EVALUATION OF CROP CANOPY SENSORS AS A TOOL FOR SOYBEAN RESEARCH AND PRODUCTION

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ABSTRACT

Determining the variables that consistently increase yields in soybean [*Glycine max* (L.) Merr.] continues to challenge researchers, agronomists and growers alike. Crop canopy sensors have emerged as a technology used in other cropping systems to monitor and manage agricultural inputs. The sensors measure reflectance in selected wavebands that are used to calculate vegetation indices that relate to unique leaf or canopy characteristics. The objectives of this study were to determine if a commercially available crop sensor could differentiate between seed treatments and foliar inputs and whether normalized difference red edge (NDRE) determinations during the growing season were significantly correlated with relative yield. Readings were taken with a RapidScan CS-45 Handheld NDVI Crop Scanner (Holland Scientific, Lincoln, NE) at four locations in eastern Nebraska during the 2014 cropping season. A factorial study was designed to evaluate five seed treatments (nontreated, fungicide, insecticide and fertility combinations), six foliar treatments (nontreated, fungicide, insecticide and fertility combinations) at pod set and two row spacings (15 and 30 in) for a total of 60 treatments, replicated four times in a split-plot (row spacing, whole plots) alpha-lattice design. Readings were taken 12 times throughout the growing season, four between emergence and R3, and 8 times at weekly intervals after foliar treatments were applied at R3. NDRE values observed at R2 showed the greatest contrast between seed treatments with an 8% increase for the fungicide + insecticide + fertility seed treatment compared to the check. Differences in NDRE values for foliar treatments varied by location with the greatest increase, 11.6%, observed for the fungicide + insecticide treatment over the check at R7. Initial results indicate that the chosen sensor detected differences in plant response to both seed and foliar treatments at specific growth stages throughout the season.

INTRODUCTION

Increasing yields is one of the primary goals of research involved in crop production. However, determining the variables that consistently increase soybean yields, or stressors that reduce soybean yields, continues to challenge researchers, agronomists and growers alike. The use of crop sensors has emerged as a new technology that has been successfully used in other cropping systems to monitor and manage agricultural inputs.

Crop sensors have been used most robustly in wheat production (Raun et al. 2005) and corn production (K. H. Holland and Schepers 2010; Solari et al. 2008) as a tool to direct in-season nitrogen management and to determine relative yields. Less work has focused on soybean production, most likely because nitrogen management is less important due to the plant's innate ability to fix its own nitrogen. However, research that has utilized crop sensing in soybeans has primarily focused on individual components of soybean production, such as detecting weed infestations (Medlin et al. 2009), identifying insect infestations (Board et al. 2007), and detecting stress induced by soybean cyst nematode (SCN) at the field level (Nutter Jr et al. 2002). Other papers have evaluated the ability to predict soybean yield using crop sensors (Ma et al. 2001) or using the combination of crop sensors and other variables (Mourtzinis et al. 2014). It remains to be determined whether crop sensors can be utilized as an effective tool in soybean production to help direct management decisions based on values correlated to overall plant vigor.

The RapidSCAN CS-45 Handheld NDVI Crop Sensor (Holland Scientific, Lincoln, NE) is an example of a crop canopy sensor that is being used in the field of agriculture. The RapidSCAN sensor is an active optical sensor that measures crop and soil reflectance at three wavelengths, 670 nm, 730 nm and 780 nm, corresponding to red, red edge (RE) and near infrared (NIR), respectively. Active sensors utilize their own radiation source, thereby eliminating the need for sufficient ambient illumination to collect reflectance readings (Holland, Lamb, and Schepers 2012). Two indices, normalized difference vegetation index (NDVI) and normalized difference red edge (NDRE), are generated from the readings for analysis. Previous research has suggested that NDRE better predicted soybean yield (Mourtzinis et al. 2014).

During the 2014 cropping season, the RapidSCAN CS-45 Handheld NDVI Crop Sensor was used to calculate NDVI and NDRE from soybean plots evaluating different combinations of seed applied and foliar applied treatments in four locations across eastern Nebraska. The goal was to (i) evaluate the sensitivity of each vegetation index at different growth stages across the growing season and (ii) determine if the sensors detected differences in reflectance readings in response to the numerous treatments.

MATERIALS AND METHODS

Experiment Design

This experiment was conducted at four locations across the eastern half of Nebraska in 2014. The fields were located in Auburn, Belgrade, Shickley and Snyder and were local cooperators' fields that were chosen to be part of the annual Soybean Management Field Days. The experiment was a factorial study designed to evaluate five seed treatments, six foliar treatments and two row spacings. The sixty treatment combinations were replicated four times at each site in a split-plot (row spacing, whole plots) alpha lattice design. Plot dimensions were 10 feet wide by 35 feet long.

Seed treatments included a fungicide, early season nitrogen, fungicide with early season nitrogen, and fungicide plus insecticide with early season nitrogen. These were evaluated against a non-treated control (Table 1). Foliar treatments were applied near the R3 growth stage and included a fungicide, fungicide plus foliar nutrients, fungicide plus insecticide, and fungicide plus insecticide plus foliar nutrients. These treatments were also evaluated against a non-treated control (Table 1). Additionally, all seed treatment and foliar treatment combinations were evaluated across soybeans planted in 15 and 30 inch rows, which result in seven rows in the 15 inch row plots and four rows in the 30 inch row plots.

The soybean variety Asgrow AG2733 was planted at all sites at a population of 140,000 seeds per acre. The planting dates for each location were as follows: Belgrade on April 28, Snyder on May 5, Shickley on May 6 and Auburn on May 7. Plots were minimized to 30 feet in length before harvest and rows two and three in the 30 inch row plots and rows three and five in the 15 inch row plots were harvested with a plot combine. Weight and moisture were collected to determine the final yield of each plot. More details about the methods used are given in Shapiro et al., 2015a and Shapiro et al. 2015b.

Table 1. Specific treatment in the 2014 SMFD factorial experiment that were "Early Season Inputs" and "Pod Set Inputs". All seed treatments were applied to seed prior to planting and all foliar applications were applied in a 15 gal/A application volume.

Early Season Inputs	Pod Set (Stage R3) Inputs
No Treatment	No Treatment
Fungicide Seed Treatment (ST) (Apron XL 7.5 g/100 kg seed + Maxim 4FS 2.5 g/100 kg seed + Vibrance 2.5 g/100 kg seed)	Fungicide (Stratego YLD 4.0 fl oz/A)
Nitrogen (N) (15 lb N as 28-0-0 applied at growth stage V2)	Fertility (UAN (28-0-0) 25 lb N/A + N-Rage (23-4-2, slow release N plus Mn) 2 gal/A + Soy Grow (0.04 Fe EDTA, 0.05 Mg EDTA, 0.27 Mn EDTA, 0.16 Zn EDTA) 1 pt/A)
Fungicide ST + N (Apron XL 7.5 g/100 kg seed + Maxim 4FS 2.5 g/100 kg seed + Vibrance 2.5 g/100 kg seed) + (15 lb N as 28-0-0 applied at growth stage V2)	Fungicide + Fertility (Stratego YLD 4.0 fl oz/A) + (UAN (28-0-0) 25 lb N/A + N-Rage (23-4-2, slow release N plus Mn) 2 gal/A + Soy Grow (0.04 Fe EDTA, 0.05 Mg EDTA, 0.27 Mn EDTA, 0.16 Zn EDTA) 1 pt/A)
Fungicide ST + Insecticide ST + N (Apron XL 7.5 g/100 kg seed + Maxim 4FS 2.5 g/100 kg seed + Vibrance 2.5 g/100 kg seed + Thiamethoxam 50 g/100 kg seed) + (15 lb N as 28-0-0 applied at growth stage V2)	Fungicide + Insecticide (Stratego YLD 4.0 fl oz/A + Leverage 360 2.8 fl oz/A)
	Fungicide + Insecticide + Fertility (Stratego YLD 4.0 fl oz/A + Leverage 360 2.8 fl oz/A) + (UAN (28-0-0) 25 lb N/A + N-Rage (23-4-2, slow release N plus Mn) 2 gal/A + Soy Grow (0.04 Fe EDTA, 0.05 Mg EDTA, 0.27 Mn EDTA, 0.16 Zn EDTA) 1 pt/A)

Crop Canopy Reflectance Readings

At regular intervals throughout the season, crop canopy reflectance measurements were recorded using a RapidScan CS-45 Handheld NDVI Crop Scanner (Holland Scientific, Lincoln, NE). The sensor was held between 1.5 to 2.5 feet above the soybean canopy by the evaluator who walked between the harvest rows and logged data from the center 25 feet. Readings were taken at the V5 and V8 vegetative growth stages, and then at weekly intervals when the soybeans reached the R2 reproductive growth stage. Readings were stopped when soybeans reached full maturity. The vegetation indices, NDVI and NDRE were calculated for each plot and compared across treatments at each time point that they were collected. The calculation for NDVI and

NDRE are described in equations 1 and 2 below.

$$\mathrm{NDVI} = \frac{R_{NIR} - R_{RED}}{R_{NIR} + R_{RED}} \qquad \text{(Equation 1)}$$

$$\mathrm{NDRE} = \frac{R_{NIR} - R_{RE}}{R_{NIR} + R_{RE}} \qquad \text{(Equation 2)}$$

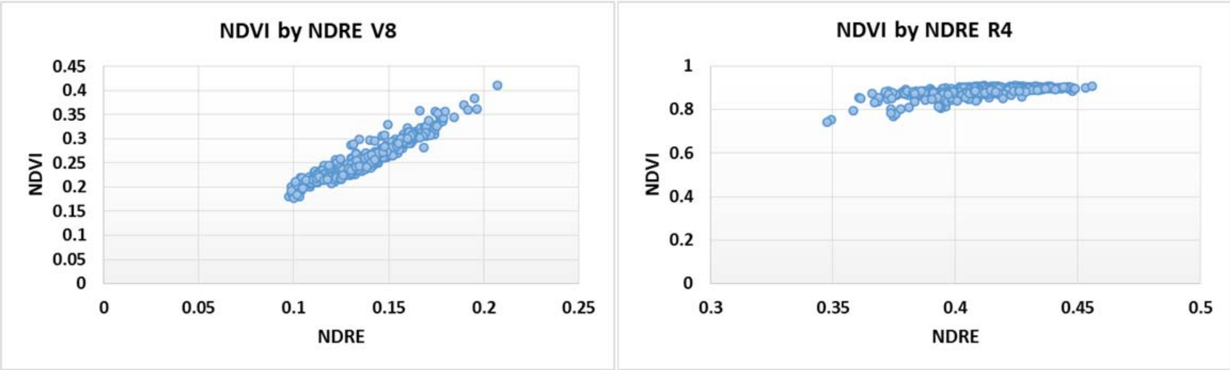
where

R_{NIR} = near-infrared reflectance (780 nm)
R_{RED} = red reflectance (670 nm)
R_{RE} = red edge reflectance (730 nm)

RESULTS AND DISCUSSION

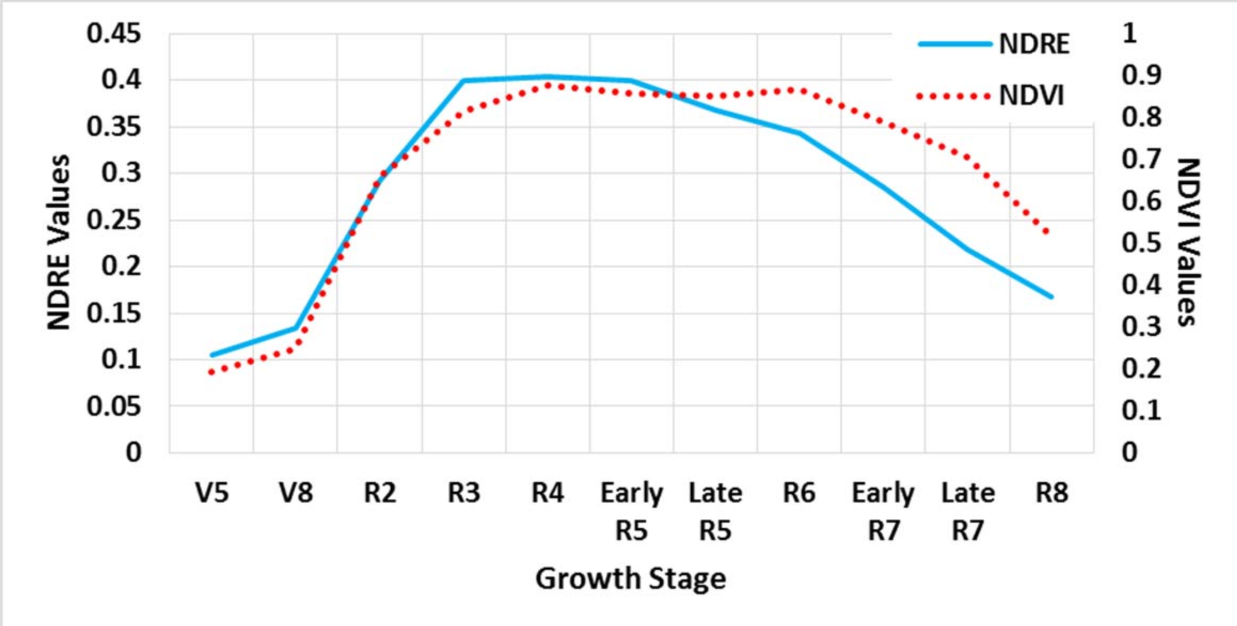
The NDVI and NDRE values for all plots were calculated at each collection time. The values were then plotted against each other to evaluate the correlation between the different indices. Because NDVI uses the red wavelength in its calculation (eq. 1), the values of the index are shown to plateau after the R2 growth stage because the red light becomes saturated. The relationship between NDVI and NDRE is shown in figure 1 for the readings collected at V8 and R4. Although both indices detect differences between treatments in the earlier vegetative stages, NDVI values remain relatively the same for all plots during the later reproductive stages. The NDRE index maintains the ability to differentiate between plots throughout the growing season.

Figure 1. NDVI values plotted against NDRE values at select growth stages throughout the growing season. NDVI values are plotted on the y axis and NDRE values are plotted on the x axis.



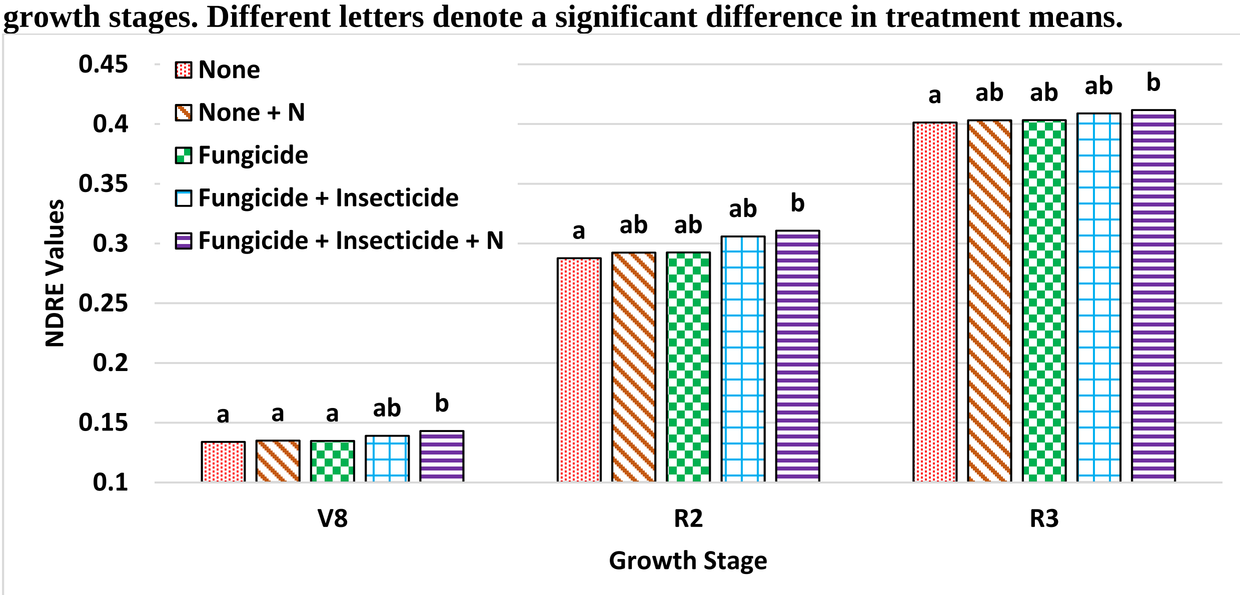
Another way to visualize this phenomenon is shown in Figure 2. This figure plots the average NDVI and NDRE values of all check plots across the growing season to show the response curve of each index. Until the soybeans reach the R2 growth stage, the curves are similar, but after R2 the NDVI curve plateaus while the NDRE curve continues to increase or decrease from one growth stage to the next.

Figure 2. Plot of average NDVI and NDRE recorded from check plots across all locations throughout the growing season.



Because the NDRE values appear to retain the ability to detect differences in reflectance over the course of the season, this index was chosen to evaluate the differences in mean reflectance between the seed and foliar treatments. Significant differences ($P<0.05$) in NDRE values were observed between the no seed treatment and the fungicide + insecticide + fertility treatment at V8, R2 and R3 growth stages across all locations.

Figure 3. Select reflectance data from the 2014 Soybean Management Field Day factorial study measuring the NDRE values for different early season seed treatments at different growth stages. Different letters denote a significant difference in treatment means.



Differences between NDRE values varied by location in regards to foliar treatments. However, significant differences ($P<0.05$) were consistently observed between no foliar treatment and the fungicide + insecticide + N treatment. Differences in canopy reflectance typically were observed starting at R5 and continuing through the R7 growth stage. Additional field studies are needed to determine what the mean differences are between foliar treatments and at what growth stage these differences are most noticeable.

SUMMARY

Crop canopy sensors have proven to be a valuable tool in agricultural crop production, especially in crops such as corn and wheat. The ability to utilize these sensors in soybeans, however, is currently not possible. More data collection is needed to understand how reflectance varies across the growing season and how different stresses and inputs influence the reflectance. The data collected during the first year of this experiment is the starting point to gain a better understanding of these questions.

The most commonly used vegetation index is the normalized difference vegetation index (NDVI). However, this study determined that NDVI becomes insensitive to changes in the crop canopy after the soybeans reach the R2 growth stage because red light becomes saturated. The normalized difference red edge (NDRE) index does not encounter this problem. It is therefore the recommendation from this study to use NDRE when evaluating crop canopy reflectance in soybeans.

Additionally, the sensor detected differences between multiple seed treatments and foliar applications throughout the season. NDRE values were significantly greater for the fungicide + insecticide + nitrogen seed treatment than for the no seed treatment at the V8, R2 and R3 growth stages. The fungicide + insecticide + fertility foliar application treatment also exhibited a significantly greater NDRE value than the no foliar application treatment between growth stages R5 and R7. This result indicates that the treatments were having an effect on the gross primary production of the plants. Additional experimentation is needed to be confident in the response that each of these inputs is having on crop canopy reflectance, and if this response correlates to the relative yield of the field in any way. It is also necessary to determine at what growth stage the crop canopy reflectance is most likely to show differences between treatments and at what growth stage the reflectance is most correlated to yield.

REFERENCES

Board, J. E., V. Maka, R. Price, D. Knight, and M. E. Baur. 2007. “Development of Vegetation Indices for Identifying Insect Infestations in Soybean.” Agron. J. 99 (3): 650–56.

Holland, K. H., and J. S. Schepers. 2010. “Derivation of a Variable Rate Nitrogen Application Model for in-Season Fertilization of Corn.” Agron. J. 102 (5): 1415–24.

Holland, K. H., D. W. Lamb, and J. S. Schepers. 2012. “Radiometry of Proximal Active Optical Sensors (AOS) for Agricultural Sensing.” IEEE J. Sel. Top. Appl. 5 (6): 1793–1802.

Ma, B. L., L. M. Dwyer, C. Costa, E. R. Cober, and M. J. Morrison. 2001. “Early Prediction of Soybean Yield from Canopy Reflectance Measurements.” Agron. J. 93 (6): 1227–34.

Medlin, C. R., D. R. Shaw, P. D. Gerard, and F. E. LaMastus. 2000. “Using Remote Sensing to Detect Weed Infestations in Glycine Max.” Weed Sci. 48 (3): 393-98.

Mourtzinis, S., S. C. Rowntree, J. J. Suhre, N. H. Weidenbenner, E. W. Wilson, V. M. Davis, S. L. Naeve, S. N. Casteel, B. W. Diers, P. D. Esker, J. E. Specht, and S. P. Conley. 2014. "The Use of Reflectance Data for In-Season Soybean Yield Prediction." Agron. J. 106 (4): 1159-68.

Nutter Jr, F. W., G. L. Tylka, J. Guan, A. J. D. Moreira, C. C. Marett, T. R. Rosburg, J. P. Basart, and C. S. Chong. 2002. "Use of Remote Sensing to Detect Soybean Cyst Nematode-Induced Plant Stress." J. Nematol. 34 (3): 222-31.

Raun, W. R., J. B. Solie, M. L. Stone, K. L. Martin, K. W. Freeman, R. W. Mullen, H. Zhang, J. S. Schepers, and G. V. Johnson. 2005. "Optical Sensor-Based Algorithm for Crop Nitrogen Fertilization." Commun. Soil Sci. Plan. 36 (19-20): 2759–81.

Shapiro, C. A., B. Krienke, J. Miller. 2015a. Effect of early season nitrogen on soybeans. *In* Soybean management field days research update (K. Glewen, editor). University of Nebraska Extension. P. 1-8. Verified 9/28/2015 at: http://ardc.unl.edu/soydaysresearch

Shapiro, C. A., L.J. Giesler, J. Miller, 2015b. Integrated evaluation of common inputs to increase soybean yields in Nebraska (2014). *In* Soybean management field days research update (K. Glewen, editor). University of Nebraska Extension. P. 9-20. Verified 9/28/2015 at: http://ardc.unl.edu/soydaysresearch

Solari, F., J. Shanahan, R. Ferguson, J. Schepers, and A. Gitelson. 2008. "Active Sensor Reflectance Measurements of Corn Nitrogen Status and Yield Potential." Agron. J. 100 (3): 571–79.

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