Performance of a Crop Canopy Reflectance Sensor to Assess Chlorophyll Content

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Introduction:

Site-specific nitrogen (N) management strategies based solely on soil properties and processes have not eliminated spatial variability in yield or diminished environment impact in a majority of situations.

Alternatively, research has shown that crop-based approaches, involving in-season assessments of leaf chlorophyll content with portable hand-held chlorophyll meters, may hold greater promise of improving N management.

Our research has shown that chlorophyll meter readings are a reasonable indicator of crop N status and provides evidence that "spoon-feeding" N to the crop on an "as needed" basis can reduce the potential for environmental contamination by N in corn production (Varvel et al., 1997) .

However, chlorophyll meters are impractical tools for managing N on a field scale basis.

The long term goal of our research has been to develop a practical means of remotely sensing leaf chlorophyll levels.

We have finished a cycle of testing on an enhanced multi spectral remote sensor system.

The sensor system arrangement can be seen in Fig. 1. Each sensor can measure light reflected off the crop in various bands of the visible and NIR spectrum, depending on the photo diodes selected. The four wave bands used were; 460nm(blue), 555nm(green), 680nm(red) and 800nm(near infrared).

The system is also designed to interface with a real-time-differential global positioning system (DGPS) for mapping crop canopy reflectance over entire fields.

The overall system, which has been designed to deliver liquid N fertilizer based on sensor-determined crop needs is shown in Fig. 1.

Specific objectives for this work were:

1) Compare the performance of corn canopy reflectance as measured with the multi-spectral reflectance sensor to variations in leaf chlorophyll concentration as determined with a Minolta (model SPAD 502) chlorophyll meter.

2) Determine if variations in canopy vigor (greenness) could be mapped with the sensor system.

References

Varvel, G.E., J.S. Schepers, and D.D. Francis. 1997. Ability for in-season correction of nitrogen deficiency in corn using chlorophyll meters. Soil Sci. Soc. Am. J. 59:1233-1239.

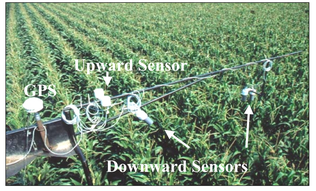

Figure 1. High clearance vehicle configured with crop circle sensors, drop nozzles and controller, which has been designed to deliver liquid N fertilizer based on sensor-determined crop needs.

Image upper mid-right depicts detail of GPS and crop circle sensors shown mounted on a boom, one facing upward (accounting for incoming solar radiation intensity) and others are facing downward to monitor crop reflectance. Image upper far-right depicts collection of chlorophyll meter and crop reflectance data.

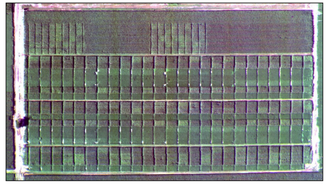

Figure 2. Aerial photograph taken in mid June of 2000 (V-9 growth stage for corn) at the MSEA site near Shelton, NE, depicting a crop rotation experiment involving soybean and corn.

Corn portion of experiment involved 4 Pioneer hybrids receiving 5 N fertilizer treatments (0, 50, 100, 150, and 200 kg/ha applied at planting). Crop circle sensor readings were collected on three dates starting in early June and proceeding to tasseling from only 2 corn hybrids receiving the five N treatments. Photograph shows corn canopy color variation associated with different N treatments.

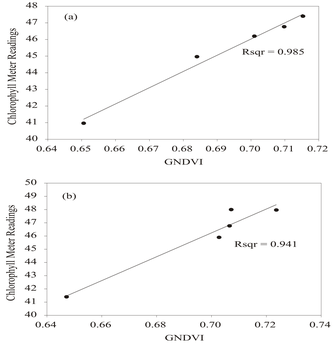

Figure 3. The relationship between chlorophyll meter readings and the green normalized vegetation difference index (GNDVI)for hybrids (a) 3162 and (b) 3394 as affected by N treatment.

The GNDVI was calculated by mathematically combining the green and near infrared reflectance bands coming from the crop circle sensor reading collected on June22 (V-9 growth stage). Sensors readings were collected in each plot with 2 downward and 1 upward looking sensors. At the same time chlorophyll meter readings on thirty plants were simultaneously collected in the same plots. Data shown here represent averages from three replications of 5 N treatments for 1 corn hybrid.

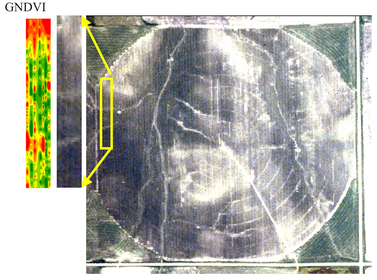

Figure 4. Aerial photograph of a center pivot field near Gibbon, NE depicting spatial variation in bare soil color.

Canopy reflectance data were collected around the early grain filling growth stage in early August of 2000 with the crop circle sensor interfaced with a DGPS for the area represented by rectangle in the northwest corner of the field. Sensor output were converted into the green normalized difference vegetation index (GNDVI) along with spatial coordinates to depict variation in canopy vegetation conditions, and this variation appears to be related to variation in soil color. This image confirms the mapping capabilities of the sensor system

Materials and Methods:

Objective 1:

Two corn hybrids; Pioneer Brand Hybrid 3162 (horizontal leaf architecture) and Pioneer Brand Hybrid 3394 (vertical leaf architecture)

Five N fertilizer rates; 0, 50, 100, 150, and 200 kg N/ha

Three replications (see Fig. 2 for aerial photograph of plot layout).

Measurements taken on three growth stagesV6 (June 8, 2000), V9 (June 22, 2000), and V15 (July 7, 2000) were:

Thirty chlorophyll meter readings per plot using a Minolta SPAD-502 meter.

Canopy reflectance taken one meter above crop (nadir view) using four wave band crop canopy reflectance sensor.

Green and NIR sensor wave bands used to calculated Green NDVI where:

GNDVI = (NIR- Green)/(NIR+Green)

Objective 2:

A center pivot field near Gibbon, NE was selected, and sensor readings along with DGPS coordinates were obtained for a small region of the field on one date for mapping of variation in canopy vigor (Fig.4).

Results:

Objective 1.

Significant differences among hybrid and N treatments for chlorophyll meter readings and canopy reflectance values, expressed as GNDVI, were observed on all three measurement dates (not shown).

Early findings suggest the sensor is capable of detecting variations in leaf chlorophyll or N status induced by varying levels of N application, since variation in the sensor readings (GNDVI) associated with N treatments was highly correlated (Fig. 3) with ground-based chlorophyll meter readings for both hybrids, particularly for the V 11 and V-15 growth stages (only V-ll data shown).

Objective 2.

Sensor output (GNDVI) variation appears to be related to variation in soil color (Fig. 4). This image confirms the mapping capabilities of the sensor system.

These results suggest that with sensors mounted on a high-clearance applicator configured with a controller and drop nozzles, we will be able to enter cornfields during the V9 to R2 application window (Fig. 1) and apply N fluid fertilizer based on crop need.

We will be testing a prototype of such an applicator in 2002 (Fig.1).

Additional research is needed to determine the appropriate control algorithm to translate sensor output into corrective action for the fertilizer applicator.