CANOPY REFLECTANCE SENSING AS IMPACTED BY CORN HYBRID GROWTH

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ABSTRACT

Detection of physical and chemical properties with canopy reflectance sensing could help predict the overall health and yield of a corn crop. Little research has been done to show differences of corn hybrids on canopy reflectance sensing. This study was conducted to examine potential hybrid differences during the early- to mid-vegetative growth stages of corn on three different soil types in Missouri. Canopy sensing (Crop Circle) and SPAD chlorophyll meter readings were taken through most growth stages from V3 to V10 on 11 (2008 growing season) and 8 (2009 growing season) hybrids. Variability within and between hybrids was most noted for corn less than 60 cm in height. Results showed that soil type (site) and soil surface wetness impacted canopy readings more than hybrid. The results of this study could prove useful in determining reasonable ranges for N-rich reflectance values in variable rate N applications.

Keywords: Canopy Sensing, Corn Hybrids, Variable Rate Nitrogen

INTRODUCTION

With growing concerns for the health of the environment and global warming, technologies that help farmers increase efficiency of agrichemical inputs have become more valued. One of the most vital components of farming is the application of fertilizers, and in corn production nitrogen (N) is usually the most important fertilizer nutrient affecting growth. The typical farming practice in many areas of the U.S. is to apply a flat rate of N to the field before planting. A major problem with this approach is that N is a mobile nutrient and can leach, or under extremely wet conditions, can denitrify and dissipate from the soil in various gaseous forms.

One strategy for reducing this problem and maximizing plant N uptake is to apply fertilizer to the crop when it is most needed. From growth stage V6 through early reproductive stages, there is a higher demand for N as the corn plant grows at a greater rate (McWilliams et al., 1999). Fertilizer applied during this period can be readily taken up by the crop, reducing the opportunity for N to be lost to leaching, run-off or denitrification (Blevins et al., 1996).

Recent research has demonstrated the use of active-sensing crop canopy sensors for determining the amount of N fertilizer to apply (Solari et al., 2008; Kitchen et al., 2010). These are considered active sensors due to their use of light emitting diodes (LED) that emit modulated light that is reflected from the canopy and detected with photodiodes (Stone et al., 1996). These sensors emit and sense light from both visible (VIS) and near-infrared (NIR) wavelengths to determine common crop indices, such as normalized difference vegetative index (NDVI), that are useful in assessing crop growth and crop N status (Kitchen et al., 2010). The basis for determining the N fertilizer rate using these canopy sensors is the development of a sufficiency index, which is derived from a ratio of measurements between corn that is known to be sufficient in N and corn that is yet to be fertilized. In some cases, farmers have not ensured an area of well-fertilized corn in a field, or they did not adequately mark the area for reconnaissance. Since reflectance characteristics of well-fertilized corn are necessary in calculating the sufficiency index, having a means of estimating these values based on growth stage and/or corn height would be helpful as a contingency.

OBJECTIVES

The primary objective of this research was to establish the seasonal variation in canopy sensor measurements of well-fertilized corn. A secondary objective was to assess the impact that corn hybrid and site characteristics (i.e. soil color) have on canopy sensor measurements throughout the growing season.

MATERIALS AND METHODS

Three Missouri sites were chosen for analysis from the 2008 growing season (Columbia, Henrietta, and Marshall) and two sites were chosen from the 2009 growing season (Columbia and Henrietta). Each site was rented ground that was planted and maintained by the University of Missouri Agricultural Extension Service Variety Trial Testing Program. There were 110 corn hybrids used at each site, submitted for trial from different seed companies. For this study, a subset of similar maturing hybrids (~114 day maturity) was selected. Eleven hybrids were used in 2008, and 8 hybrids were used in 2009. Sites were planted in a randomized block design that included three blocks. Figure 1 shows one of the sites studied in 2009.

Fig. 1. An overview of the plots in Henrietta, MO in 2009; each flag represents a measured plot.

Early in the growing season (~V3) each plot was flagged for identification. Starting when the corn was about 10 cm tall and on 3-5 day intervals, each site was revisited and a set measurements obtained.

A handheld Crop Circle canopy sensor (Model ACS-210, Holland Scientific, Inc., Lincoln, NE) was used in this study. Readings were obtained by holding the sensor approximately 45 cm over the top of the plants and taking measurements down each of the center two rows of each plot. The data from the Crop Circle were averaged to get an overall inverse simple ratio (ISR) of each plot, which is the ratio of the reflectance in the visible waveband to that in the NIR waveband. The ISR can also be derived from the NDVI using the equation: ISR = (1-NDVI)/(1+NDVI) (Kitchen et. al, 2010).

Fig. 2. Collection of Crop Circle (left), SPAD, and height (right) measurements.

A Minolta 502 SPAD chlorophyll meter (Konica Minolta, Hong Kong) was used to estimate plant chlorophyll content by measuring light transmittance through the leaf at 650 nm. This wavelength has been associated with chlorophyll activity. Chlorophyll is a main contributing factor to leaf greenness, and is correlated to N deficiency (Blackmer et al., 1994). The SPAD meter was clamped onto the most recently collared leaf, mid-way along the blade. Fifteen plants were sampled within each plot, and these readings were averaged to get an overall plot value. Figure 2 shows an example of canopy data collection procedures at two experimental sites.

Height measurements were also taken by measuring from the ground to the whorl of the plant. This measurement allowed for tracking of height differences through the growing season by hybrid. Height also gave another variable to evaluate for overall health of the corn plant.

Bare soil areas on one plot the first year and six plots the second year were used to take reflectance measurements of the soil with the active canopy sensor. These values changed as a function of surface wetness. During 2009, a sample of soil from the top few centimeters was taken and analyzed for soil moisture. Soil moisture content affecting soil color was assessed as a potential factor affecting canopy readings during the early V-stages of growth.

Apparent soil profile electrical conductivity (EC_a) was obtained using an EM38 sensor (Geonics Limited, Mississauga, Ontario, Canada). This short, hand-held bar was set in the center of each plot to attain the bulk soil EC_a. Using non-contact sensing, the EM38 uses two coils, one for generating an electromagnetic field and the other to sense secondary currents generated by interaction between the soil profile and the primary current (McNeill, 1980, 1992). For non-saline agricultural soils, low soil EC_a values generally indicate that the soil has low clay content and high EC_a values indicate soils with higher clay content (Sudduth et al., 2001).

Statistical software (SAS, SAS Institute Inc., Cary, North Carolina, USA), was used to determine important relationships between data sets. After viewing scatter graphs of ISR versus height, it was determined that when corn was ~60 cm there was notable change in ISR values. After this height, it was clear that either plant physiology had changed or that soil color was no longer a contributing factor in the canopy measurements. Therefore the data was split into two growth stage datasets: one less than 60 cm (G1) and the other greater than or equal to 60 cm (G2). Proc REG was used to model SPAD, height, and yield against ISR by year and by growth phase. Proc GLM was used to assess site and hybrid effects on ISR, SPAD, and height. The model was examined by year and growth phase.

RESULTS AND DISCUSSION

Canopy Reflectance

The graphs of ISR versus height (Fig. 3) all show a very distinct trend similar to an exponential decay model. In the early stages of growth when corn was ~20 cm tall, ISR values were in the 0.3 to 0.5 range. This was due to the small amount of corn biomass, with the sensor detecting mostly soil. The impact of soil can be seen in the second row of graphs (Fig. 3 C&D) as all soil reflectance readings are in the 0.35 to 0.55 range. Once plants attained a height of 60 cm, there was a noticeable shift in the ISR readings, with ISR values decreasing much more slowly as height increased beyond that point.

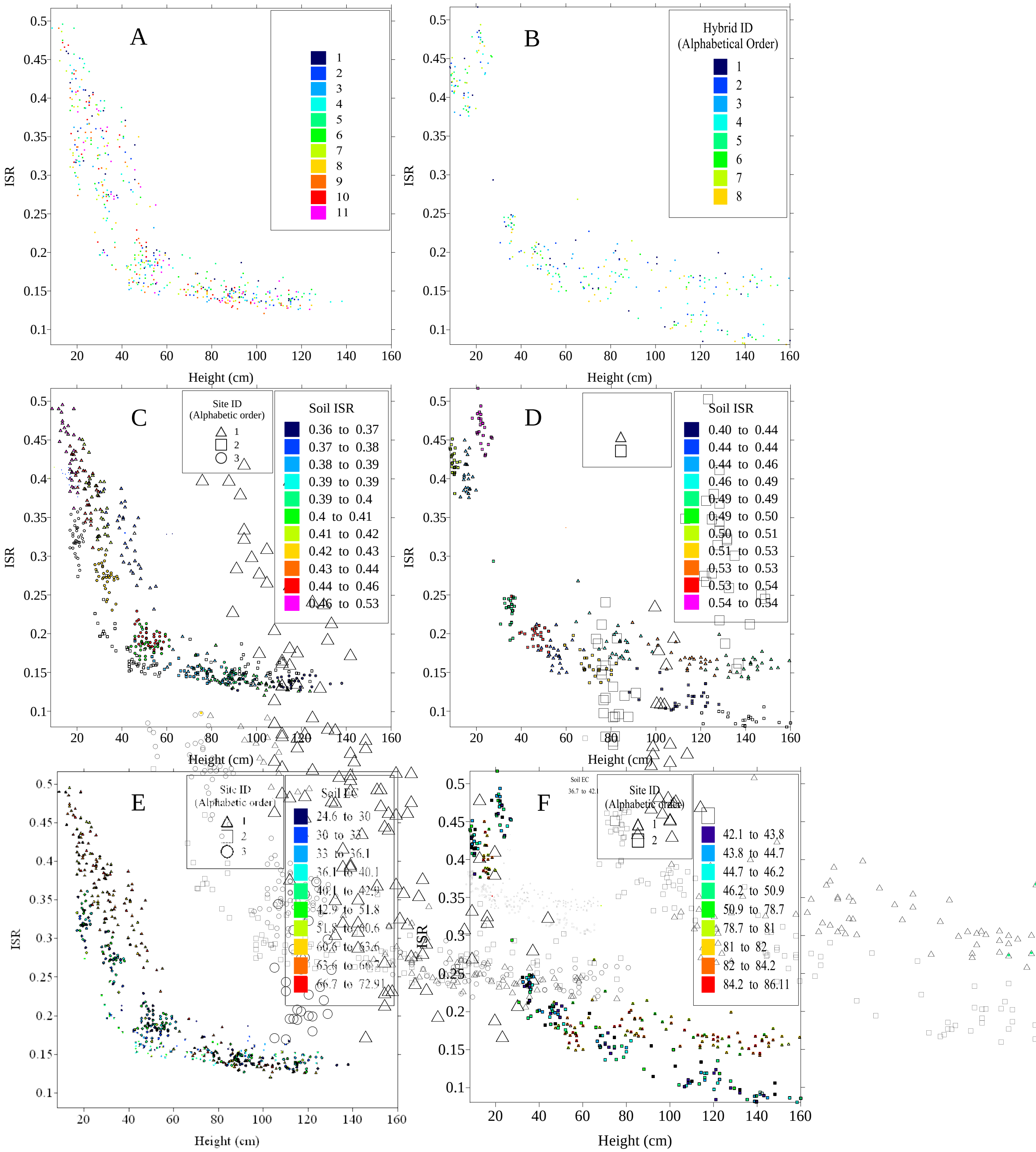

Fig. 3. Reflectance as ISR values for 2008 (left column) and 2009 (right column) growing seasons in relation to crop height. Impact of hybrid (A and B), soil ISR and site (C and D), and soil EC and site (E and F) are illustrated.

Table 1. Analysis of variance significance (F-test Pr>F) is shown for ISR, height, and SPAD response variables as influenced site, hybrid, and site*hybrid. NS stands for not significant.

		ISR		Height		SPAD	
		G1	G2	G1	G2	G1	G2
2008	Site	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
	Hybrid	NS	<0.01	NS	NS	<0.01	<0.01
	Site*Hybrid	NS	NS	NS	NS	NS	NS
2009	Site	NS	<0.01	0.03	NS	NS	<0.01
	Hybrid	NS	NS	NS	NS	<0.01	<0.01
	Site*Hybrid	NS	NS	NS	NS	NS	NS

Table 1 indicates the significance of hybrid and site. Site significantly impacted all these response variables in both growth stages in 2008, but was less of a factor in 2009. Part of this may be due to the fact there was only 2 sites in 2009, and therefore less statistical power in analysis for the second year. The soils of these study sites are quite contrasting, with the Columbia site being on a claypan soil, the Henrietta site being on an alluvial soil, and the Marshall site on a loess soil. With these differences came differences in surface soil color, soil depth and overall soil productivity. Therefore, the fact that site was found to be significantly different was not surprising.

Hybrid only significantly affected ISR during growth stage 2 of 2008. Both biomass and color of the soil and crop are contributing factors to the reflectance measurements obtained by the canopy sensor. By examining the significance values for height (an indicator of biomass) and SPAD (an indicator of color), one might gain a better understanding of the relative contribution to ISR. Hybrid had no significant effect on height, whereas it consistently affected SPAD readings as a function of plant color.

Height

Plant height was impacted by site, but was not affected by hybrid or by the hybrid by site interaction (Table 1). This was evident in that fact that only a few times were there any noticeable variations in height, and when there were differences they could be attributed to other environmental factors such as water or wind damage.

Leaf Chlorophyll Content

SPAD measurements varied in the range of 30-40 units in the early season and 50-60 units later in the season. Figure 4 below depicts the change in SPAD throughout the measurement period for one site-year. At later stages of growth (greater than V7) all SPAD readings were above 50. Because hybrid was generally important for explaining variations in SPAD readings, but not for variations in ISR nor height measurements, one might conclude that SPAD readings are much more sensitive to the N health of the crop [as discussed by Kitchen et al. (2010)]. Another conclusion might be that ISR values are more impacted by biomass than by crop color.

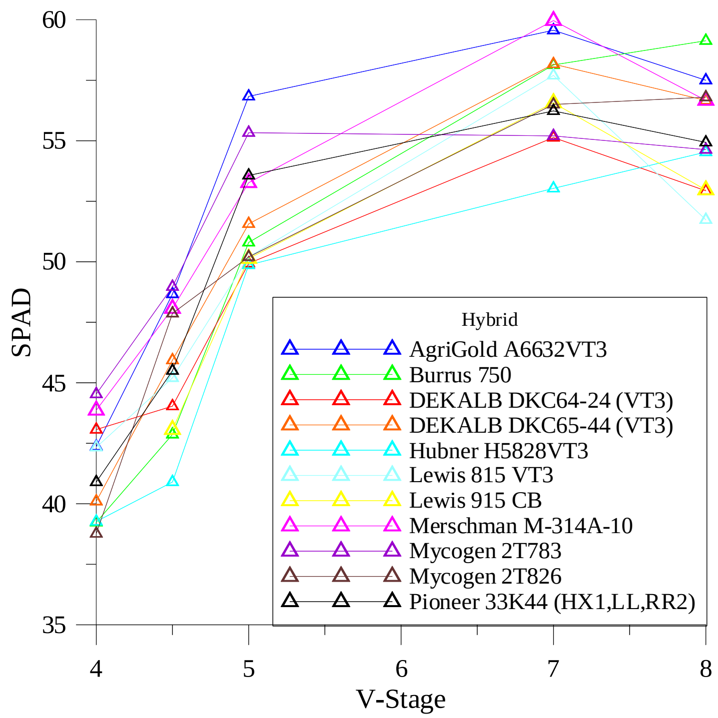

Fig. 4. Average SPAD values by hybrid over the 2008 growing season in Columbia, MO.

Characterizing Seasonal Changes in Canopy Reflectance

To determine the norm of what one would expect to see in a typical growing season, boundary lines were drawn with both years of ISR data combined (Fig. 5). This provides better understanding of limits of ISR for healthly corn as a function of crop height. The boundary line concept uses a subset from the “best and worst performing points” from a graph and by using either an equation to create a curve or drawing in a curve, the upper and lower boundary is defined (Kitchen et al., 1999, Webb 1972). It is assumed that points between the lines represent plants that were grown under typical growing conditions and performed normally; whereas, points not between the boundary lines represent unusual conditions (Kitchen et al., 1999). Thus, for corn that is 60 cm tall, one would expect ISR values to range from about 0.15 to 0.24. If sensor readings exceeded 0.24, some other factor (e.g. crop stand) was likely compromised. If ISR values were less than 0.15 at this corn height, other issues (e.g. poor weed control, sensor malfunction) might be considered.

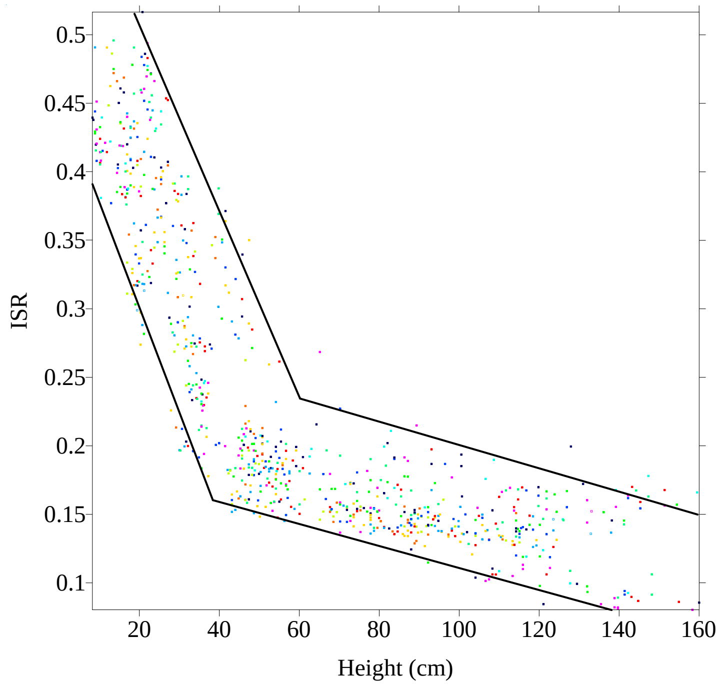

Fig. 5. Canopy reflectance as ISR values combined over both years, relative to crop height. Drawn on the graph are upper and lower ~98% boundary lines.

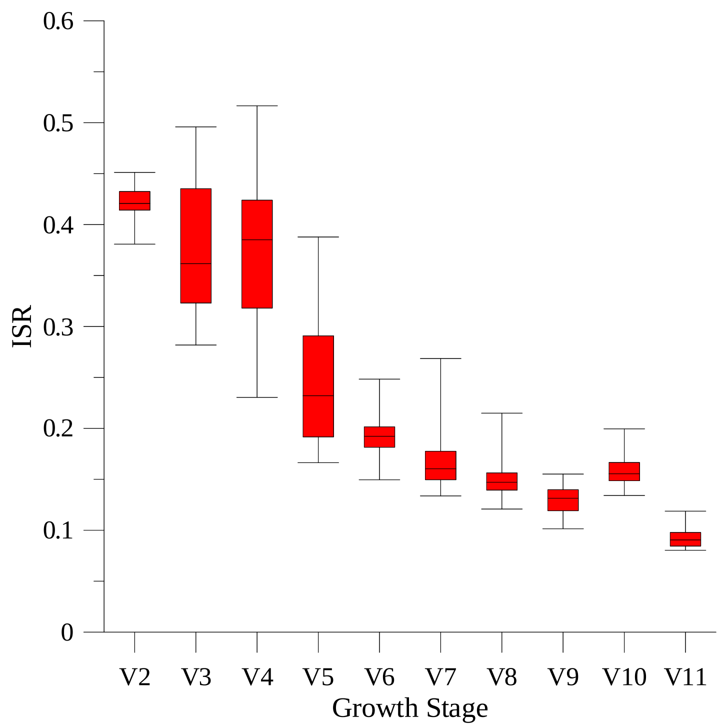

Fig. 6. Canopy reflectance as ISR values combined over both years, relative to growth stage. Plots show minimum, maximum (whiskers), median (box line), lower quartile, and upper quartile (box) information.

Figure 6 provides another way of looking at the Figure 3 data, but as box and whisker plots and in relation to crop growth stage. Both these figures are useful as they help define the boundaries of readings one might obtain over multiple hybrids and locations.

CONCLUSION

Seasonal changes in canopy sensor reflectance were well documented. Compiled, this data could be used to set boundaries to the variation that users might expect to see in canopy measurements of well fertilized corn over the growing season. Early in the season, ISR was predominantly affected by soil variations, but as the season progressed, these variations became less of a factor. Little significant effect by hybrid was found on ISR or height measurements. However, results indicated hybrid did have an effect on leaf color (by SPAD). We concluded that with the canopy sensor, ISR differences were more closely related to biomass than to leaf color. The primary value of this study is the measurement of variation in corn seasonal growth on canopy reflectance measurements. This data quantifies the potential range of sensor readings one might expect for well fertilized corn. When no N reference is available, these findings could be used by farmers to form a contingency N reference estimate for variable rate N applications.

DISCLAIMER

Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture or the University of Missouri.

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