Optimizing Nitrogen Fertilization of Cotton Using Sensor-Based Canopy Reflectance

Jac J. Varco, Amelia A.A. Fox, and Totsanat Rattanakaew, Plant and Soil Sciences Dept., Mississippi State University

Introduction:

Embedding nutrient management goals into N fertilization practices requires attention to satisfying crop demand for N in spatially variable fields to maximize N use efficiency and productivity. Various vegetation Indices (VI) have been examined for their utility in detecting crop health relative to crop N status or as an indicator of available soil N. Some VI's have greater utility in detecting crop biomass, while others have greater capabilities in detecting greenness which is more relatable to either leaf N or whole plant N concentration. Combined indices such as the Canopy Chlorophyll Content Index (CCCI) as described by Barnes et al. (2000) utilize reflectance in the red-edge wavelength region for greenness detection, while normalizing for biomass or canopy density (Eitel et al., 2010). Alluvial soils, typically used for cotton (*Gossypium hirsutum* L.) production in Mississippi display a high degree of spatial variability in soil properties due to alternating textural differences within managed fields (Buscaglia and Varco, 2003). Utilizing canopy reflectance as a tool to detect spatial patterns to be utilized in variable rate management schemes assumes that the crop is a strong integrator of all soil and plant growth factors; and thus, serves as a strong indicator of N status. Although crop stresses can be numerous, grower's manage them well, while the highly biologically active and mobile N can impart a fairly strong signature across fields.

Objectives:

1. To compare a sensor-based side dress liquid fertilizer N application to a grower's practice and response to fixed N rates in terms of leaf tissue N concentrations, lint yield, and N-use efficiency.
2. To compare whether a second factor used to adjust a sensor-based side dress can improve N-use efficiency.

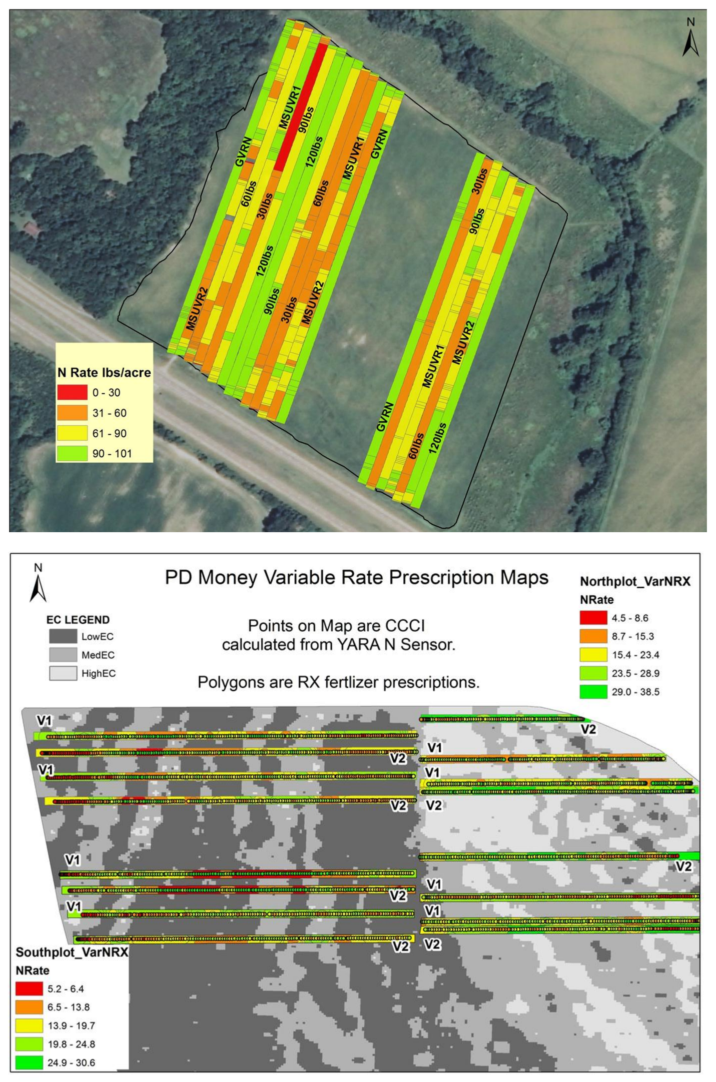
Methods:

Experimental sites:
2012- S. of Natchez, Mississippi; Convent silt loam 45.9%, Morganfield silt loam 53.9%
RCB 3 replications, strip plots, non-irrigated, planted 21 April, ST 5288 B2F
2013-2014 N.W. Money, Mississippi; Dubbs-Dundee Complex 75.1%, Tensas silty clay loam 22.7%, Tensas-Alligator Complex 2.1%
RCB 4 replications, strip plots, land-planed and furrow irrigated 3 x's, planted 21 May DP 1321 B2RF
Twelve row plots, spacing of 0.97 m (38 inches) and variable in length.
Grower's cultural practices used, conventional tillage for all site/years.
Fertilizer N rates of 33.7, 67.4, 101.1, 134.8 kg N ha^{-1} applied 23 May 2012 at Natchez along with variable rate (VR) treatments, and for Money North plots these rates were applied 13 June including a base rate of 33.7 kg N ha^{-1} to VR treatments. All 2013 South plots prior to planting on 12 April received 78.6 kg N ha^{-1} and a sidedress supplement at early squaring (29 June) of 0, 28, 56, and 84 kg N ha^{-1} for total rates of 78.6, 106.7, 134.7, and 162.7 kg N ha^{-1} and VR treatments were applied for both North and South sites on 1 July 2013.
Variable rate treatments applied at pinhead to early squaring following canopy reflectance using a YARA N Sensor (Yara International ASA, Oslo, Norway) and calculation of a Simplified CCCI (SCCCI). The SCCCI was calculated as reported by Raper and Varco (2014) as Normalized Difference Red Edge index (NDRE)/Normalized Difference Vegetation Index (NDVI). Reflectance at wavelengths of red edge=720 nm, NIR=840, and red=650 nm was used to calculate NDRE/NDVI. The SCCCI was calibrated to historical crop growth and greenness and expressed as fertilizer N equivalence. Estimated fertilizer equivalence based on crop growth was then subtracted from a target N rate; whereby, the result equaled the target N rate to be applied. A prescription map output of target N rates as a shapefile was generated in ArcGIS. Treatments labeled VR1 are sensor based only and VR2 are sensor based adjusted for historical corn yield the previous year at the Natchez site, and soil electrical conductivity (EC) for 2013 at the Money site. At Natchez, the grower used a VR application based on soil CEC. Three categories were identified; Corn yield/Soil EC Low, Medium, and High. Relative to sensor based targets, 33.7 kg N ha^{-1} was subtracted from low classifications and added to high classifications, while nothing changed for medium classifications. All N applied as liquid UAN (28-0-0-5S) banded 22.cm from the row and approximately 7.5 cm deep.
Cotton was harvested with a 6-row picker equipped with a round module builder
Statistical analysis was conducted using SAS 9.3 General Linear Models. Variable treatments were compared to the grower's current practice, GVRN-CEC based variable rate at Natchez site, and 134.8 kg N ha^{-1} at Money site.

Fig. 1. Facilitation of canopy reflectance for greenness and biomass utilizing a tractor mounted YARA N Sensor.

Fig. 1. Six-row cotton picker with round module builder. Trailer scale used to weigh round modules.

Fig. 3. Treatment maps for Natchez 2012 (top) and Money 2013



Results and Discussion:

Effects of N treatments on leaf N % are shown in Tables 1-3. All N treatments increased leaf N % at early bloom compared to 2nd week of squaring, while all declined from early bloom to peak bloom. Nitrogen rate effects were evident throughout and VR treatments maintained leaf N % similar to 134.8 kg N ha^{-1}. At Money in 2013, leaf N % tended to increase from early bloom to peak bloom possibly due to an irrigation event on 12 July. Nitrogen rate effects were most evident at peak bloom, while VR treatments maintained greater leaf N than the greatest constant rate applied at each site.

Table 1. Nitrogen treatment effects on leaf N % at three stages of cotton growth at Natchez, Miss. in 2012.

N Treatment, kg ha^{-1}	2nd week squaring 6/6/12	Early Bloom 6/20/12	Peak Bloom 7/17/12
33.7	4.08	4.52	3.64
67.4	4.45	4.90	4.01
101.1	4.50	5.05	3.95
134.8	4.52	5.02	4.08
GVRN/109.3	4.71	5.14	4.14
VR1/85.6	4.49	4.99	4.02
VR2/75.0	4.60	4.98	4.06
$LSD_{(0.05)}$	0.48	0.34	0.17

Table 2. Nitrogen treatment effects on leaf N % at three stages of cotton growth at Money, Miss. North site in 2013.

N Treatment, kg ha^{-1}	Early Square 6/27/13	Early Bloom 7/15/13	Peak Bloom 7/29/13
33.7	5.06	3.90	3.86
67.4	4.89	4.16	4.38
101.1	5.35	4.07	4.42
134.8	5.34	4.23	4.65
VR1/103.4	5.11	4.06	4.90
VR2/120.0	5.13	4.12	4.93
$LSD_{(0.05)}$	0.18	0.29	0.22

Table 3. Nitrogen treatment effects on leaf N % at three stages of cotton growth at Money, Miss. South site in 2013.

N Treatment, kg ha^{-1}	Early Square 6/27/13	Early Bloom 7/15/13	Peak Bloom 7/29/13
78.6	4.58	4.43	4.61
106.7	4.61	4.55	5.00
134.7	4.56	4.59	5.09
162.7	4.63	4.56	5.20
VR1/145.6	4.63	4.58	5.46
VR2/147.8	4.62	4.41	5.37
$LSD_{(0.05)}$	0.13	0.25	0.26

Lint yield response to N treatments is shown in Figs. 4-6. The VR1 treatment at Natchez resulted in the greatest yield and out performed the grower's CEC based VR treatment (GVRN). The VR2 treatment resulted in a lower average N rate applied, but yields were reduced. At Money in 2013, both VR1 and 2 treatments resulted in a lower average N rate while not significantly reducing lint yield. Both VR treatments resulted in a greater average N rate applied and numerically increased yield but the result was not significant.

Fig. 4. Effects of N treatments on cotton lint yield in 2012 at Natchez, Miss.

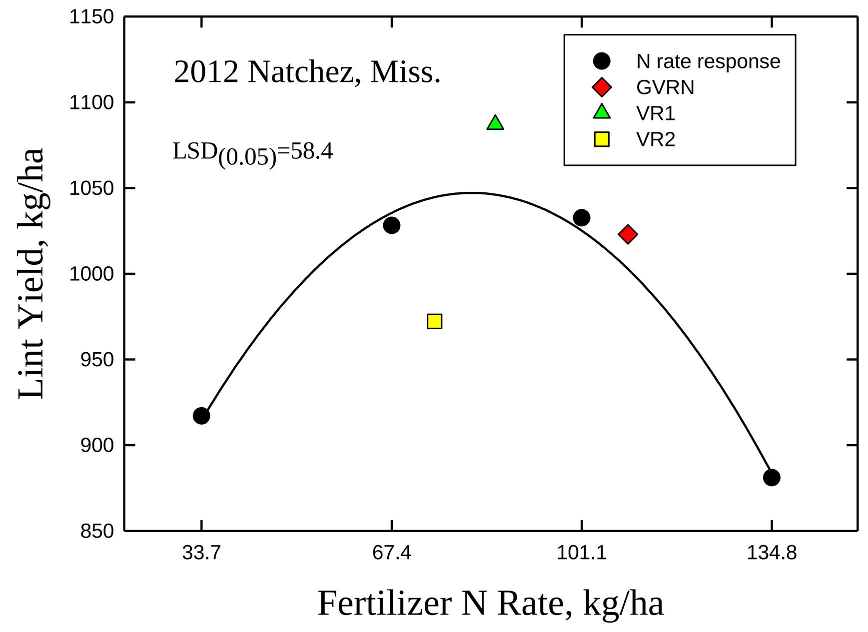


Fig. 5. Effects of N treatments on cotton lint yield in 2013 at Money North site.

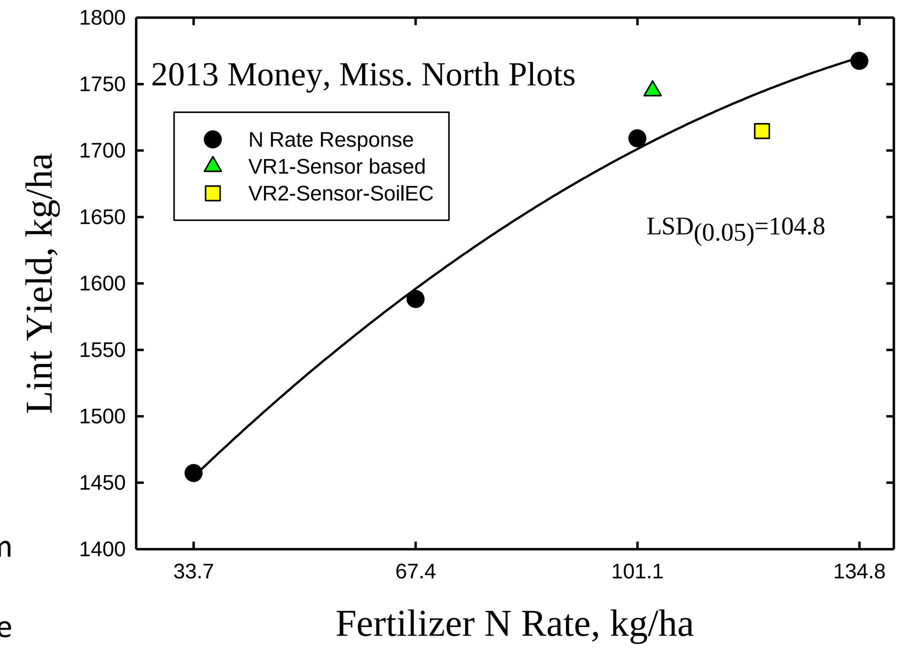
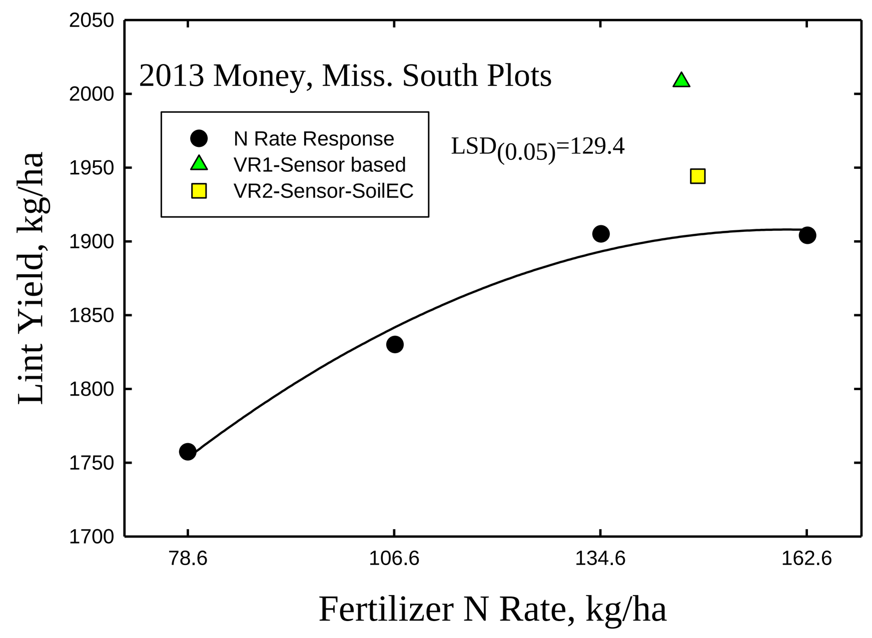


Fig. 6. Effects of N treatments on cotton lint yield in 2013 at Money South site.



The quantity of lint produced per kg of fertilizer N applied without accounting for soil N availability is shown in Table 4. Lint output per kg of applied N decreases as N rate increases. Values were greater for VR1 and VR2 treatments relative to the grower treatment or applied rate indicating an increase in N-use efficiency with sensor based applications.

Table 4. Nitrogen treatment effects on kg-lint produced per kg N applied plus soil N supplied.

N Treatment, kg ha^{-1}	Natchez 2012	Money North 2013	Money South 2013
33.7/78.6	30.2	43.2	22.4
67.4/106.7	15.3	23.6	17.2
101.1/134.7	10.2	16.9	14.1
134.8/162.7	6.5	13.1	11.7
GVRN	9.4	N/A	N/A
VR1	12.7	16.9	13.8
VR2	13.0	14.3	13.2

Conclusions:

Utilization of canopy reflectance near early cotton squaring and expressed as the SCCCI, provided favorable lint yield results; whereby, lint output per kg of N applied was increased relative to the producer's current practice. Detecting cotton biomass and greenness appears to be a viable indicator of crop N needs. Spatially driven application of fertilizer N to cotton can reduce over- and under-application rates and improve fertilizer N utilization. Canopy reflectance requires calibration to known cotton growth response to N availability and intuitive grower input to adjust minimum, maximum, and perceived optimum average field rate.

References:

1. Barnes, E.M., T.R. Clarke, S.E. Richards, P.D. Colaizzi, J. Haberland, M. Kostrzewski, P. Waller, C. Choi, E. Riley T. Thompson, R.J. Lascano, H. Li, M.S. Moran. 2000. Coincident detection of crop water stress, nitrogen status and canopy density using ground based multispectral data. Unpaginated C_ROM (13.pdf) *In* P.C. Robert et al. (eds.), Proc. 5th International Conf. on Precision Agriculture, Bloomington, MN 16-19 July 2000. ASA, CSSA, and SSSA, Madison, WI.
2. Buscaglia, H.J., and J.J. Varco. 2003. Comparison of sampling designs in the detection of spatial variability of Mississippi Delta soils. Soil Sci. Soc. Am. J. 67:1180-1185.
3. Eitel, J. U. H., R.F. Keefe, D.S. Long, A.s. Davis, and L.A. Vierling. 2010. Active ground optical remote sensing for improved monitoring of seedling stress in nurseries. Sensors:10:2843-2850.
4. Raper, T.B., and J. J. Varco. 2014. Canopy-scale wavelength and vegetative index sensitivities to cotton growth parameters and nitrogen status. Prec. Agric. 15, DOI 10.1007/s11119-014-9383-4.

Acknowledgement – This research was supported by a USDA/NRCS Conservation Initiative Grant.