VEGETATIVE ASSESSMENT OF PHOSPHORUS AND NITROGEN STATUS IN MAIZE USING REMOTE SENSING

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Abstract

Assess spatial variability of soil P and N is not only costly but also a time consuming processes. Remote sensing measurements of canopy spectral reflectance can provide a rapid and non-destructive method for assessing plant-canopy nutrient status. The main objective of this research was to detect P and N stress during the early corn growth by selecting specific wavelengths, or combinations of them, using narrow band field sensors. In 2001, two corn experiments were planted over an old manure experiment in which important soil P content differences were expected among the residual treatments. Reflectance measurements were recorded at different growth stages, with two four-narrow-band field sensors (sensor 1: 415, 440, 460 and 550 nm; sensor 2: 600, 632, 680 and 800 nm) with a 28° optic field of view. The preliminary results of this research have revealed that the blue portion of the spectrum (wavelength at 415nm) showed some sensitivity to leaf P content at the growth stage of V-6. Reflectance at 550nm, also recorded at V-6, showed sensitivity to variations in chlorophyll content and therefore to variations in plant N content.

Introduction

The tightening of economic and environmental constraints that affect farmers has resulted in a call for more efficient management systems. Besides maximizing crop production, the input of fertilizers and biocides should be reduced to a minimum. Precision agriculture responds to this challenge by developing management strategies that incorporate field variability (Van Alphen and Stoorvogel, 2000). One such strategy involves remote sensing measurements of canopy spectral reflectance to provide a rapid and non-destructive method for assessing plant-canopy biophysical parameters, such as nutrient status that allows a reactive decision over site-specific nutrient deficiencies situations. Specifically, the leaf's internal structure and pigment concentrations, and soil background features, determine the characteristic spectral reflectance, transmittance, and absorption of radiation by a plant canopy (Weiser et al., 1986).

Recent research has focused on determining the appropriate wavelength or wavelength combinations to characterize crop nitrogen (N) and phosphorus (P) deficiencies. The availability of soil mineral N affects the rate of leaf initiation and expansion, final leaf size and the foliar senescence rate. The resulting leaf area duration links soil mineral N and yield. The conversion of intercepted radiation into biomass also depends on N via effects of the foliar N content. Soil mineral nitrogen and crop yields are linked via nitrate uptake and the conversion of nitrate into proteins and chlorophylls. This pathway suggests several ways in which the crop N status can be

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evaluated (Schröder et al., 2000). Blackmer et al. (1994) stated that light reflectance near 550nm was best for separating N treatment differences and could be used to detect N deficiencies in corn.

Phosphorus deficiencies in corn usually are manifested as stunted plants that are dark green in color and that have purple and red color along the leaf margin due to the production of anthocyanin. Osborne (1999) found that the prediction of total P content in corn plants was best in the early growth stages (before V8) using reflectance in the blue and NIR region. In another study, Sembiring et al (1998) found that P concentration in wheat tissue could be predicted at earlier growth stages using the reflectance ratio 705nm/505nm. The main spectral feature of anthocyanin absorption in vivo, reported by Gitelson et al. (2001), was a peak around 550 nm. Based on this, these authors developed a quantitative nondestructive technique to subtract chlorophyll contribution to reflectance in this spectral region and retrieve anthocyanin content in leaves: ARI (Anthocyanin Reflectance Index)= $(R_{550})^{-1} - (R_{700})^{-1}$. This index could be used as an indirect measurement of P deficiencies.

The quality and quantity of the radiation reflected from a plant canopy is also affected by additional factors such as area, orientation, and shape of leaves. Additionally, other factors such as solar azimuth and zenith angles, distance and position of the sensor with respect to the target and the sun, and atmospheric condition also affect the reflected radiation (Weiser et al., 1986). Measuring canopy reflectance from a nadir view angle during early vegetative growth, Bausch and Duke (1996) found that soil background effects are a major obstacle because they create changes in canopy reflectance that are not crop related. The authors attributed these changes to both the amount of soil "seen" by the radiometer due to leaf area index differences and the surface soil moisture content.

Objectives

The main objective of this research is to detect P and N stress during the early corn growth by selecting specific wavelengths, or combinations of them, using narrow band field sensors. A second objective is to minimize the soil background effects by selecting the optimum off-nadir angle for the sensor to look at the target, as well as using an appropriate background.

Materials and Methods

Two corn experiments were planted in different planting dates (April 28th and May 9th, 2001) in a farm near Shelton, Nebraska. The trials were installed over an old manure experiment (finished in 1997) and in which important soil P content differences were expected among the residual treatments. Those treatments consisted of one check and four manure types (beef feedlot, turkey, sheep feedlot, and compost) that were applied to meet crop P needs. One set of plots received extra N as needed and the other one was N deficient. The degree of N deficiency varied with manure type. This year, no fertilizer was applied at planting, and a unique rate of 100kg N/ha was applied at V-6 on the plots that had N fertilizer history. Soil samples were taken immediately before planting and at the corn stage of V-6, and analyzed for P and NO_3^-. Plant samples were taken both at V-3 and V-6, and analyzed for P and N content. Reflectance measurements were recorded at V3, V4 and V6, with two four-narrow-band field sensors (sensor 1: 415, 440, 460 and 550 nm; sensor 2: 600, 632, 680 and 800 nm) with a 28° optic field of view.

The sensors were pointed in a 30° angle from the horizontal and about 40cm from the target, resulting in a field of view of 18cm diameter. A black panel was always located behind the plants, as a high -absorbing background. The sensors were set up on a rack over the front of a four-wheel drive vehicle (ATV). Reflectance at V-3 was recorded statically in two points of each plot. At V-4 and V-6 the reflectance was recorded by running the sensors continuously along each plot. As an estimate of plant N status, SPAD readings were taken on each plot at the stage of V-6 in the last whole-developed leaf.

Prior to starting with the reflectance measurements, an "angle exercise" was conducted to detect the optimal position of the sensor to gather the vegetation reflectance. A 30° angle was determined as the most sensitive and was used as the default sensor angle of the experiment.

Results and Discussion

The off-nadir sensor angle seemed to maximize the amount of vegetation and minimize the presence of soil background within the instantaneous field of view (IFOV). The selection of a highly spectral absorbent background (black) seemed to increase the sensitivity of vegetation reflectance compared to bare soil.

The preliminary results of this research have revealed that the blue portion of the spectrum (wavelength at 415nm) showed some sensitivity to leaf P content at the growth stage of V-6. In the treatments with plant P content within the range of 0.32% to 0.5%, this variable was explaining about the 43% of variation in reflectance at 415nm (Figure 1). This relationship was different between the manure and the control plots, probably due to N deficiencies in the latter ones during past years as well as in this year.

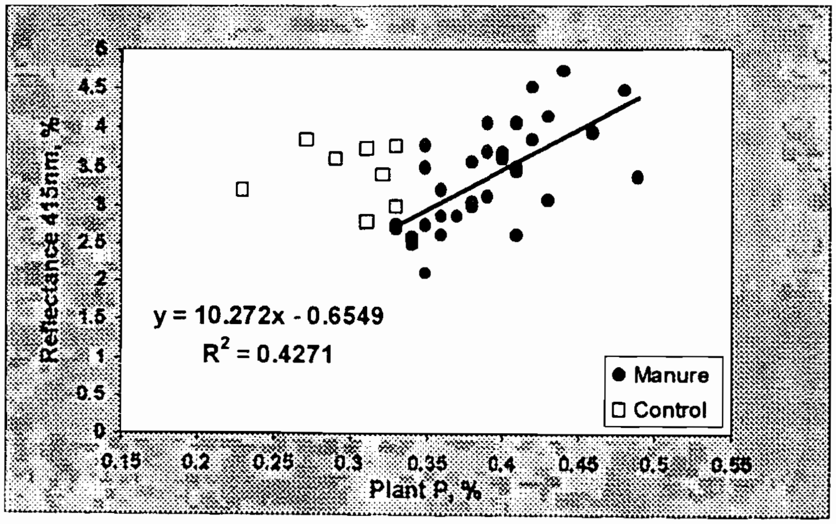

Figure 1. Relationship between reflectance at 415nm and plant P content at growth stage V-6

As other authors have earlier reported, the reflectance at 550nm showed sensitivity to variations in the chlorophyll index (SPAD readings) and therefore to variations in plant N content. The relationship between reflectance at 550nm and chlorophyll readings was negative, with a r^2 =

0.56 (Figure 2). The higher the chlorophyll contents the greater the absorption of light at 550nm by chlorophyll molecules, and therefore the less reflectance at the same wavelength.

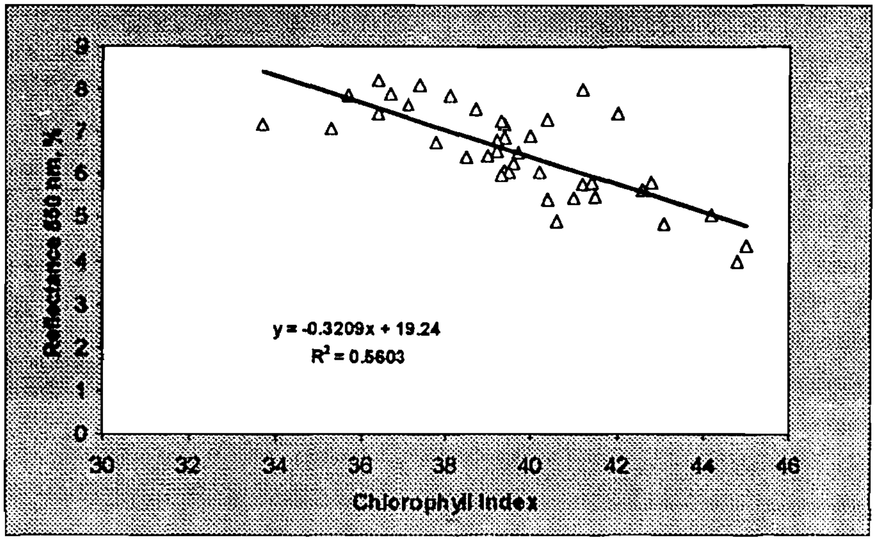

Figure 2. Relationship between reflectance at 550nm and Chlorophyll at growth stage V-6.

Conclusions

The reflectance measurements recorded with the two narrow-band field sensors could be used to generate algorithms sensitive to N and P stress. However, further research and analysis are needed to improve the selection of wavelengths specifically sensitive to P and N status in corn. However, other observations were that positioning of the plant relative to the sensor was critical. Work is underway to better understand this effect.

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