Report to the fluid Fertilizer Foundation

USE OF REMOTE SENSING IN COTTON TO DETERMINE POTASSIUM STATUS AND YIELD

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Use of Remote Sensing in Cotton to Determine Potassium Status and Yield

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Introduction

Cotton has a less dense rooting system than other row crops, and therefore is less efficient at extracting nutrients such as K that move through the soil by diffusion. This leads to deficiency symptoms occurring on soils that show sufficient soil K on a soil test report. Unpredictable deficiencies, paired with the spatial variability of soil K in production fields, makes proper fertilization for K difficult. It has been determined that N deficiency could be determined using spectral reflectance indices before deficiency symptoms were visible on the plant. However, these indices are also sensitive to detecting other plant growth stressors including drought stress and other nutrient deficiency. If producers use these indices to detect N deficiency, when in reality, other stressors are affecting the index readings, producers would apply unnecessary N fertilizer which is environmentally and economically costly. The goal of this study was to observe if indices used to determine N deficiency were sensitive to K deficiency in cotton.

Objectives and Hypotheses

This study aimed to determine if cultivars differed in values from currently available indices formulated for N-status detection from active sensors. It also set out to determine if these N-sensitive indices were sensitive to leaf K concentration and available K_2O in the soil, and to evaluate the role these indices play in predicting yield. It was hypothesized that NDVI would more accurately predict leaf K, available K_2O, and yield than the NDRE, due to the red-edge band used in the NDRE reflecting changes in chlorophyll, which is not affected by K deficiency. It was also believed that the NDVI and the NDRE would more accurately determine the K parameters chosen than the CCCI, due to the strong influence of the red-edge band in the index. Yield would be most accurately predicted by the CCCI, due to yield being influenced by both

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chlorophyll content and biomass, and the CCCI involving the red-edge band to reflect chlorophyll content and the near infrared band to detect biomass.

Materials and Methods

The early detection of K deficiency using remote sensing experiment was conducted on the Lon Mann Cotton Research Station of the University of Arkansas. Soils in this trial consisted of relatively uniform Calloway Series (Fine-silty, mixed, active, thermic Aquic Fraglossudalfs). Soil samples were taken from shoulders of beds in each plot and analyzed for nutrient concentration, pH, and organic matter. Three varieties of cotton (DeltaPine 0912 B2RF, Phytogen 499 WRF, and Stoneville 5458 B2F) were planted. All fertilization besides K fertilization was applied following soil test recommendations. Four K treatments of 0, 33.6, 67.2, and 100.8 kg K/ha (0, 30, 60, and 90 lb/acre) were applied as potassium chloride (KCl) at approximately PHS. Plots were four 1 m (38 inches) rows wide and approximately 15.24 m (50 feet) long with cotton planted 11.5 plants per meter (3.5 plants per foot). Plots were furrow irrigated as needed. Spectral reflectance measurements were taken at FF and FF3 using a Crop Circle ACS-430 sensor with a GeoSCOUT GLS-400 data logger (Holland Scientific, Inc., Lincoln, NE). Sensor was held at approximately .914 m (36 inches) above canopy. Measurements were taken by holding the sensor above the canopy and walking between the first and second row and the third and fourth row of each plot. Wavelengths measured included 650 nm (red), 720 nm (red-edge), and 840 nm (near infrared [NIR]). Three indices from these wavelengths were calculated. The normalized difference red edge index (NDRE) was calculated by subtracting the measurements from the red-edge from the NIR and dividing that by the sum of the measurements from red-edge and the NIR (Figure 1). The normalized difference vegetation index (NDVI) was calculated from subtracting the measurements from the red from the NIR, and dividing that by the sum of the measurements from the red and the NIR (Figure 1). The canopy chlorophyll content index (CCCI) was calculated by dividing the NDRE by the NDVI (Figure 1). The NDRE is used to estimate chlorophyll content, where the NDVI is used to estimate canopy cover. The CCCI takes both of these estimations to make a multi-dimensional measurement of plant health. Data points were taken using a GPS attached to the data logger so that points could be assigned to their respective plots using ArcGIS 10.2.2.

Leaf samples were taken from the fourth node from the top of five plants in each plot and were analyzed for K concentration (Soil and Plant Testing Laboratory, University of Arkansas, Fayetteville, AR). Leaf K concentration was compared to index measurements to determine the accuracy of spectral reflectance values to determine K deficiency. Lint yield was also recorded at harvest and was compared to index measurements to observe any correlation between spectral reflectance and yield.

Statistical Analysis

This experiment was a completely randomized design with replications varying between four and eight, due to the layout of the trial. Correlations between K concentration and yield with cultivar as an additional main effect at each growth stage were determined using linear regression analysis in JMP Pro 11 with an alpha level of 0.05. Before data were analyzed, outliers were determined multivariate jackknife distances and excluded.

Results

The NDVI was significantly correlated ($p<0.05$) with the interaction between cultivar and leaf K concentration at FF with an r^2 value of 0.815 (Table 1). The NDRE was also significantly correlated with the interaction between cultivar and leaf K concentration at FF with an r^2 value of 0.617 (Table 1). The significant interaction indicates that to accurately determine K status using the NDVI or NDRE, a cultivar correction factor must be used. The CCCI was not significantly correlated ($p<0.05$) with leaf K concentration at FF (Table 1). At FF3, no interaction between cultivar and leaf K was significant, however, the NDRE and the CCCI had significant correlations ($p<0.05$) with cultivar with r^2 values of 0.335 and 0.689, respectively (Table 1). This indicates NDRE and CCCI differ by cultivar, regardless of leaf K status. The leaf K concentration range at FF3 was 0.4-1.2%, well below the sufficient leaf K range of 2-4%. It is likely that leaf K was too low overall at the FF3 stage for the spectral reflectance indices to detect leaf K status.

Index values at FF and FF3 were correlated with yield data to observe if it was possible to use spectral reflectance data to predict yield early- or late-season. All three indices had significant interactions between cultivar and yield at FF and FF3. AT FF, the NDVI, NDRE, and CCCI had r^2 values of 0.311, 0.339, and 0.201, respectively (Table 2). At FF3, the NDVI, NDRE, and CCCI had r^2 values of 0.338, 0.277, and 0.693, respectively (Table 2). The highest r^2

value was observed using the CCCI at FF3 (Table 2). Yield was best predicted later in the season and using an index that involves both bands that reflect changes in chlorophyll and biomass.

Conclusions

Overall, leaf K concentration was best described using early-season NDVI with a cultivar correction factor. Late-season K concentrations were too low for accurate detection of significant differences. Yield was best predicted using the CCCI with a cultivar correction factor later in the season.

Figures and Tables

$$NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}}$$

$$NDRE = \frac{R_{NIR} - R_{EDGE}}{R_{NIR} + R_{EDGE}}$$

$$CCCI = \frac{\mathrm{NDRE}}{\mathrm{NDVI}}$$

Figure 1. Description of spectral reflectance indices used to determine K deficiency.

Table 1. Effect of Cultivar and Leaf K on Spectral Reflectance Index Values

Growth Stage	Effect	NDVI		NDRE		CCCI	
FF	Cultivar	0.0343	Adjusted R^2=0.815	NS*		NS	
	Leaf K%	0.0274		0.0395	Adjusted R^2=0.617	NS	
	Cul * K%	0.0014		0.0087		NS	
FF3	Cultivar	NS		0.0058	Adjusted R^2=0.335	0.0131	Adjusted R^2=0.689
	Leaf K%	NS		NS		NS	
	Cul * K%	NS		NS		NS	

*NS indicates an insignificant correlation.

Table 2. Relationship between Cultivar and Yield and Spectral Reflectance Index Values

Growth Stage	Effect	NDVI		NDRE		CCCI	
FF	Cultivar	NS*		NS		NS	
	Yield	<0.0001	Adjusted R^2=0.311	<0.0001	Adjusted R^2=0.339	NS	
	Cul * Yield	0.0009		0.0032		0.0019	Adjusted R^2=0.201
FF3	Cultivar	0.0004	Adjusted R^2= 0.338	0.0003	Adjusted R^2=0.277	0.0036	Adjusted R^2=0.693
	Yield	0.0408		NS		NS	
	Cul*Yield	<0.0001		0.0031		0.0056	

*NS indicates an insignificant correlation.