RESEARCH REPORT FOR 2014
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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JUSTIFICATION

Potassium (K) is an essential nutrient for plant growth, yield development, and fiber quality. However, deficiencies of K still appear widely and unpredictably in cotton. There has been much research concerning K partitioning in older, non-transgenic cultivars, but no studies looking at modern, transgenic cultivars. Plant dry matter can have as much as 10% K by weight (Szczerba et al., 2009), but the optimum amount for cotton is 2-5% (Marschner, 1995; Oosterhuis et al., 2013). Cotton bolls can accumulate K to concentrations above 40 mg/g of the dry weight (Kafkafi and Xu, 1996). Potassium uptake is slow during the seedling stage, increases rapidly at flowering, and slows after the maximum is reached at maturity (Oosterhuis, 2002). Cotton's K needs are highest during boll set because bolls are a major K sink. During the development of a boll, K concentration in plant tissue increases from 10 g kg^{-1} to 55 g kg^{-1} at maturity (Oosterhuis, 2002). Potassium is involved in numerous physiological processes (Oosterhuis et al., 2013) and a deficiency can affect a number of plant characteristics such as reductions in lint yield and biomass production (Yang et al., 2011; Pettigrew & Meredith, 1997). Traditional K deficiency symptoms differ from recent K deficiency symptoms due to genotypic changes in cultivars over time (Dong et al., 2004; Oosterhuis et al., 2013).

Recent technological advances have made it possible to remotely sense electromagnetic energy reflected and absorbed by plant tissues, which may be an indication of nutrient deficiencies. The reflectance percentages of different wavelengths from the crop canopy may be a non-invasive diagnostic tool to observe K deficiencies in field (Thomas et al., 1967). Most research in this field has focused on nitrogen fertility, whereas information on K reflectance wavelengths and K deficiency is lacking, showing the need for more in-depth research. 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 (1) determine the effect of K soil availability on partitioning of K in the plant as the season progressed, and (2) to examine the response of two contrasting indices to variety and changes in available potassium.

MATERIALS AND METHODS

This study took place during the 2014 growing season at the Lon Mann Cotton Research Center in Marianna, AR. The design was a randomized complete block with four K rates (0, 30, 60, and 90 lb K_2O/acre) and three cultivars (Phytogen 499, Stoneville 5458, and Delta Pine 0912) replicated 4 times. Potassium was applied pre-plant as KCl.At pinhead square (PHS), first flower (FF), three weeks after first flower (FF3), and six weeks after first flower (FF6), whole plants were sampled from one-meter row. Plants were then divided into stems, petioles, leaves, and reproductive components. Chlorophyll measurements were also taken at this time. Dry matter and K concentrations of these plant parts were recorded, as well as yield components at the end of season. Spectral reflectance was measured using a Crop Circle ACS-470at FF, FF3, and FF6. Fully expanded leaves were taken from each plot at these times as well to compare reflectance data to actual leaf K concentrations.

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. Available K 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 only treatments with analyzed data thus far include PHY499 with 0 lb K_2O/acre, PHY499 with 90 lb K_2O/acre, DP0912 with 0 lb K_2O/acre, and DP0912 with 90 lb K_2O/acre.

Potassium Partitioning Results

Major K shifts occurred in the leaves and reproductive component from PHS to FF3. Regardless of treatment, reproductive component K significantly increased throughout the season ($p<0.05$). DP0912 with lb K_2O/acre had significantly higher reproductive component K than PHY499 with 90 lb K_2O/acre ($p<0.05$). At PHS, there were no significant differences between any treatments regarding reproductive component K ($p<0.05$).

Leaf K significantly decreased throughout the season in every treatment, however, there were no differences between any treatments at each growth stage ($p<0.05$) (Fig. 1a). Little change was observed in K partitioning to petioles and stems over the growing season. Reproductive component K increased significantly over the grwoting season ($p=0.05$) across all treatments. DP0912 had significantly higher K than did PYT499 in reproductive parts within K levels (Fig. 2b).

Chlorophyll Results

Chlorophyll measurements were only affected by K level and only at PHS and FF. In these growth stages, 0 and 30 lb K_2O/acre treatments had significantly higher chlorophyll content than did the 60 and 90 lb K_2O/acre treatments ($p<0.05$).

Yield Results

Comparing the four treatments already analyzed, DP0912 with both 0 and 90 lb K_2O/acre had significantly higher yields than PHY499 with both 0 and 90 lb K_2O/acre ($p<0.05$). However, there was no significant yield differences between cultivars when K was not included as a variable.

Spectral Reflectance Results

Data for 2014 spectral reflectance have all been measured and are currently being analyzed.

Conclusions

The increased translocation of K to reproductive units in DP0912 could have led to the higher yields as compared to PHY499. There were no differences in leaf K partitioning in low or high K environments or between cultivars. Over the growing season, K in reproductive components increased as leaf K decreased. In low K situations, DP0912 yielded higher and partitioned more K into reproductive components than did PHY499, indicating a higher tolerance to K deficiency. Spectral reflectance results are still being analyzed. The spectral data is still being analyzed. However, preliminary plots did not show clear relationships, and this may be due to the lack of difference in K partitioning in leaves between K treatments experienced this year.

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 necessitate a third 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.

Literature Cited

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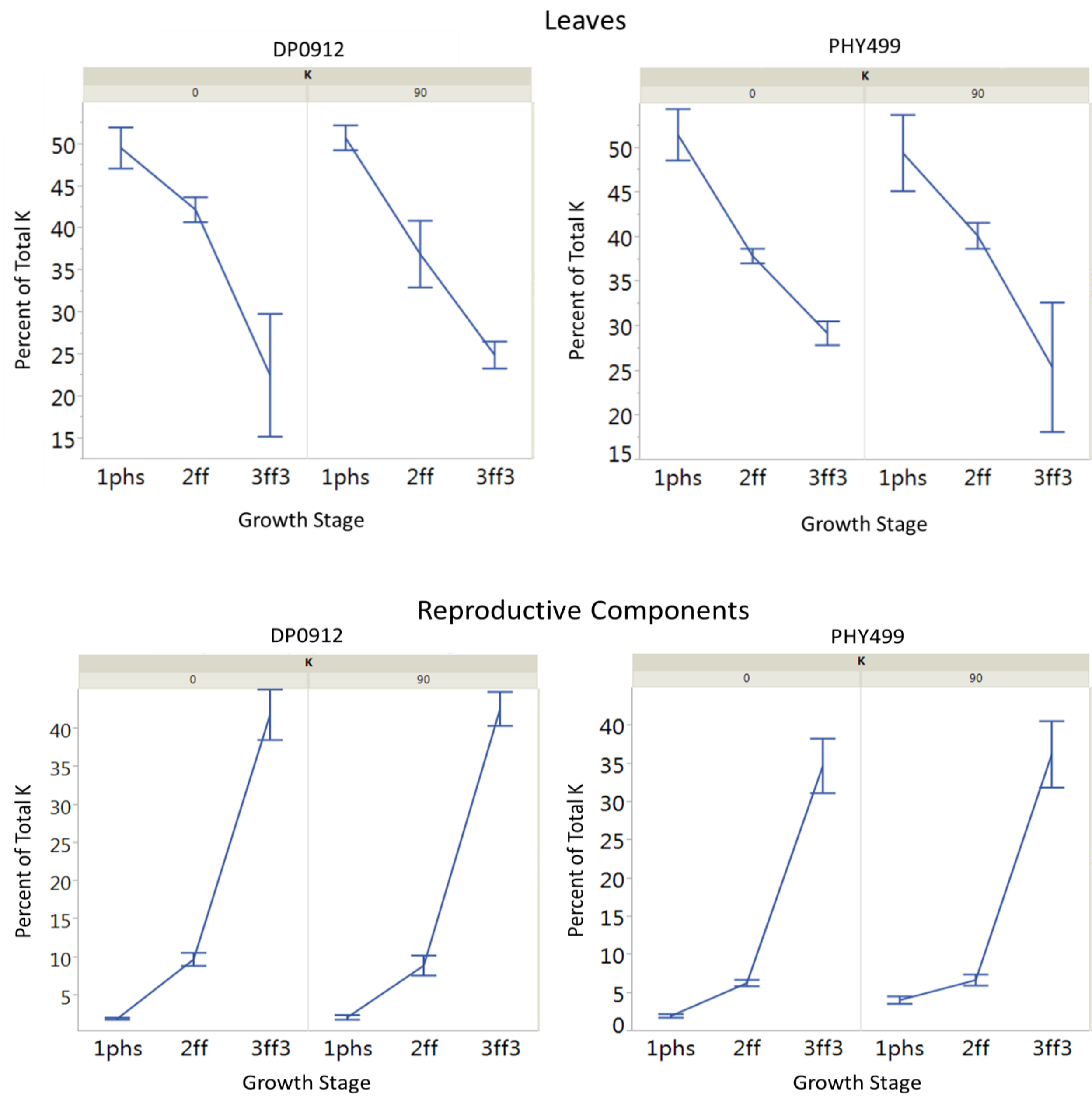

Figure 1. K in leaves and reproductive components for two cultivars measured at three growth stages, pinhead square, first flower and three weeks after first flower.

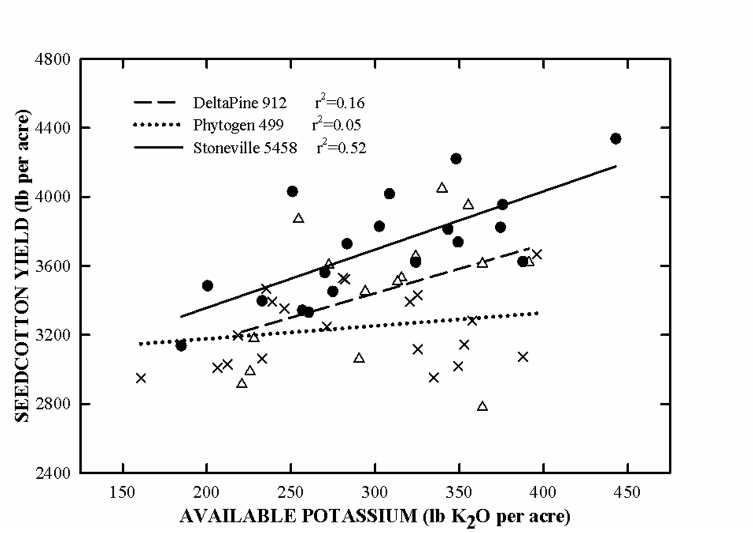

Figure 2.1: Response of seedcotton yield to available K_2O .

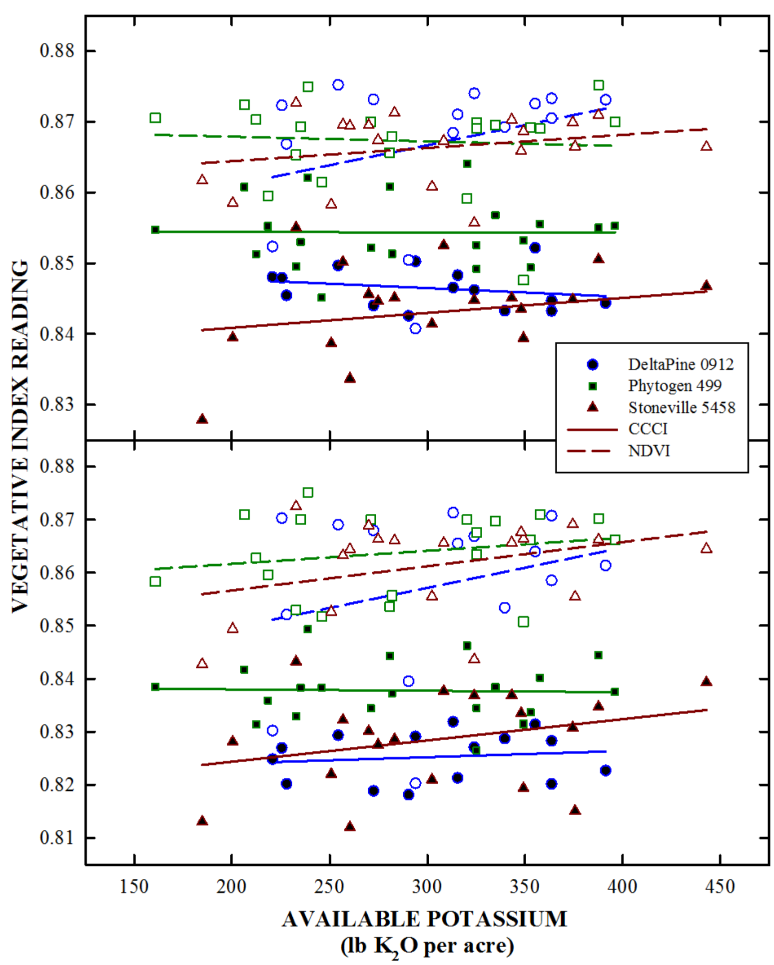

Figure 2.2: Response of the Normalized Difference Vegetation Index (NDVI) and the Canopy Chlorophyll Content Index (CCCI) by variety to changes in available K_2O.