A Look At Potassium Deficiency in Cotton

Canopy reflective indices used to examine plant available K.

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Summary: *The data from this research suggest the that use of some cultivar adjustment factor will have to be implemented if sufficiency reflectance datum is collected on a nearby field of a different cultivar or if a threshold value approach is used to drive variable rate nitrogen (N) applications. Additional research is needed to better characterize index responses in soils of lower K status or under seasons that are more favorable for the development of K deficiencies.*

Cotton has been labeled as a poor extractor of soil potassium (K) as compared to other more fibrous rooted crops, particularly with respect to K located near the surface. These root characteristics, coupled with the inherent stratification of K in production agriculture and the increased K demand from higher-yielding and earlier-maturing cotton cultivars currently grown across the US Corn Belt, frequently result in K deficiencies appearing in the later-flowering or early boll-filling periods.

These deficiencies are of interest from a remote-sensing standpoint for a couple of reasons:

- First, early diagnosis of the K deficiency from a ground-based reflection unit could potentially drive an ameliorating application of K to the soil (if early enough in the growing season) or as a foliar application of K. This could drastically reduce or potentially remove the yield penalty associated with the deficiency, increase efficiency of the fertilizer, and thereby increase the profitability.
- Second, the occurrence of K deficiencies in the upper canopy of a cultivar's particular reflectance properties could influence other remote-sensing activities, such as the diagnosis of N stress and potential amelioration alternatives.

Objective

The objective of this research was to examine the response of two reflectance indices, calculated from measured reflectance in the red, red-edge, and near–infrared spectral regions, to changes in cultivar and plant-available K.

Site/Treatment/Analysis

Block trial. A randomized strip, complete block trial with five replications was conducted in 2012 and 2013 at the Lon Mann Cotton Research Center located in Marianna, AR.

Soil samples were collected from bed shoulders at 6-inch depths from each plot on 31 January 2012 and analyzed (Mehlich-3 extraction) by the University of Arkansas Soil Testing Laboratory.

Treatments consisted of 0, 30, 60, and 90 lbs/A of K_2O applied to Phytogen 499 WRF (PHY499), Stoneville 5458 B2RF (ST5458) and DeltaPine 0912 B2RF (DP0912) varieties within three weeks of planting (Figure 1).

Regression analysis tested the response of seed-cotton yield and index readings to changes in available K_2O.

Available K. The calculated amount of available K was chosen in lieu of applied K fertilizer rate due to initial differences in soil K concentrations. Plant available K_2O was calculated as [(ppm soil test K x 2 x 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 lbs/A assuming 2 million lbs soil/A furrow slice.

Reflectance

Reflectance was measured at two-week intervals beginning at flowering with the Crop Circle ACS-470 (Holland Scientific Inc., Lincoln, NE) [Figure 2]).

Analysis for 2012 was conducted on data collected 7 August and 22 August 2012, as consistent K deficiencies across the trial were only noted by 22

Figure 1. Image of cotton plots with muriate of potash (0-0-60) prills on soil surface.

August 2012.

In 2013, analyses were conducted on data collected early (18 July 2013) and late (22 August 2013). Consistent K deficiency symptoms were not noted during the season. Red (650 nm), red-edge (730 nm) and near infrared (760 nm) were used to calculate equations described in Figure 3.

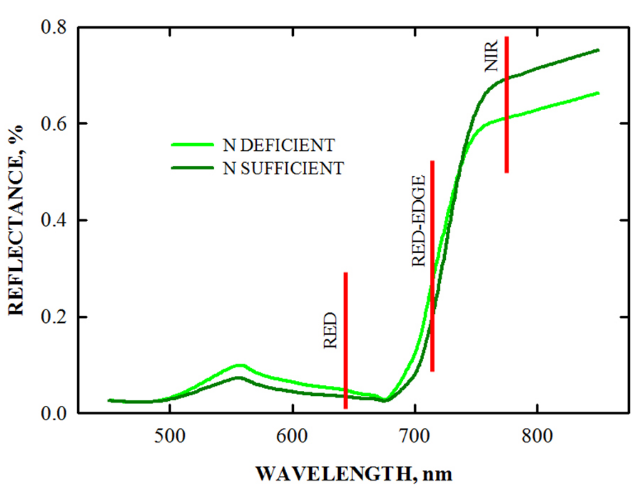
Analysis of variance was conducted for both reflectance dates and yield data in JMP 10 (SAS Institute Inc., Cary, NC). Independent variables in the model included block, available K_2O variety, and the interaction between available K_2O, and variety.

2012 results

The 2012 response to seed-cotton to changes in variety and available K_2O was significant ($p \leq 0.05$) as was the interaction between these two terms ($p \leq 0.10$).

Results suggest increases in available K_2O did not significantly increase PHY499 seed-cotton yields, but did increase DP0912 and ST5458 yields.

Figure 2. Collecting sensor reflectance data in the cotton field.



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

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

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

Figure 3. Reflectance signature curve of N deficient and N sufficient cotton. Red bars represent center of red, red-edge, and near-infrared regions typically used by active sensors. Equations represent calculations of commonly used reflectance indices of the Normalized Difference Vegetation Index (NDVI), the Normalized Difference Red-Edge Index (NDRE), and the more recently developed Canopy Chlorophyll Content Index (CCCI).

As evident by the plant available K levels and relatively high yields, severe K deficiencies were not noted.

Low to moderately sufficient soil K may have contributed to the failure of PHY499 yields to respond to increased plant-available K. Still, the moderately strong response of ST5458 and slight response of DP0912 do not suggest that increased K availability could increase yields within the tested range of plant-available K_2O for these two cultivars.

Visible K deficiency symptoms were noted during the first week of flower in ST5458 plots but were not consistent across the field until near peak flower.

As a result, reflectance was measured at mid-flower (7 August 2012) and after peak flower 22 August 2012).

Images of typical canopy response to varying K_2O applications can be seen in Figure 3. Responses from both sampling dates were similar.

The interaction effects between plant-available K_2O and cultivar on the Normalized Difference Vegetation Index (NDVI) readings were significant ($p \leq 0.10$ [Figure 4]).

However, the Canopy Chlorophyll Content Index (CCCI) was only significantly affected by variety, as available K had no significant effect on CCCI ($p \leq 0.05$ [Figure 4]).

2013 results

During the 2013 season, neither index responded significantly to available K_2O ($p \leq 0.05$). This held true for both sampling dates (18 July and 22 August 2013).

The response of CCCI to cultivar was significant in both sampling dates ($p \leq 0.05$), with PHY499 resulting in significantly greater, and DP0912 resulting in significantly lower CCCI values.

In contrast, the response of NDVI to variety was not significant at the first sampling date and, although as significant response was noted in the later sampling date, the only varietal separation was noted with PHY499 (Figure 5).

Overview

Potassium deficiencies severe enough to impact reflectance during the typical side-dress N application

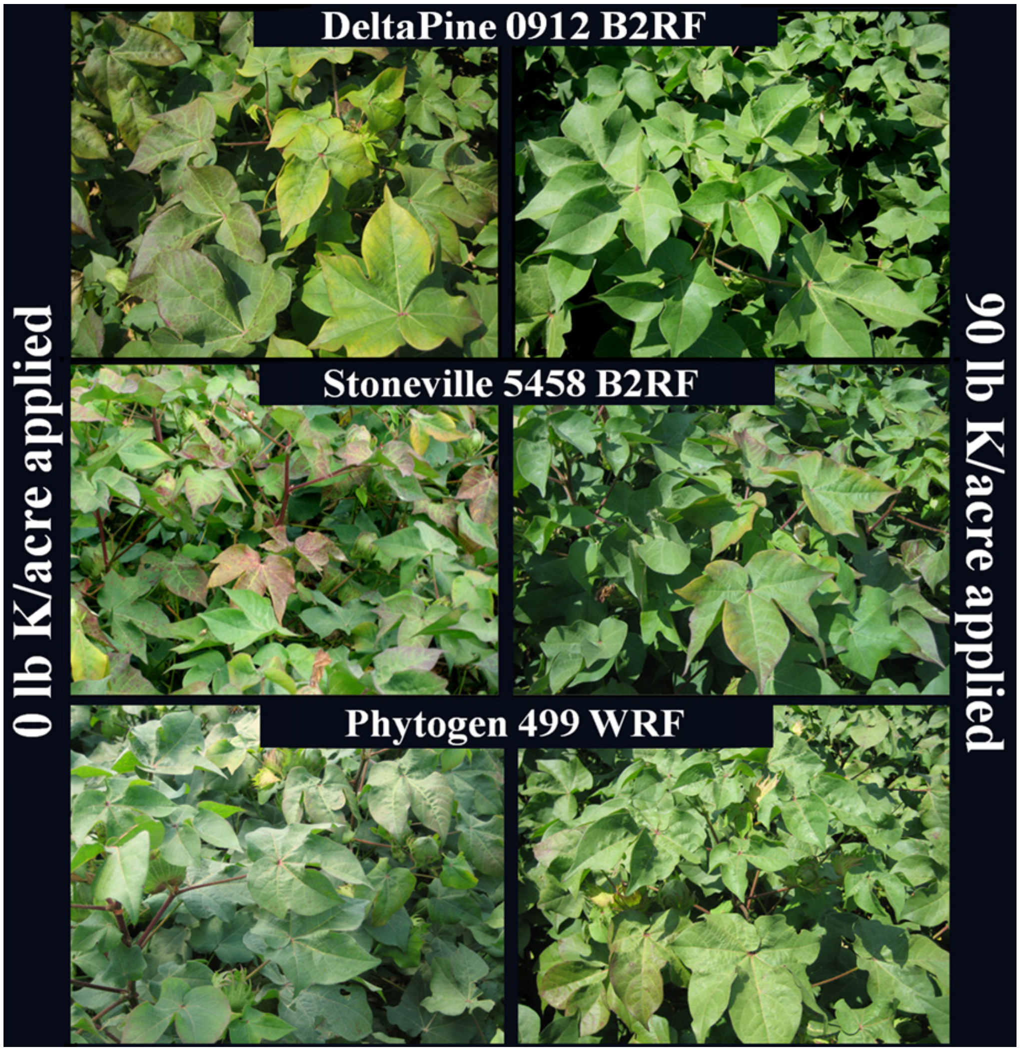


Figure 4. Images of deficiency symptoms noted on 23 Aug 2012 in all three tested varieties at low (0 lb K_2O/acre) and high (90 lb K_2O/acre) rates.

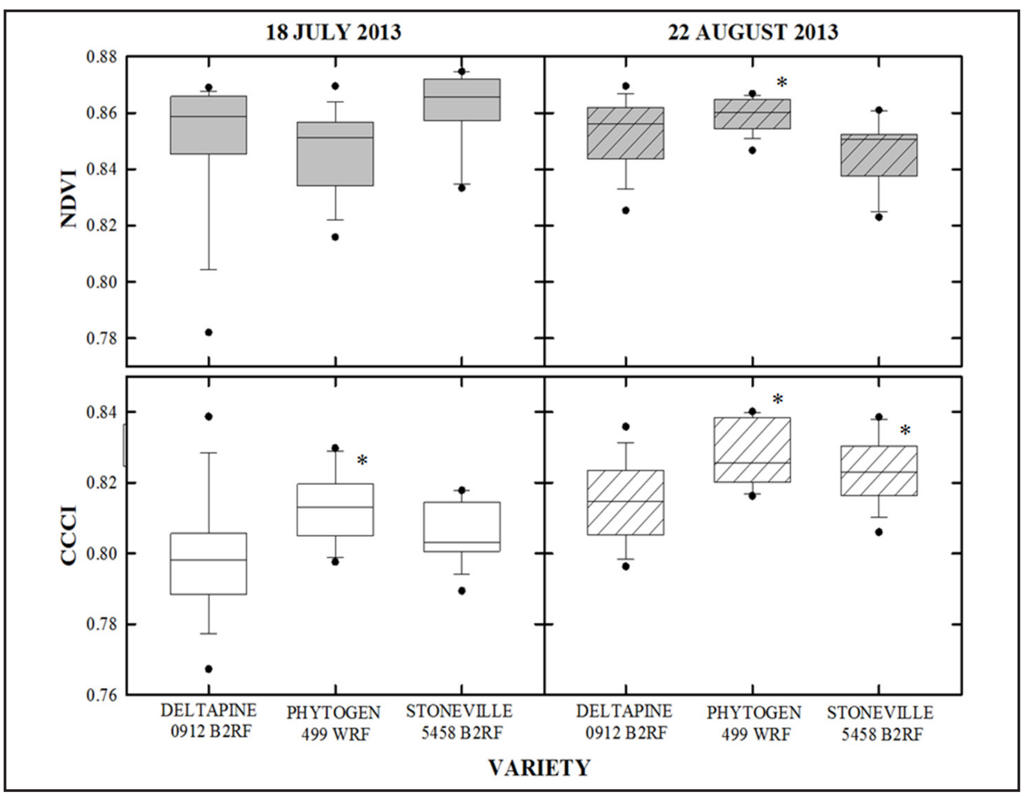


Figure 5. Response of the Normalized Difference Vegetation Index (NDVI) and the Canopy Chlorophyll Content Index (CCCI) to different varieties.

window were not noted in either 2012 or 2013. Still, the significant interaction of variety and plant-available K on NDVI noted in 2012 suggests that cultivar-specific models may have to be developed to characterize specific NDVI responses to varying soil-K concentration if K deficiencies occur during the sidedress N application window or if NDVI will be used to drive foliar N or K applications.

Failure to detect deficiencies of K during the 2013 growing season may be partially explained by an exceptionally mild summer, which was suspected to support exceptional root growth and therefore greater K uptake under the low-moderate soil test K values.

Still, the significant impact of variety on CCCI and lack of impact of available K_2O on this index suggest a simple varietal correction term could be developed and implemented if the index was used to drive variable rate N applications, regardless of application type (early-mid soil application or late foliar).

Summing up

The data collected suggest that the use of some cultivar-adjustment factor will have to be implemented if sufficiency reflective data are collected on a nearby field of a different cultivar or if a threshold value approach is used to drive variable rate N applications.

Neither tested index provided strong, reliable insight into plant K status during a period in which a soil or foliar K application could be made, but this may be partially attributed to the presence of only slight K deficiencies in either tested year.

Additional research is needed to better characterize index responses in soils of lower K status or under seasons that are more favorable for the development of K deficiencies.

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