RESEARCH REPORT FOR 2013
TO
FLUID FERTILIZER FOUNDATION

Use of Remote Sensing in Cotton to Accurately Predict the Onset of Nutrient Stress for Foliar Alleviation for Optimizing Yield and Quality

by

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January 2014

SYNOPSIS AND JUSTIFICATION

Recent advances in technology and the increased availability of canopy reflectance hardware has resulted in the development and utilization of vegetation indices to drive on-the-go variable rate applications of fertilizer nitrogen (N). Although the spectral response of crops to N stress has been thoroughly defined (Samborski et al., 2009), the spectral response to differing varieties and available potassium (K) quantities have not been examined in such detail. As a result, sensitivities of these indices to variables other than N deficiency have been shown to result in over application of N when N is not the most limiting yield factor (Zillman et al., 2006).

Leaf reflectance measured by a spectrometer is typically sensitive to changes in N status, however, research has shown a deterioration of this relationship when K is not sufficient (Fridgen and Varco, 2004). Further complicating sensor-driven, variable rate applications of N, K deficiency symptoms may appear unpredictably (Oosterhuis and Wier, 2010) on soil that has a sufficient soil test K level (Cope, 1981). Moreover, the large spectrum of varieties in upland cotton production encompasses vastly different structural features and physiological maturity patterns. The most frequently utilized index, normalized vegetation difference index (NDVI), has been reported to be sensitive to variety during the flowering period, with relationships deteriorating later in the growing season (Benitez Ramirez and Wilkerson, 2010).

Although neither the response to variety nor available K is typically considered in the development of a canopy reflectance based, N-sensitive index, the responses of each index to these variables must be considered to prevent inaccurate N fertilization and subsequent environmental and financial repercussions. Therefore, the main objective of this research was to examine the response of two contrasting indices to variety and changes in available K.

MATERIALS AND METHODS

A randomized strip, complete block trial with five replications was conducted at the Lon Mann Cotton Research Center in Marianna, AR. Soil samples were taken from bed shoulders at 6 inch depths from each plot (60 total plots) on 31 January and analyzed (Mehlich-3 extraction) by the University of Arkansas Soil Testing Laboratory in Marianna, AR. Treatments consisted of an untreated check (0 lb K_2O/acre), 30, 60, and 90 lb K_2O/acre applied to Phytogen 499 WRF, Stoneville 5458 B2RF, and DeltaPine 912 B2RF varieties. Cotton was planted on 8 May at a plant density of 3.5 plants/foot. Plots consisted of four rows 50 foot in length. Row spacing was 38 inches. Fertilizer N was applied in a split application (60% at emergence and 40% at first square) to total 100 lb N per acre. All other inputs and thresholds were established and maintained to isolate K as the sole yield-restricting input.

Reflectance measurements were taken on two dates (7 and 22 August) after visible deficiency characteristics were evident using the Crop Circle ACS-470 (Holland Scientific Inc., Lincoln, NE). The center two rows of each plot were measured at a sensor-to-canopy height of 36 inches. The three measured wavelengths were centered in the red (650 nm), red-edge (670 nm) and near infrared (760 nm) regions. Data was trimmed to exclude values taken within 5 feet of the plot ends. These wavelengths were then used to calculate two contrasting indices: NDVI, which has been shown to be sensitive to changes in plant structure and biomass (Bronson et al., 2003), and the Canopy Chlorophyll Content Index (CCCI) which has a heightened sensitivity to N stress and is less responsive to changes in plant biomass than NDVI (Raper and Varco, 2011). Seedcotton yield was determined by mechanically harvesting the center two 50 foot rows of each plot.

Regression analysis tested the response of seedcotton yield and index readings to changes in available K_2O. Analysis of variance was conducted for both reflectance dates and yield data in JMP 10 (SAS Institute Inc., Cary, NC). Independent variables in the model included block, available K, variety, and the interaction between available K and variety. The calculated amount of available K was chosen in lieu of the applied K fertilizer rate due to initial differences in soil K concentrations (**Table** 1 and Table 2). Available K_2O was calculated as [(ppm soil test K × 2 × 1.2) + lb K_2O fertilizer/acre] where 1.2 is the factor for converting K to K_2O and 2.0 is the factor for converting ppm to lb/acre assuming 2 million pounds soil/acre furrow slice.

RESULTS AND DISCUSSION

The response of seedcotton to changes in variety and available K_2O were significant ($p \leq 0.05$), as was the interaction between these two terms ($p \leq 0.10$) (Figure 1). Results suggest increases in available K_2O did not significantly increase Phytogen 499 seedcotton yields, but did increase DeltaPine 912 and Stoneville 5458 yields. As evident by the available K_2O levels and relatively high yields, severe K deficiencies were not noted. Sufficient soil K may have contributed to the failure of Phytogen 499 yields to respond to increased available K_2O. Still, the moderately strong response of Stoneville 5458 and slight response of DeltaPine 912 does suggest that increased K_2O availability could increase yields within this range for these two varieties.

Visible K deficiency symptoms were noted in control plots during the first week of flower in Stoneville 5458 plots but were not consistent across the field until near peak flower. As a result, reflectance was measured at mid-flower (7 August) and after peak flower (22 August). Responses from both sampling dates were similar. The interaction effects between available K_2O and variety on NDVI readings were significant ($p \leq 0.10$) (Figure 2 and Table 3). However, CCCI was significantly affected only by variety, as available K_2O had no significant effect on CCCI ($p \leq 0.05$, Figure 2).

Results suggest NDVI is sensitive to variety and changes in available K_2O. The interaction between variety and available K_2O suggests that individual models will have to be developed to characterize specific NDVI response to an individual variety's sensitivity to changes in available K_2O. In contrast, CCCI was only significantly affected by variety, which suggests that a variety specific correction term could be developed and implemented. It should be noted that significant response of an index to variety should be highly preferred over the response of an index to available K_2O, because variety is spatially consistent.

PRACTICAL APPLICATIONS

The adoption of on-the-go sensor readings to drive variable rate N applications must incorporate some correctional factor for variety if NDVI or CCCI is used. Furthermore, it appears that

NDVI based algorithms have the potential to recommend increased fertilizer N when K deficiencies are present. In contrast, CCCI does not appear to be susceptible to such errors.

PROJECT DURATION

These results warrant a second year of field studies since visible, consistent moderate- to severe-K deficiencies were not evident until near peak flower. Deficiencies which occur earlier in the growing season would most likely result in greater yield responses to applied K and an increased response of reflectance indices to applied K. The second year of results should help separate index responses to K and give more information on the potential to drive foliar fertilizations from these values.

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Table 1: Soil test K (Mehlich 3) results and calculated available K_2O concentrations from soil samples taken in Marianna, AR.

	Mehlich-3-extractable soil potassium (ppm)		
Replication	Min	Mean	Maximum
1	63	86	135
2	67	95	133
3	96	122	139
4	80	109	147

	Calculated available soil potassium (lb K_2O/acre)[a]		
Replication	Min	Mean	Maximum
1	181	259	349
2	160	258	349
3	260	341	391
4	232	316	442

[a]Calculated available soil K represents a conversion of soil parts per million (ppm) to lb of available K_2O per acre added to lb of applied K_2O fertilizer, with 100% availability of applied fertilizer assumed.

Table 2: Analysis of variance results for response of soil K to plot location (within replication) and replication.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio	Prob>F
Plot location	14	7780.233	555.731	2.2204	0.0234
Replication	3	10760.600	3586.867	14.3312	<.0001
Error	42	10511.900	250.28		
Total	59	29052.733			

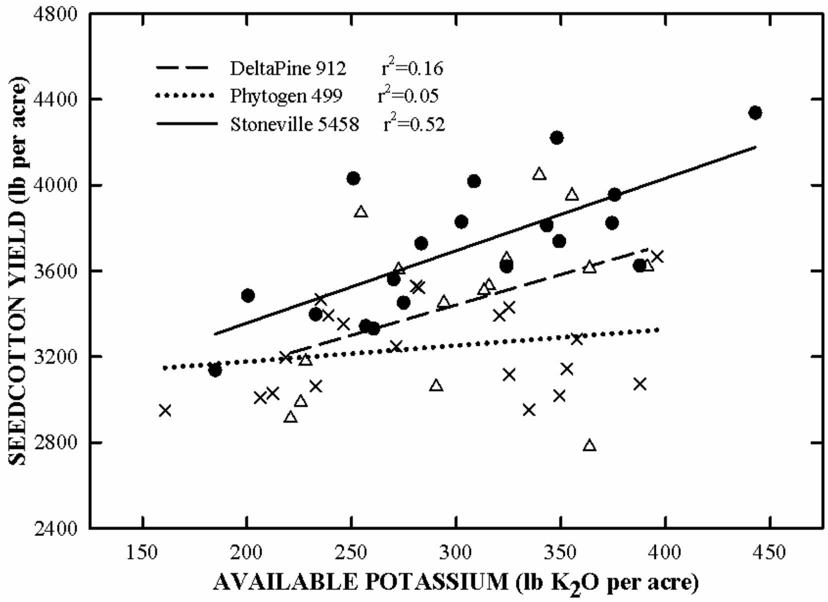

Figure 1: Response of seedcotton yield to available K_2O.

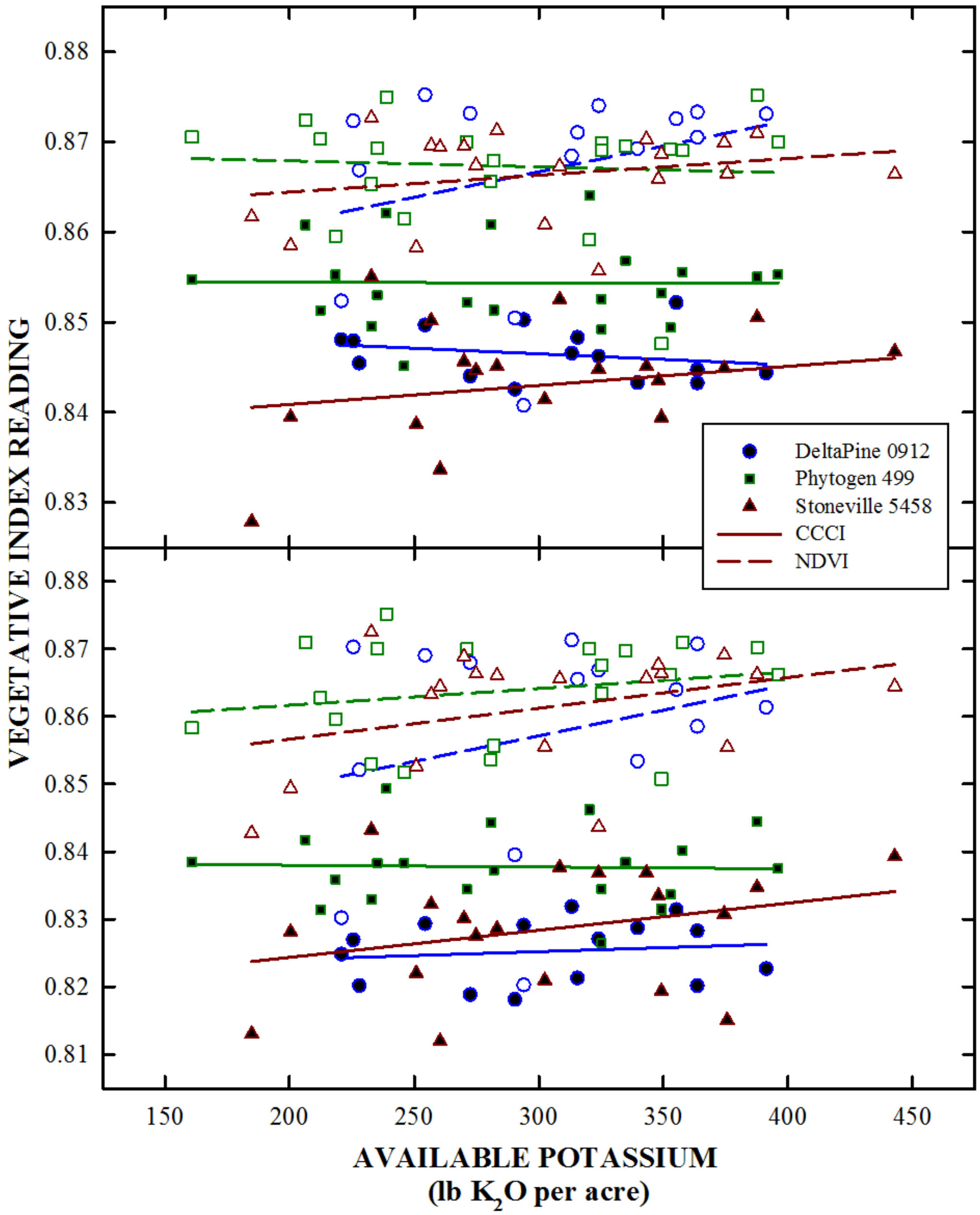

Figure 2: Response of the Normalized Difference Vegetation Index (NDVI) and the Canopy Chlorophyll Content Index (CCCI) by variety to changes in available K_2O.

Table 3: Coefficient of determinations (r^2) for response of the Normalized Difference Vegetation Index (NDVI) and the Canopy Chlorophyll Content Index (CCCI) by variety to changes in available K_2O.

Variety	Coefficient of Determination (r^2)			
	Canopy Chlorophyll Content Index (CCCI)		Normalized Difference Vegetation Index (NDVI)	
	7 Aug	22 Aug	[a]7 Aug	[a]22 Aug
DeltaPine 912	0.000	0.001	0.004	0.046
Phytogen 499	0.056	0.019	0.090	0.069
Stoneville 5458	0.038	0.086	0.064	0.122

[a]Interaction term of variety and available K_2O was only significant for NDVI ($p \leq 0.10$).