IMPROVING NITROGEN USE EFFICIENCY IN COTTON THROUGH OPTICAL SENSING

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Abstract

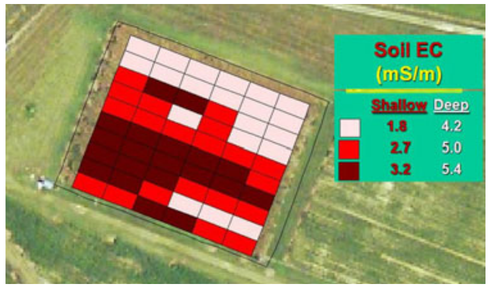
There is currently no established empirical method to determine N requirements for cotton utilizing optical sensing techniques. In addition, due to significant variations in soil type in the Southeastern Coastal Plain region, the algorithm for predicting N requirements should be modified to account for the effect of spatial variation as it affects the crop's ability to respond to additional fertilizer. The objective of this study was to develop an algorithm for variable-rate application of nitrogen in cotton production utilizing plant NDVI (Normalized Difference Vegetation Index) and soil electrical conductivity (EC) data. The production field was divided into three management zones based on EC data. Five different rates of nitrogen fertilizer (0, 30, 60, 90, and 120 lbs/acre) were applied to plots of each zone for developing the "N-rate" algorithm. Equipment was developed for applying nitrogen "Ramped Calibration Strips" in production fields for predicting the potential response to applied N fertilizer. Six GreenSeeker optical sensors were used for measuring crop NDVI. The results showed that there is a potential to use mid-season specific plant NDVI data for variable-rate application of N fertilizer in cotton production. The soil EC data should be included in the N-rate prediction equation for the Southeastern Coastal Plain region. The variable-rate N application predicted 31% less fertilizer compared to uniform N applications. In low EC areas, seed cotton yield increased as N rates increased. However, in medium and high EC areas there was no yield response above 90 lbs/acre N.

Introduction

High production costs and low cotton prices make it more important for our growers to reduce crop inputs and maximize yields. Drastic increases in the cost of oil and the subsequent increase in N fertilizer costs has forced many producers to consider the variable-rate or reduced rate N fertilizer application. Over the last several years, many growers have begun to utilize multispectral aerial imagery to variably apply inputs during the growing season.

Considerable soil variation occurs within and across production fields in the Southeastern US which will have a major impact on fertilizer management strategies. Currently farmers apply a uniform rate of N fertilizer across an entire field or even farm. However, plant demand and response to N changes from year to year and mobile nutrients (such as N) are used, lost, and stored differently as soil texture varies. Therefore, uniform application of N fertilizer over the entire field can be both costly and environmentally questionable. Malakoff (1998) reported that excess nitrogen flowing down the Mississippi each year is estimated to be worth $750,000,000.

Researchers at Oklahoma State University (OSU) have developed Algorithms for crop nitrogen fertilization based on optical sensors. Theses Algorithms calculate N requirements for wheat, corn, canola, rice, and Bermuda grass. The N fertilizer rates depends on making an in-season estimate of the potential or predicted yield, determining the likely yield response to additional nitrogen fertilizer, and finally calculating N required obtaining that additional yield (Raun et al., 2005). The results showed $36 to $39/acre profit in corn production while reducing N application rate by 45 to 70% compared to farmers practice. There is currently no established empirical method to determine N requirements for cotton utilizing the OSU procedure. In addition, due to significant variations in soil type in our area, the algorithm for predicting N requirements should be modified to account for the effect of spatial variation as it affects the crop's ability to respond to additional fertilizer.



Objectives

The objective of this project was to develop an algorithm for variable-rate application of nitrogen in cotton production utilizing plant NDVI (Normalized Difference Vegetation Index) and soil electrical conductivity (EC) data.

Materials and Methods

Tests were conducted in a 4-acre section of a field near Blackville, SC. A commercially available soil electrical conductivity (EC) measurement system (Veris Technologies 3100) was used to identify variations in soil texture across the field. The test field then was divided into three management zones based on soil EC data and each zone was divided into 60 ft by 8-row plots (Figure 1).

Five different rates of nitrogen fertilizer (0, 30, 60, 90, and 120 lbs/acre) were replicated three times in plots of each zone using a Randomized Complete Block design arrangement.
Figure 1: The test field with zone and plot arrangements

Cotton (Delta & Pine Land 555 Bt/RR) was planted on May 14th 2007, and carried to yield using recommended practices for seeding, insect, and weed control and plots were irrigated 8 times during the growing season (5.25 in. total). Our work in 2006 showed a strong correlation between plant NDVI and cotton yield (Khalilian et al., 2007). Therefore, we investigated the feasibility of predicting cotton yield utilizing algorithms similar to those developed by OSU for corn and wheat (Raun et al., 2005). Plant Normalized Difference Vegetation Index (NDVI) was measured during the growing season using a 6-row sprayer-mounted GreenSeeker® RT-200 mapping system (NTech Industries, Inc. Ukiah, CA). NDVI readings were taken from test plots 39, 47, 58, 67, and 80 days after cotton emergence. Plant height and SPAD readings were taken three times (58, 67, and 80 days after emergence) from all test plots. For each sampling date, 10 leaves from each plot were analyzed for N concentration.

In-season estimated yield, or INSEY was calculated by dividing NDVI measurements by the number of days from emergence to sensing. Cotton was harvested at crop maturity using a spindle picker equipped with an AgLeader yield monitor and GPS unit to map changes in lint yield within and among treatments. Linear and non-linear regression models were used to determine the relationships present between cotton yield and NDVI using Procedures in SAS. In addition, the relationship between actual cotton yield and the In-season estimated yield (INSEY) was used for developing the N prediction algorithm.

Identifying a specific yield potential (YP_0) does not translate directly to an N recommendation. Determining the extent to which the crop will respond to additional N is equally important (Raun et al., 2005). The current algorithm employed at Oklahoma State University uses the predicted yield potential (YP_0) and estimated response index (RI) from NDVI readings to predict yield potential when N is applied (YP_N). Crop reflectance was calibrated using multiple N rate calibration plots, or ramp approach similar to those used for wheat and corn (Raun et al., 2006). The Nitrogen Ramped Calibration Strip (N-RCS) is a new technology that applies increasing levels of nitrogen (N) in a strip across a fixed distance.

Equipment was developed for applying nitrogen to "Ramped Calibration Strips" for predicting the potential response to applied N fertilizer (Figure 2). With this system, a ground driven wheel sends signals (based on a preset fixed distance) to the controller for changing the N rate to the next level. Ramp calibration strips with 16 rates of N ranging from 0 to 150 lbs/acre were applied in each zone (Figure 3). The N-RCS were applied on June 7, 2007 about 25 days after the planting date. The response index (RI) was calculated by dividing the highest NDVI reading in the ramped calibration strips by NDVI measurements of the adjacent area in each zone: RI= (NDVI $_{Ramp}$)/ (NDVI $_{Field}$).

Figure 2: The Clemson nitrogen ramp calibration strips applicator

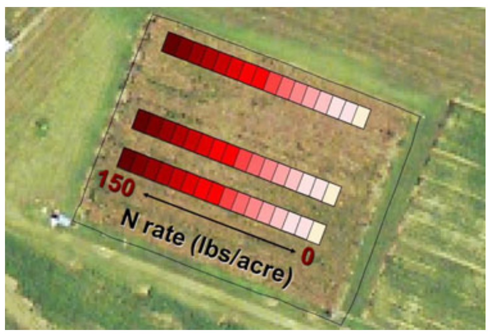


Figure 3: Nitrogen ramped calibration strips established in each zones

The predicted attainable yield (YP_N) with added nitrogen was calculated by multiplying YP_0 by RI. The predicted yield potential (YP_N) should not exceed the maximum cotton yield (YP_{MAX}) for a given region and management practices. In our case the YP_{MAX} was set at three bales/acre for the "Savannah Valley Region" of South Carolina. Nitrogen fertilizer rate was then determined by dividing the difference in lint & seed N uptake of YP_N and YP_0 by the nitrogen use efficiency for cotton (50%).

Results and Discussion

Figure 4 shows the effects of N rate on plant NDVI for 39, 47, 58, and 67 days after cotton emergence. The NDVI values increased as the EC values increased. The management zone one (Low EC values – green line) had the lowest NDVI values followed by zone two (Mid EC values – red line) and zone three (high EC values – blue line), respectively. For sampling dates of 39, 47, and 58 days after cotton emergence, the NDVI increased as N rates increased up to 90 lb N/acre. However, it did not show further response to higher rates of nitrogen.

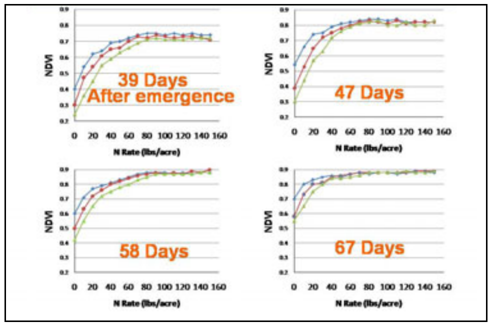


Figure 4: Effects of N rate on NDVI

The NDVI values increased with days after emergence. For lower rates of nitrogen (0, 30, and 60 lbs/acre), the NDVI values increased with days-after-emergence for all sampling dates (Figure 5). For higher N rates, the NDVI values decreased after the third sampling date (60 days after emergence).

Figure 6 shows yield prediction equations for the test field (left) and for each management zone (right). There was a high correlation between INSEY and actual seed cotton yields. The values of R^2 increased significantly when the shallow EC data were included in the yield prediction equations. The results showed that there is a potential to use mid-season specific plant NDVI data for variable-rate application of N fertilizer in cotton production. The soil EC data should be included in the N-rate prediction equation for the Southeastern Coastal Plain region.

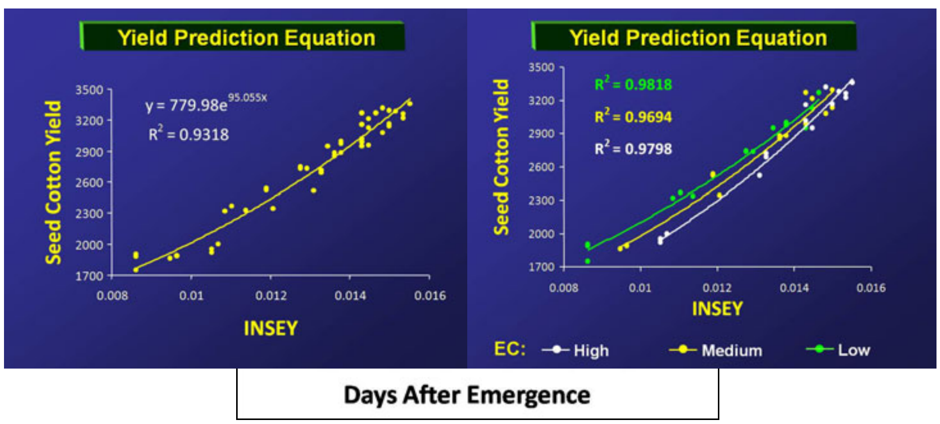


Figure 5: Effects of nitrogen rates and days after emergence on NDVI.

Figure 6: The effects of application methods on PGR requirements.

Figure 7 shows YP_0; calculate YP_N, and YP_{MAX} values for seed cotton (left). The RI value for this test was 1.5 and the YP_{MAX} was set at three bales/acre for the "Savannah Valley Region" of South Carolina. The N recommendation was calculated by dividing the difference in lint & seed N uptake of YP_N and YP_0 by the nitrogen use efficiency for cotton (50%). The variable-rate N application predicted 31% less fertilizer compared to uniform N applications. In low EC areas, seed cotton yield increased as N rates increased. However, in medium and high EC areas there was no yield response above 90 lbs/acre N.

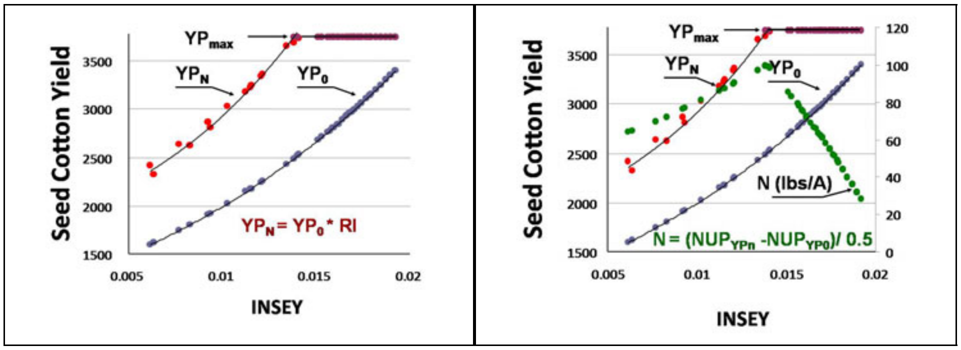


Figure 7: The effects of application methods on PGR requirements.

Summary

The results showed that there is a potential to use mid-season specific plant NDVI data for variable-rate application of N fertilizer in cotton production. The soil EC data should be included in the N-rate prediction equation for the Southeastern Coastal Plain region. The variable-rate N application predicted 31% less fertilizer compared to uniform N applications. In low EC areas, seed cotton yield increased as N rates increased. However, in medium and high EC areas there was no yield response above 90 lbs/acre N.

Acknowledgements

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Disclaimer

Mention of a trade name does not imply endorsement of the product by Clemson University to the exclusion of others that might be available.

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