Utilization of Spectral Imaging to Detect N and K Sufficiency in Cotton

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ABSTRACT

Nitrogen and K as well as other plant nutrients influence the spectral properties of individual crop leaves and plant canopies. Technology is currently available that can measure reflectance at spectral resolutions of less than 2 nm. Thus, the identification of specific changes in spectral reflectance relative to plant nutrient concentration may be possible. Field studies with variations in soil K availability and N fertilization were used to study spectral reflectance properties of individual leaves and plant canopies influenced by plant nutrition. Leaf samples at different stages of plant development were used to determine the N and K status and their relationship to spectral images and reflectance measurements. Aerial images were taken at 1067 m. with four digital cameras equipped with narrow band pass filters. Bands used were green at 540nm, red at 695 nm and near infra red at 790nm and 840 nm. Leaf and canopy reflectance were measured with a spectro-radiometer that scanned from 350 nm to 1050 nm with a special resolution of 1.6 nm. Aerial imaging was useful in identifying N and K stress anomalies. Crop health varies with N and K nutritional status, suggesting that aerial imaging would be a useful tool in directing producers to problem areas. Correlations were found between leaf N and K concentrations and spectral reflectance at certain wavelengths and growth stages, suggesting that remote sensing at a high degree of spectral resolution may be able to assist in the identification and mapping of field scale variability in N and K nutritional status.

Introduction

Spectral imaging of plant canopies has been used to identify crop stress. For example, water stress is detected through increased reflectance resulting from changes in chlorophyll and tissue water content (Carter *et al.*, 1992). Reflectance in the infrared region has been useful to detect increases in leaf temperature due to moisture stress but reflectance changes in the visible light region detect stresses sooner (Carter *et al.*, 1996). Detection of stress caused by nutritional deficiencies using spectral imaging is plausible since chlorophyll and leaf greenness are affected by many of elemental plant nutrients.

Identifying specific wavelength or wavelength ratios is needed to fingerprint specific nutritional disorders better. Strong relationships between total N content of loblolly pine needles and reflectance at 551 nm have been reported (Tsay *et al.*, 1982; Nelson *et al.*, 1986). Additionally, Carter *et al.* (1989) found relationships between various wavelengths and K, Ca, and Mg concentrations in loblolly pine needles. Ma *et al.* (1996) reported differentiating between N treatments on corn using radiometer readings at 600 nm and 800 nm as well as a normalized difference vegetation index (NDVI) and that canopy reflectance correlated with yield. Intensive management of N and K in cotton production represents significant costs. Remote sensing could provide producers with a technologically advanced method of managing nutrients with agronomic, economic and environmental benefits. The objective of this study was to determine the effects of variable N and K nutrition on cotton spectral reflectance.

Material and Methods

Field research was conducted at the Plant Science Research Centre (PSRC), Mississippi State, MS in 1997 and 1998. The soil type location is a Leeper silty clay loam (Fine, smectitic, nonacid, thermic Vertic Epiaquept). Cotton variety Suregrow 125 was planted no-till each year at 13 to 16 seeds/m. Fertilizer N treatments of 0, 67, 134, and 201 kg N/ha were established by broadcasting half the rate as ammonium nitrate at planting and the remainder at early square. Potassium was applied at rates of 0, 34, 68, and 102 kg K/ha as muriate of potash broadcast prior to planting. The initial soil test K was in the medium range. Plot size was 3.86 m by 9.14 m with a row spacing of 0.965 m. Treatments were in complete blocks with four replications. At various growth stages, reflectance measurements were taken with a GER1500 spectro-radiometer (Geophysical and Environmental Research Corp., Millbrook, NY) in 1997 and a LI-COR 1800 spectro-radiometer (LI-COR, Inc., Lincoln, NE) in 1998. Reflectance was measured on three recently matured leaves on the 3rd to 4th main-stem node from terminal. These leaves were also sampled for N and K analysis.

Remote sensing of the plot area was conducted periodically throughout the season when weather conditions were favourable. Four digital cameras each having a different narrow band pass filter were mounted in a fixed wing aircraft flown at approximately 1067 m. The filters used were green (540 nm), red (695 nm) and near infrared at 790 nm and 840nm. The spatial resolution was approximately 0.65 m. The flyover data collected was processed using image analysis software and a normalized difference vegetation index (NDVI) was calculated using NDVI= (NIR-Red)/(NIR+Red).

Results and Discussion

The effect of varying N availability on leaf reflectance at peak flowering for field plots in 1997 is shown in Fig. 1. Beginning at a wavelength of about 525 nm and continuing up through about 640 nm there was separation in the N treatments. The spectral resolution using the GER is about 1.6 nm. Separation in N treatments appears to be the most equally incremented centred about a wavelength of 600 nm. Correlation of the mean reflectance readings at 600 nm with either fertilizer N rate or leaf tissue was very strong (Fig. 2).

Reflectance measurements taken from field plots in 1998 with the LI-COR 1800 are shown in Figs. 3 and 4. Measurements taken the first week of flowering show separation between fertilizer N treatments, especially near 600 nm. There was a non-proportional increase in reflectance for the non-fertilized treatment in the fourth week of flowering. This is expected with the onset of boll formation and partitioning of leaf N to developing bolls.

Separating K treatments using leaf reflectance was not as definitive as it was for N. The only sampling time that leaf reflectance showed a response to K status was during late boll filling (Fig. 5). Treatment separation in reflectance readings was found from 605 nm to 640 nm, especially for the 0 kg K/ha treatments. This effect suggests an alteration in leaf reflectance due to K deficiency. Further investigation is necessary to determine how specific this effect is to K deficiency and whether other nutritional disorders may produce similar responses (Masoni *et al.* 1996). Correlation of leaf reflectance with either fertilizer K rate or leaf tissue K was strong at a wavelength of 631 nm (Fig. 6). However, the change in reflectance at this wavelength from 0 kg K/ha to 102 kg K/ha was only a little more than 3%.

Flyover images taken during the second week of flowering (July 25, 1997) showed clear separation in treatments using an NDVI enhanced image (Data not shown). There was evidence of stress for both N and K shown by the number of yellow to orange to red coloured pixels for the 0 kg N/ha and 0 kg K/ha treatments. Pixel colours were primarily yellow and green for the first incremental rate of both N and K. The two highest rates For both nutrients resulted in yellow to shades of green. Although stress was evident, it remains an anomaly due to lack of known specific nutritional effects on leaf reflectance at specific wavelengths.

Conclusions

Leaf reflectance using a hyperspectral scanner is showing promise for the early detection of N sufficiency, while K nutritional effects on reflectance are not as consistent and may be diagnostic only during late boll filling. Multispectral imaging can be used to detect anomalies related to N and K deficiencies from aerial platforms, but traditional ground methods are still necessary to pinpoint the nutritional disorder. The development of hyperspectral signatures and decision support models could lead to specific detection of nutritional disorders in cotton. Remote sensing is another tool in nutritional disorder detection in addition to traditional methods (e.g., visual identification, soil testing, and plant analysis) and should prove useful in the determination of spatial relations in nutrient availability.

References

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Figure 1. Fertilizer N rate effects on leaf reflectance at peak flowering in 1997.

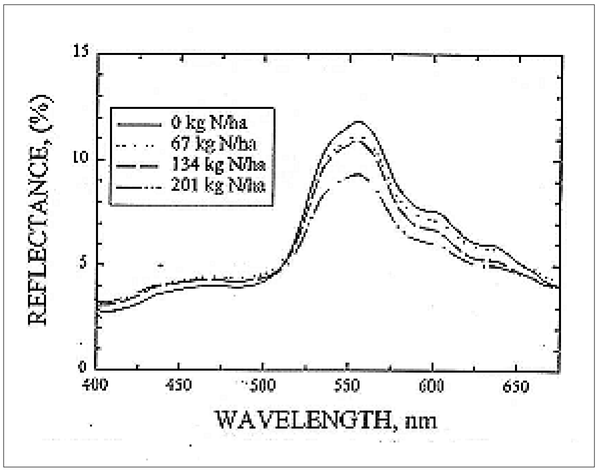


Figure 2. Effects of fertilizer N rate and leaf tissue reflectance at 660 nm at peak flowering in 1997.

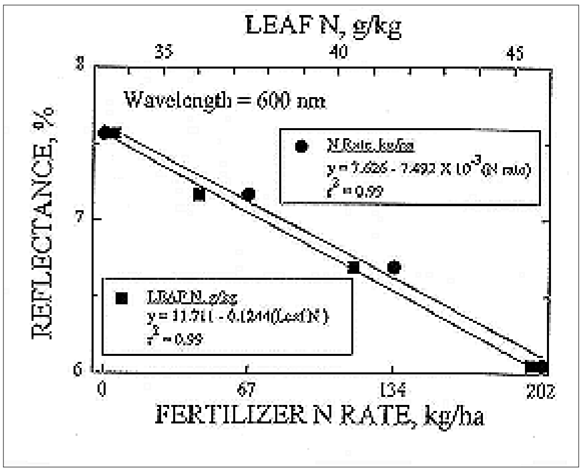


Figure 3. Fertilizer N rate effects on leaf reflectance in the first week of flowering in 1998.

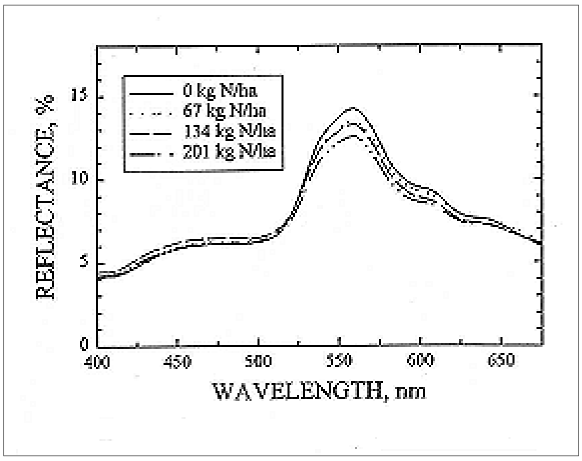


Figure 4. Fertilizer N rate effects on leaf reflectance in the fourth week of flowering in 1998.

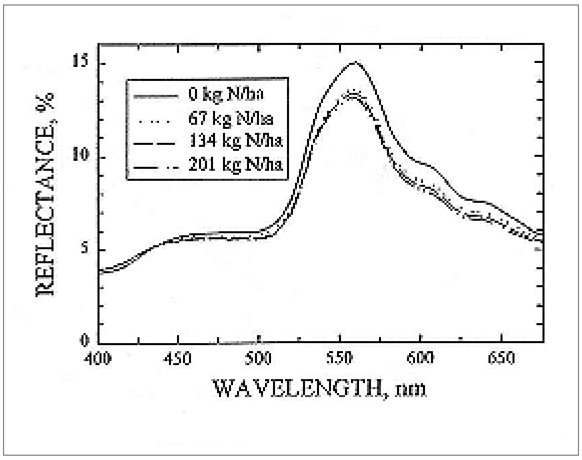


Figure 5. Fertilizer K effects on canopy reflectance in the seventh week of flowering in 1997.

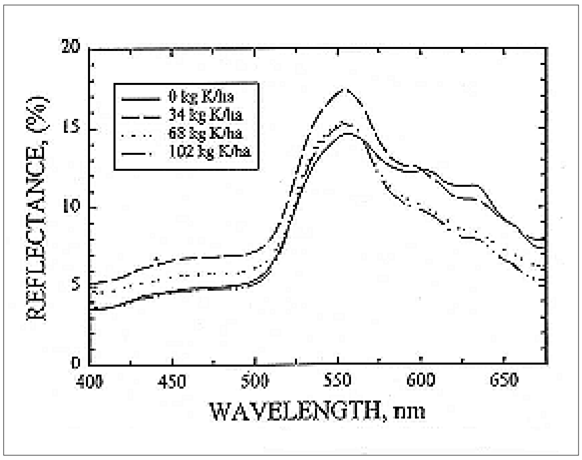
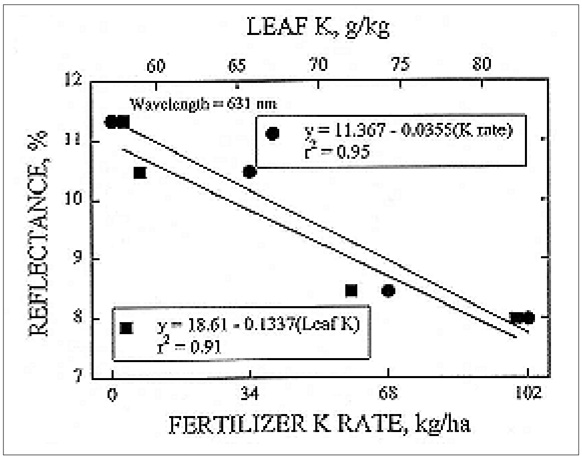


Figure 6. Effects of fertilizer K rate and leaf tissue K on leaf reflectance during the seventh week of flowering in 1997 [1].



1 Leaf samples were taken in the 6th week of flowering