Improving Nitrogen Use Efficiency In Cotton: A Remote Sensor-Based Approach

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Introduction

Remote sensing is a precision agriculture technique for instant and non-destructive acquisition of crop spectral information. The integration of remote sensing technology in cotton production has the potential to improve management decisions on rate and timing of application for irrigation, pesticide, plant growth regulator and nitrogen (N) fertilizer. Nitrogen fertilizer is one of the major agricultural inputs and considered as the largest expense in cotton production. With recent declines in acreage due to competition from grain crops, a refined fertilizer N-management system that has the potential to increase N use efficiency is essential to maintain a productive and environment-friendly cotton industry in the Mid-South. Yield level and available soil N are essential sources of information to project in-season N rate requirement of cotton. This study was initiated in 2008 to develop an on-site decision tool to determine midseason N rate requirement of cotton. This sensor-based approach requires two components: 1) cotton lint yield potential equation, and 2) model for an in-season estimate of the likelihood of obtaining a response to sidedress N which will be used to project lint yield level and available soil N, respectively.

Materials & Methods

In 2008, cotton trials were established at three sites in Louisiana representing areas where cotton is commonly grown (St. Joseph on a silt loam – NERS-sl and clay loam – NERS-cl soil, and in Winnsboro on a silt loam soil - MRRS-sl). The treatments included six N rates (0, 30, 60, 90, 120, and 150 lbs N ac^{-1}) applied at planting, with and without plant growth regulator arranged in a randomized complete block design with four replicates. Normalized difference vegetation index (NDV) readings were collected using a GreenSeekerTM handheld sensor at different growth stages (early square, early bloom, two- and four weeks after early bloom). At harvest, lint was picked from the two middle rows. Grab samples were collected for % lint determination.

Analysis of variance for the effects of N rate, plant growth regulator and their interaction on lint yield was conducted using PROC MIXED in SAS. Lint yield and N rate data were regressed using non-linear regression (PROC NLIN in SAS) to obtain an estimate of optimal N rate for the three sites. Similar analysis was conducted using estimate of biomass (NDVI/number of days from planting to sensing) as the dependent variable for each of the growth stages. For each growth stage, the relationship between lint yield and NDVI readings was determined. Increases in lint yield attributed to N fertilization were determined by obtaining the ratio of lint yield from the highest N-fertilizer plot and the check plot (response index). The response index using NDVI (RINDVI) was also determined and then regressed with the response index using lint yield (RIHarvest).

Results and Discussion

<u>Cotton Response to N Fertilizer and Optimal N Rates: Midseason vs. Harvest</u>

The analysis of variance for lint yield showed that there was no interaction between PGR and N rate across sites. This means that cotton lint yield response to N fertilization was consistent with or without PGR. Cotton responded to N fertilization in NERS-sl and MRRS-sl, and did not in NERS-cl. These agreed with the observations obtained from the evaluation conducted at midseason (two weeks after early bloom) using NDVI readings. The linear plateau model determined that lint yield was maximized at 101 and 90 lbs N ac^{-1} in MRRS-sl and NERS-sl, respectively. The NDVI readings collected two weeks after early bloom provided comparable estimates of optimal N rate. The N rates were 92 and 85 lbs N ac^{-1} for MRRS-sl and NERS-sl, respectively.

<u>Components of the On-Site Decision N Tool Using Remote Sensor</u>

The NDVI readings collected two weeks after early bloom showed the best association with lint yield when compared with the rest of the growth stages. This initially suggests that the window for optimum sensing dates in terms of the number of days from planting to sensing would be 70-80 days. Prior to combining the data from different sites, the NDVI readings were divided by the number of days from planting to sensing (in-season estimate lint yield, INSEY). The relationship between lint yield and INSEY was best described by an exponential model (Figure 1). The NDVI is a good index of biomass and the sensor can determine the biomass as it relates to lint yield regardless of the magnitude of cotton response to N fertilization. The initial results showed that the sensor-based predicted RI (RINDVI) can explain 40% of variability in the actual lint yield RI (RIHarvest) (Figure 2). The RIHarvest is determined at harvest which is after the fact. This becomes less of use for midseason N requirement determination since yield response to N fertilization differs from one year to another. An established relationship between RINDVI and RIHarvest implies that the lint yield response to N fertilization can now be determined earlier in the season which is essential for determination of midseason N rate requirements. The linear equation (Figure 2) suggests that the actual increases in lint yield attributed to N fertilization can be estimated when RINDVI is known. With the current estimation procedure established for lint yield potential and cotton response to N fertilization using midseason NDVI readings, the functional equation that runs the proposed on-site N decision tool (Figure 3) is summarize as:

$$F_n = \frac{YP_0N_g}{\varepsilon_n}(RI - 1)$$

where:

F_n = N application rate, lb N ac^{-1}

Y_0 = Estimated in-season yield potential, lb ac^{-1}

N_g = N content in seed cotton, lb N ac^{-1}

ε_n = Expected N use efficiency (range from 0.5 to 0.7)

RI = Estimate of cotton response to N fertilization using NDVI

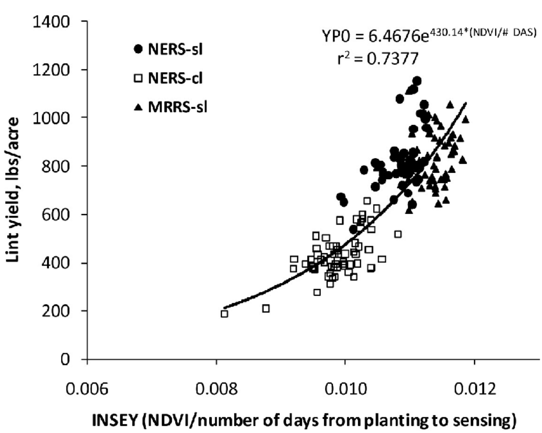

Figure 1. Relationship between actual lint yield and in-season estimated yield potential (normalized difference vegetation index/number of days from planting to sensing). NDVI data were collected two weeks after early bloom.

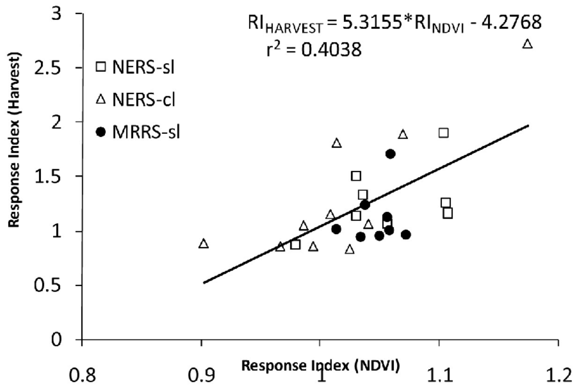

Figure 2. Relationship of sensor-based estimated increased in lint yield and actual lint yield increase due to N fertilization.

Sensor Based N Rate Calculator, Cotton 2009

DATA ENTRY	
Max yield, lbs/ac	3000
Planting Date	10-May-09
Sensing Date	8-Jul-09
NDVI, N Rich Strip	0.6585
NDVI, Farmer practice	0.5795
NUE expected	0.6
RESULTS	
Response Index	1.76
Days, planting to sensing	58
Potential yield (0-N), lbs/ac	476
Potential yield (+ N), lbs/ac	839
Fertilizer N, lb N/ac	**85**

Note:

NRS (Nitrogen Rich Strip) - plots receiving non limiting amount of N fertilizer applied at preplant

FP (Farmer Practice)- plots receiving modest amount of N applied at preplant

NDVI (normalized difference vegetative index)

Max yield - average yield x 2

PROCEDURE:

1. Farmer is asked to Establish the Maximum Yield Achievable, For that Year (YPMAX)
2. Sense the N Rich Strip (NRS)
3. Sense a strip parallel to the NRS (Farmer Practice or FP)
4. Determine how many days from planting to sensing
5. Compute INSEY (NDVI/days from planting to sensing)
6. Predict yield
7. Predict seed cotton N uptake in FP
8. Predict seed cotton N uptake in FP based on RI
9. N rate = (seed cotton N uptake in FP based on RI - seed cotton N uptake in FP)/expected NUE

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Figure 3. On-site decision tool for cotton using remote sensor.