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

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Research Objective

• Using Remote Sensing Technologies and Nitrogen-Sensitive Indices to Predict Cotton K Status and Yield
Outline

- Introduction
  - K in cotton
  - Spatial variability in fields
  - Spectral response to N and K
- Objectives and Hypotheses
- Methods
- Results
  - Leaf K Concentration
  - Plant Available K$_2$O
  - Yield
- Discussion
- Conclusions
Introduction

• Cotton is less efficient at extracting K from soil than other row crops

• Leaf deficiency symptoms include yellowing, drying of leaf tips, and an overall bronzing of affected leaves
  - Upper leaf deficiencies possibly due to high yielding, short season cultivars and the sink demand of bolls

• Deficiencies can occur unpredictably and under sufficient soil K conditions
Production fields are spatially variable
Introduction

SPECTRAL REFLECTANCE RESPONSE TO N

WAVELENGTH, nm

500 600 700 800

REFLECTANCE, %

0.0
0.2
0.4
0.6
0.8

N DEFICIENT

N SUFFICIENT

\[
NDVI = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}}
\]

\[
NDRE = \frac{R_{NIR} - R_{EDGE}}{R_{NIR} + R_{EDGE}}
\]

\[
CCCI = \frac{NDRE}{NDVI}
\]
Introduction

• Raper et al (2013) tested spectral reflectance indices to remotely sense N deficiency by correlating chlorophyll content with reflectance indices
  • Measure cotton N status in real-time

• Found an average response across the first and third weeks of flowering in several indices to changes in selected cotton growth parameters
Introduction

• Indices may be sensitive to more than N deficiency
  • Water and nutrient stress

• Unnecessary N application environmentally and economically costly

• Goal of remote sensing research to distribute fertilizer N, K based on spatial demand
Objectives

• Determine if cultivars differ in values from currently available indices formulated for N-status detection from active sensors

• Determine if N-sensitive indices are sensitive to leaf K concentration and available K$_2$O in the soil

• Evaluate the role of N-sensitive indices in predicting yield
Hypotheses

• NDVI would more accurately predict leaf K, available K$_2$O, and yield than NDRE, due to the red-edge band reflecting changes in chlorophyll and the near infrared band reflecting biomass and cell structure.

• Both NDVI and NDRE would more accurately predict parameters than the CCCI due to the strong influence of the red-edge in the index.
Methods

• Location—Lon Mann Cotton Research Station
  • Marianna, AR

• Long-term cotton K fertility trial plot

• Calloway Silt Loam
Methods

• Completely Randomized Design
  • 4 row plots, 50’ length
  • Planted 3.5 plants/ft on 38” beds
  • Furrow irrigated as needed
  • Fertilizer N applied uniformly

• Treatments
  • K₂O Rates
    • 0, 30, 60, 90 lb acre⁻¹
    • Preplant 0-0-60
  • Cultivars
    • Phytogen 499 WRF
    • Stoneville 5458 B2RF
    • DeltaPine 0912 B2RF
Measurements

• **Soil samples**
  • Mehlich 3 extraction
  • For analysis, available K was used instead of K rate due to variability of K in field. This was calculated using the formula:
    • Available K = (Soil Test K x 2 x 1.2) + Fertilizer K

• **Tissue**
  • Leaf K

• **Reflectance**
  • Crop Circle ACS-470
    • Active light sensor
    • 10 AM-2 PM
    • First flower (FF) and three weeks post first flower (FF3)
    • 36” height above canopy
Analysis

• Data points evaluated and assigned to plots using ArcGIS and ArcMAP 10.2.2

• Regression analysis on JMP Pro 11
## Results—Leaf K%

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Effect</th>
<th>NDVI</th>
<th>NDRE</th>
<th>CCCI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>adjusted R^2=0.815</td>
<td></td>
</tr>
<tr>
<td>FF</td>
<td>Cultivar</td>
<td>0.0343</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf K%</td>
<td>0.0274</td>
<td>0.0395</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cul * K%</td>
<td>0.0014</td>
<td>0.0087</td>
<td></td>
</tr>
<tr>
<td>FF3</td>
<td>Cultivar</td>
<td>NS</td>
<td>0.0058</td>
<td>0.0131</td>
</tr>
<tr>
<td></td>
<td>Leaf K%</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cul * K%</td>
<td>NS</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>
Leaf K %—NDVI

First Flower

Three Weeks Post First Flower

This graph shows the relationship between leaf K% and NDVI at different stages of plant growth. The data points are color-coded by genotype: PHY499 (blue), DP0912 (orange), and ST5458 (gray). The graphs indicate a strong correlation between leaf K% and NDVI at both the first flower stage and three weeks post first flower, with different trends for each genotype.
Leaf K %—NDRE

First Flower

Three Weeks Post First Flower

VEGETATIVE INDEX READING

LEAF K%

0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3

0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3

0.3 0.5 0.7 0.9 1.1 1.3

PHY499
DP0912
ST5458
Leaf K% — CCCI

**First Flower**

**Three Weeks Post First Flower**

- **VEGETATIVE INDEX READING**
- **LEAF K%**

Graphs showing the relationship between leaf K% and vegetative index reading for different samples at different time points.
## Results—Available K$_2$O

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Effect</th>
<th>NDVI</th>
<th>NDRE</th>
<th>CCCI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FF</strong></td>
<td>Cultivar</td>
<td>0.0472</td>
<td>Adjusted $R^2=0.798$</td>
<td>NS</td>
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<tr>
<td></td>
<td>Avail K$_2$O</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Cul * K$_2$O</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>FF3</strong></td>
<td>Cultivar</td>
<td>0.0048</td>
<td>Adjusted $R^2=0.344$</td>
<td>0.0166</td>
</tr>
<tr>
<td></td>
<td>Avail K$_2$O</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Cul * K$_2$O</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
Available K₂O—NDVI

First Flower

Three Weeks Post First Flower

Available K₂O (lb/acre)

Vegetative Index Reading
Available K$_2$O—NDRE

***Vegetative Index Reading***

**First Flower**

**Three Weeks Post First Flower**
Available K₂O—CCCI

**First Flower**

**Three Weeks Post First Flower**
Results—Yield

Cumulative Yield Data

<table>
<thead>
<tr>
<th>YIELD (LB/ACRE)</th>
<th>PHY499</th>
<th>DP0912</th>
<th>ST5458</th>
</tr>
</thead>
<tbody>
<tr>
<td>YIELD (LB/ACRE)</td>
<td>1200</td>
<td>1100</td>
<td>1000</td>
</tr>
</tbody>
</table>

The graph shows the cumulative yield data for PHY499, DP0912, and ST5458.
## Results—Yield

<table>
<thead>
<tr>
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<th>Effect</th>
<th>NDVI</th>
<th>NDRE</th>
<th>CCCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF</td>
<td>Cultivar</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Yield</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td></td>
<td>Cul*Yield</td>
<td>0.0009</td>
<td>0.0032</td>
<td>0.0019</td>
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<tr>
<td>FF3</td>
<td>Cultivar</td>
<td>0.0004</td>
<td>0.0003</td>
<td>0.0036</td>
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<tr>
<td></td>
<td>Yield</td>
<td>0.0408</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Cul*Yield</td>
<td>&lt;0.0001</td>
<td>0.0031</td>
<td>0.0056</td>
</tr>
</tbody>
</table>
Discussion

- Early-season NDVI most accurately describes leaf K
  - Red-edge related to chlorophyll whereas near infrared related to cellular structure and intracellular spaces
  - Leaves too deficient later in season to detect differences
    - FF3 leaf K range from 0.4-1.2%

- Available K\textsubscript{2}O possibly too low to make a difference in reflectance values
  - Long-term fertility plots
  - Leaf K more efficient in describing plant status
Discussion

• Yield most accurately predicted by late-season CCCI
  • CCCI relies on both biomass and chlorophyll content
  • Yield related to both biomass and chlorophyll content

• Two-year study, need multiple soil types, locations and cultivars for adoption by producers
Conclusions

• Early-season NDVI most accurately determines leaf K concentration

• Indices chosen were unable to determine plant available K$_2$O in the soil

• Yield was best predicted using the CCCI late-season
Acknowledgements

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