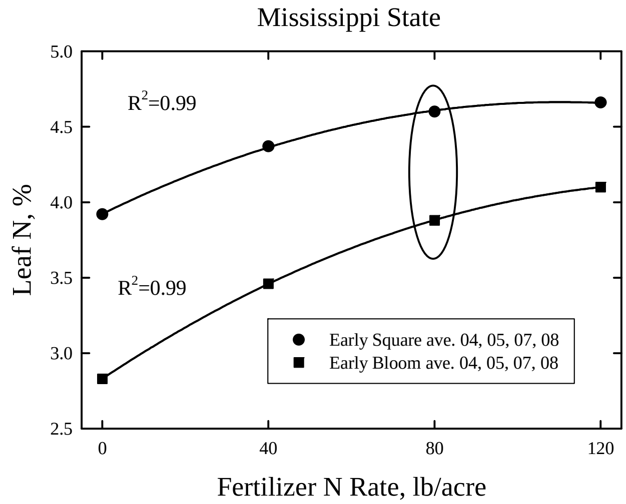

Fig. 6. Average % leaf tissue N response for the years 2004, 2005, 2007, and 2008 in response to fertilizer N rates.

Plotting only GNDVI values for the 80 lb N/acre treatment symbolizes potential target GNDVI values during the period of early squaring through to early flowering Fig. 7. It is obvious that target GNDVI values are ever changing and vary widely during this period. Thus, an agronomic response model used to direct fertilizer N would have to be calibrated for expected growth for the stage of growth at application.

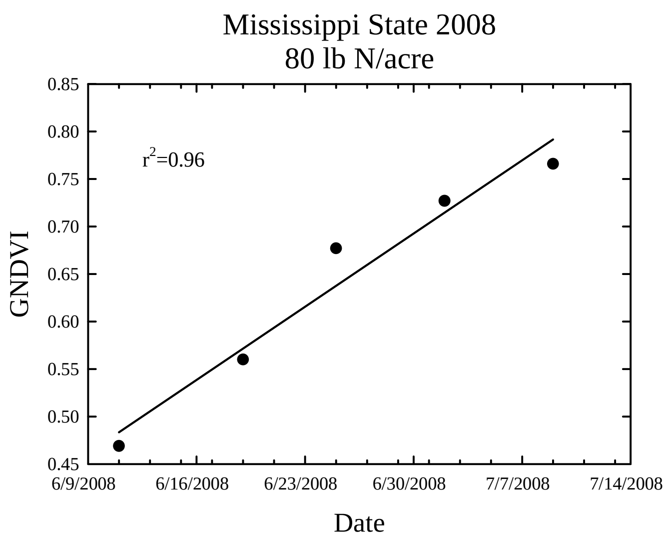

Fig. 7. Temporal changes in GNDVI for the 80 lb N/acre fertilizer rate in 2008 for selected stages of growth from early square through to early flowering.

In effect as shown in Fig. 8, using the slope of the relationship between GNDVI and the fertilizer N rate for a specific stage of growth and a target optimum N rate such as 80 lb/acre with a corresponding GNDVI of 0.68, a sidedress N rate could easily be calculated. For example, if a GNDVI of 0.65 was sensed, the difference between it and the target would result in 50 lb N/acre sidedress application rate.

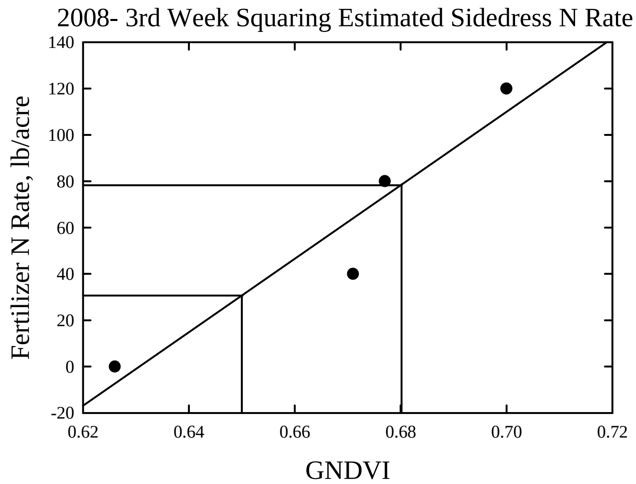

Fig. 8. Simulated calculation of a sidedress N rate at a specific stage of growth (3^{rd} week of squaring) based on a target fertilizer N rate of 80 lb N/acre.

Conclusions

In conclusion, on-the-go sensors can assist in the mapping of spatial and temporal variations in growth and nutrition. Real time crop reflectance can assist in the application of fertilizer N to account for spatial differences in N availability. The profit maximizing N rate should continue to be pursued as the desired target.

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