Nebraska Soybean Board
Year-End Research Findings Report

Please use this form to summarize the practical benefits of your research project and what has been accomplished. Your answers need to convey why the project is important and how the results will impact soybean production.

Project Title: Establishing the Effectiveness of Active Optical Sensors as a Tool for Soybean Research and Production

Contractor & Principal Investigator: University of Nebraska-Lincoln Loren J. Giesler and Joshua Miller

Please check/fill in appropriate box:

- ☒ ***Continuation research project***
- ☐ ***Year ☐ of ☐ research project (e.g., Year 1 of 2)***

1. What was the focus of the research project or educational activity?

The objectives of this project are to: 1.) Determine the effectiveness of using optical sensor reflectance readings to identify the effects of early and late season inputs, 2.) Determine the sensitivity of the crop sensor to varietal/genetic differences within the UNL soybean breading program, and 3.) Identify the growth stage (s) when optical sensor readings can be collected to determine a relative yield with high confidence.

2. What are the major findings of the research or impacts of the educational activity?

Two years of data have been collected and continue to be analyzed. The sensor being tested was able to detect significant differences between seed and foliar treatments. Also, there appears to be a correlation between reflectance readings and the final yield of the plots. Multiple reflectance readings over the course of the season are being used to calculate a cumulative reflectance value. This value has been determined to predict the productivity of a field, high yielding portions and low yielding portions, before the R3 growth stage.

3. Briefly summarize, in lay terms, the impact your findings have had, or will have, on improving the productivity of soybeans in Nebraska and the U.S.

Improving yields for soybean farmers is the common goal of most projects. The goal of this project is to evaluate the potential use of active (sensor generated light source) optical sensors for use to benefit research for high throughput phenotyping in germplasm development as well as response to crop production inputs. Should this sensor type prove to be useful as it has in other crops, such as corn and wheat, then the application could result in assisting management inputs at the early and later (R3) stages of crop development. Additionally, the sensor has proven to be able to predict the relative yield of a soybean field prior to harvest. This could assist growers to identify lower yielding portions of their field for management, or to allow growers to effectively market grain based on predicted yields.

Active optical sensors can be used at any geography as they generate their own source and if proven effective should be a very widely applicable crop response variable that could be monitored at any geography. This sensor type was tested in 2014 and 2015 at the Soybean Management Field Day locations and has shown promise to its potential use. Soybeans have not been critically evaluated for application and this is on the front stage of research with this tool.

4. Describe how your findings have been (or soon will be) distributed to (a) farmers and (b) public researchers. List specific publications, websites, press releases. etc.

A description of this study, as well as preliminary findings, have been presented at the Soybean Management Field Days in 2014 and 2015. Information from the study was reported in the SMFD Research Updates cited below

Miller, J., Arneson, N., Giesler, L., & Shapiro, C. (2015). Integrated evaluation of common inputs to increase soybean yield in Nebraska. Soybean Management Field Days Research Update. University of Nebraska – Lincoln Extension.

Shapiro, C., Krienke, B., & Miller, J. (2014). Effect of early season nitrogen on soybeans. Soybean Management Field Days Research Update. University of Nebraska – Lincoln Extension.

Shapiro, C., Giesler, L., & Miller, J. (2014). Integrated evaluation of common inputs to increase soybean yield in Nebraska. Soybean Management Field Days Research Update. University of Nebraska – Lincoln Extension.

Additionally, results from this experiment have been presented at the ASA meetings in 2015 and 2016. The first journal publication is expected to be submitted to the Agronomy Journal in January summarizing the complete integrated study. The first journal publication covering the use of crop canopy sensors will follow shortly, either in the Agronomy Journal or International Journal of Remote Sensing.

5. Did the NE soybean checkoff funding support for your project leverage any additional state or Federal funding support? Please list sources and dollars approved.

All project personnel are grant funded and no state or federal funds were leveraged.

*****This form must be completed and submitted with the fourth quarter report.***

Institute of Agriculture and Natural Resources
Department of Plant Pathology

Year End Report for FY 2016
Establishing the Effectiveness of Active Optical Sensors as a Tool for Soybean Research and Production
Project #: 26-6235-0264-001

Loren J. Giesler, Extension Plant Pathologist
Joshua Miller, Doctor of Plant Health and Plant Pathology PhD Student

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. The goal of this study is to evaluate the effectiveness of a commercially available crop sensor to detect differences in reflectance that is caused by multiple variables, including insect and disease pressure, soybean cyst nematode (SCN) infestation, and plant nutrient levels, as well as predict relative soybean yields within a field.

This project involves two experiments. The first experiment was conducted on the Integrated Management trials that were part of the Soybean Management Field Day sites in 2014 and 2015. The goals of this experiment were to evaluate the effectiveness of the sensor to detect differences in crop canopy due to management practices, to determine which vegetation index was most appropriate to use in soybeans, and whether the sensor could characterize the productivity of a field prior to harvest. The second experiment was conducted on soybean producer's fields with known presence of SCN in 2015 and 2016. The goals of this experiment are to determine whether the sensor can detect stresses induced by SCN infection and whether vegetation indices obtained from the crop canopy sensor is correlated to SCN presence and abundance within the soil.

Experiment 1

During the cropping seasons of 2014 and 2015, a RapidSCAN CS-45 Handheld NDVI Crop Sensor from Holland Scientific was used to measure red, red edge (RE) and near infrared (NIR) reflectance from soybean plots in eight locations in eastern Nebraska (four each year) that were part of the Soybean Management Field Days. The RapidSCAN sensor is an active optical sensor that measures crop and soil reflectance at three wavelengths, 670 nm, 730 nm and 780 nm. Active sensors utilize their own radiation source, thereby eliminating the need for sufficient ambient illumination to collect reflectance

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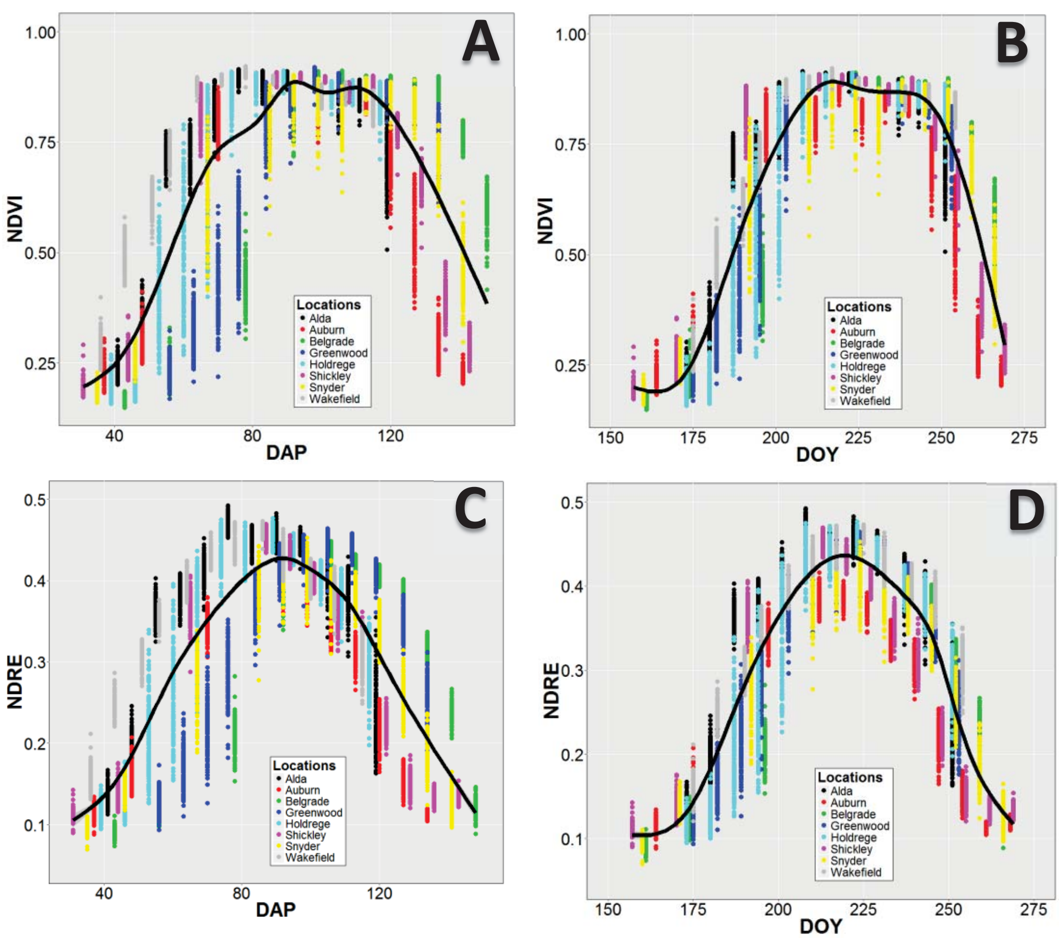
readings (Kyle H. Holland, Lamb, and Schepers 2012). Two indices, normalized difference vegetation index (NDVI) and normalized difference red edge (NDRE), are generated from the readings for analysis. Readings were taken from each experimental unit twelve times throughout the growing season.

The NDVI and NDRE indices of all experimental units within the eight locations were plotted by days after planting (DAP) and by day of year (DOY) (Figure 1). These plots indicated that analyzing the data for DOY allowed for comparisons between locations due to the fact that soybeans are photoperiod dependent. The limitations of NDVI were also illustrated by these plots because red light reaches a point of saturation when crop canopies become larger. This is clear in Figure 1, A and B as the plot reaches a plateau close to DOY 210 when the soybeans were in the early reproductive stages. The NDRE index did not result in a plateau and continued to increase and/or decrease as the season progressed (Figure 1, D). This evidence confirmed that the NDRE is the more suitable index to use when evaluating soybean crop canopies later in the season.

Figure 1. NDVI and NDRE of experimental units plotted by days after planting (DAP) and day of year (DOY).



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The twelve readings were taken throughout the growing season from early vegetative stages to late reproductive stages. In 2014, significant differences (P<0.05) in NDRE readings were observed between the no seed treatment, nitrogen, and fungicide treatments and the fungicide + insecticide + fertility treatment at V8, R2 and R3 growth stages. The no treatment and nitrogen seed treatments were also significantly different from the fungicide + insecticide treatment at R2 (Figure 2). NDRE readings were significantly different (P<0.05) at R6 between the no treatment, fungicide and fertility treatments and treatments 4, 5 and 6 (fungicide + fertility, fungicide + insecticide, and fungicide + insecticide + fertility, respectively) (Figure 3). Similar differences were observed at later growth stages but only at certain locations.

Figure 2. 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.

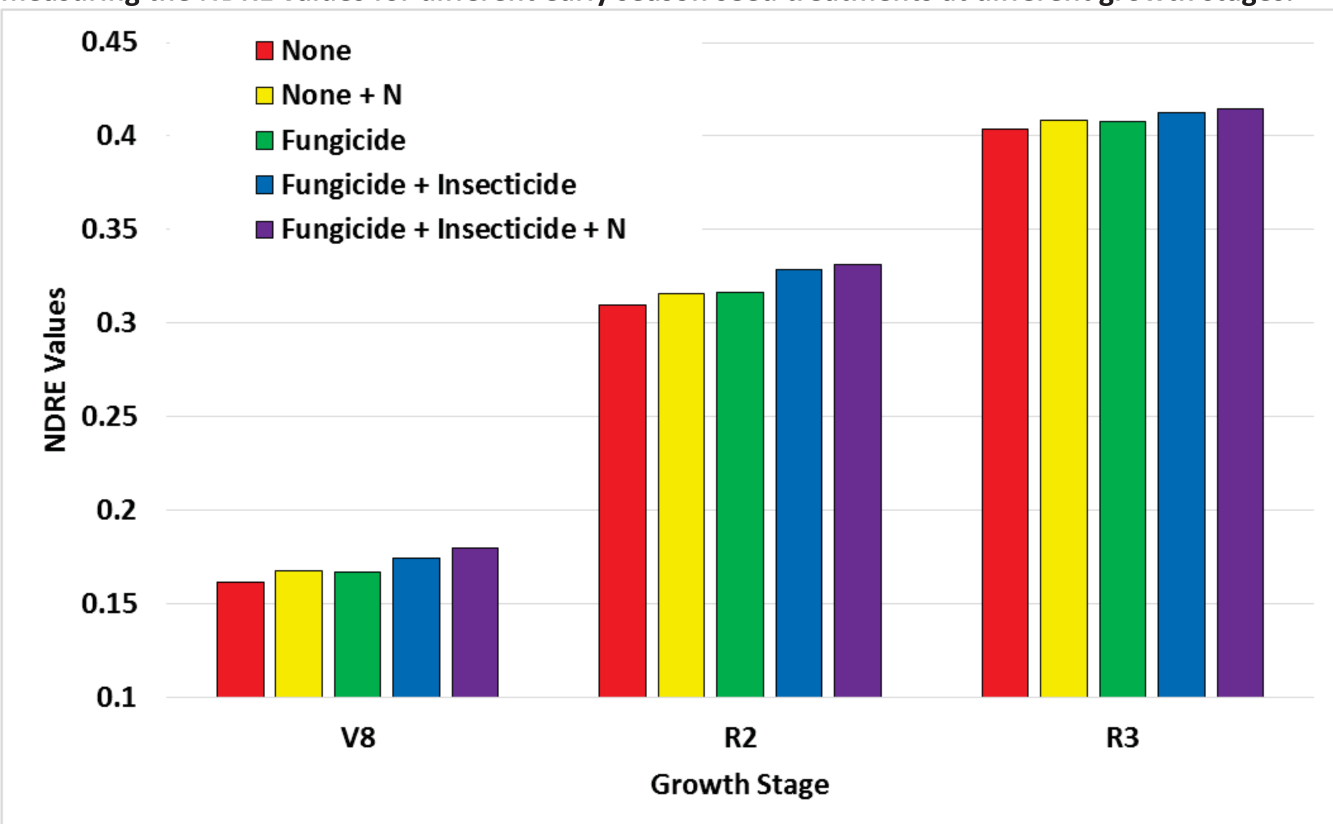

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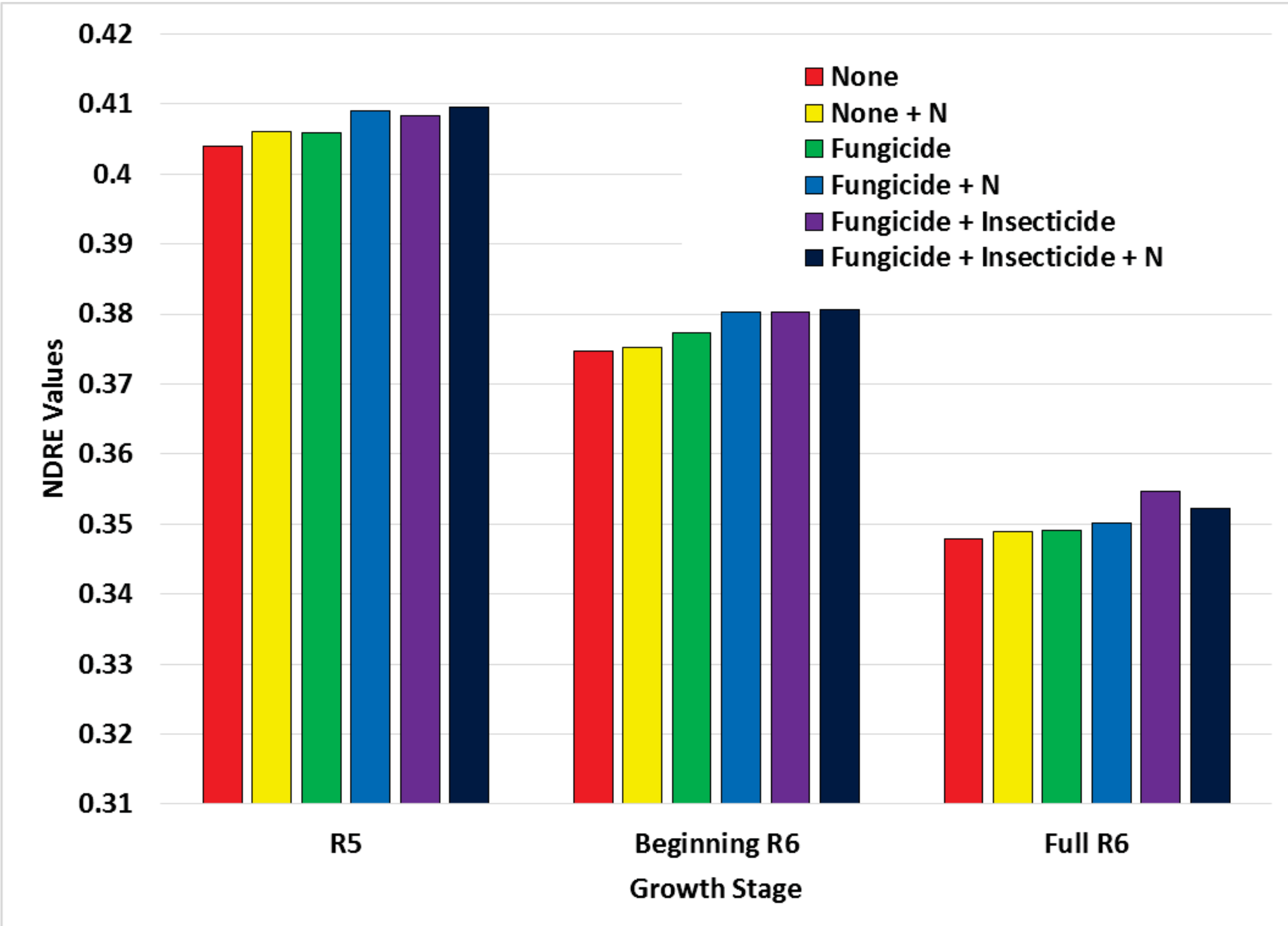
Figure 3. Select reflectance data from the 2014 Soybean Management Field Day factorial study measuring the NDRE values for different late season inputs at different growth stages.



The results illustrate the potential for active optical sensors to be used in soybean research and production as a tool to determine input effects and direct in-season management. Further work is needed to better understand how different inputs affect sensor readings, to what extent yield-limiting variables affect sensor readings, and at what growth stage the sensors are most effective.

The last objective of the first experiment was to determine if the sensors could be used to characterize the productivity of the field prior to harvest. To achieve this, the area under the disease progress curve (AUDPC) calculation was used. This calculation is typically used to quantify changes in disease severity over time. In this experiment, NDRE values were used in place of disease severity

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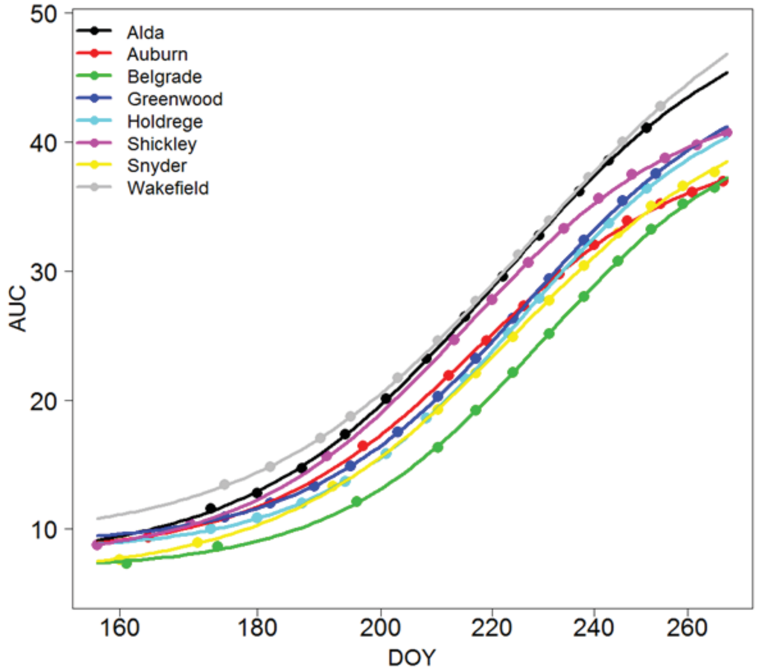
ratings to quantify the cumulative reflectance of each experimental unit as the season progressed (Figure 4).

Figure 4. Average area under the reflectance progress curve (AURPC) for each location.



Area under the reflectance progress curve (AURPC) was calculated from early vegetative growth stages through the R3 growth stage. To determine if these values could be used to characterize the productivity of a soybean field, the values were plotted against yield and a linear model was applied to determine if the relationship was significant. In seven of the eight locations, the model was significant (p=0.05) and the higher AURPC resulted in higher yield (Figure 5).

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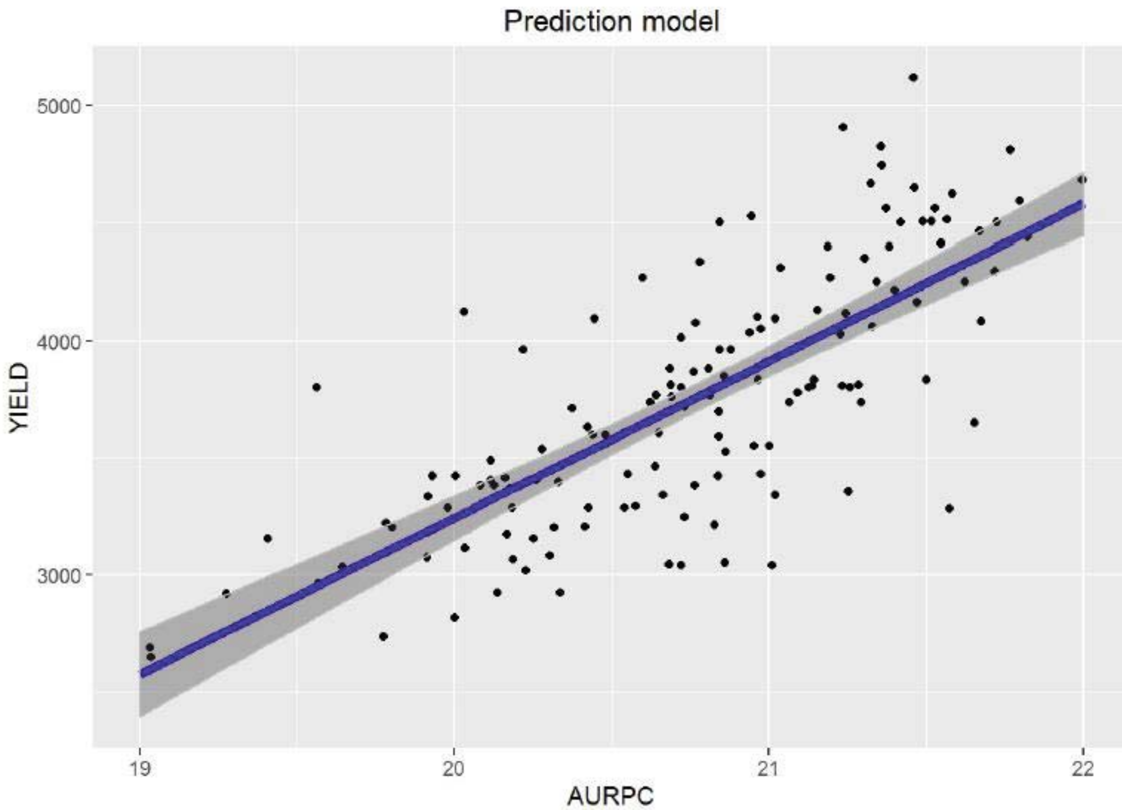
Figure 5. Prediction model for yield using AURPC at the Alda location. 95% confidence intervals are indicated by the shaded region.



The AURPC values were also used to create a heat map for each location and categorized as either i) Top 25%; ii) Middle 50%; or iii) Bottom 25% (Figure 6A). A heat map was also generated for the yield of each location using the same categories (Figure 6B). Odds ratios were calculated to determine the likelihood of correctly identifying the yield category with the AURPC category. The odds ratio table for the Alda location is shown in Table 1 and the odds ratio table for all locations is shown in Table 2. These results indicate that the use of AURPC could be used to confidently characterize the high and low yielding portions of a soybean field early in the reproductive stages when management decisions could still be made on the field.

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Figure 6. Heat maps indicating the top 25% (green), middle 50% (white), and bottom 25% (red) of AURCP (A) and yield (B) for the Alda location.

A. AURPC Heat Map

1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014
901	902	903	904	905	906	907	908	909	910	911	912	913	914
801	802	803	804	805	806	807	808	809	810	811	812	813	814
701	702	703	704	705	706	707	708	709	710	711	712	713	714
601	602	603	604	605	606	607	608	609	610	611	612	613	614
501	502	503	504	505	506	507	508	509	510	511	512	513	514
401	402	403	404	405	406	407	408	409	410	411	412	413	414
301	302	303	304	305	306	307	308	309	310	311	312	313	314
201	202	203	204	205	206	207	208	209	210	211	212	213	214
101	102	103	104	105	106	107	108	109	110	111	112	113	114

B. Yield Heat Map

1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014
901	902	903	904	905	906	907	908	909	910	911	912	913	914
801	802	803	804	805	806	807	808	809	810	811	812	813	814
701	702	703	704	705	706	707	708	709	710	711	712	713	714
601	602	603	604	605	606	607	608	609	610	611	612	613	614
501	502	503	504	505	506	507	508	509	510	511	512	513	514
401	402	403	404	405	406	407	408	409	410	411	412	413	414
301	302	303	304	305	306	307	308	309	310	311	312	313	314
201	202	203	204	205	206	207	208	209	210	211	212	213	214
101	102	103	104	105	106	107	108	109	110	111	112	113	114

Table 1. Odds ratio table for Alda indicating likelihood of predicting yield category with AURPC.

AURPC \ Yield	Bottom 25%	Middle 50%	Top 25%
Bottom 25%	0.588	0.412	0.000
Middle 50%	0.183	0.704	0.113
Top 25%	0.029	0.206	0.765

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Table 2. Odds ratio table for all locations indicating likelihood of predicting yield category with AURPC.

AURPC \ Yield	Bottom 25%	Middle 50%	Top 25%
Bottom 25%	0.527	0.371	0.102
Middle 50%	0.180	0.585	0.234
Top 25%	0.117	0.441	0.441

The second experiment was conducted during the 2015 and 2016 cropping season in three locations each year across eastern Nebraska to evaluate the effect soybean cyst nematode populations have on sensor readings. Two infested sites and one non-infested site were selected each year. Four SCN resistant PI 88788 varieties and four SCN susceptible varieties were planted in a randomized complete block design with eight replications. The RapidScan crop sensor was used to take readings at different growth stages throughout the season. Additionally, a thermal camera was utilized at these sites during 2015 to determine which technology is most accurate at detecting the onset and severity of stress induced by SCN. The thermal imaging was utilized at the onset of reproductive growth when SCN begins to have a greater affect soybean growth and seed production. At this stage, all data has been collected and samples are being processed to determine SCN populations for each experimental unit. Once samples are processed, the data will be analyzed to determine whether the sensor is related to initial SCN populations, final SCN populations, of if there is a threshold that SCN populations must reach before enough stress is put on the soybean plants to be detected by changes in crop canopy reflectance.

These experiments show promise for the use of a commercially-available crop canopy sensor to be used in soybean research and production. This project is expected to be completed in the Spring of 2017. To date, results have been presented at the 2015 and 2016 Soybean Management Field Days, as well as the North Central Extension-Industry Soil Fertility Conference (2015), and Tri-Societies meetings (2015 and 2016). Thank you for your continued funding and support.

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