Comparison of Ground-Based Active Crop Canopy Sensor and Aerial Passive Crop Canopy Sensor for In-Season Nitrogen Management

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ABSTRACT

Crop canopy sensors represent one tool available to help calculate a reactive in-season nitrogen (N) application rate in corn. When utilizing such systems, corn growers must decide between using active versus passive crop canopy sensors. The objectives of this study was to 1) determine the correlation between N management by remote sensing using a passive sensor and N management using proximal sensing with an active sensors. Treatments were arranged as field length strips in a randomized complete block design with 5 replication. Base rates of N were applied near planting. Side-dress of N was applied on the active sensor strips with a high clearance applicator using Ag Leader OptRx® sensors, and the passive sensor strips with a high clearance applicator directed by multispectral imagery from an eBee SQ using a Sequoia sensor. Applications controlled via sensors were applied from V10 to V12 growth stage of corn. Aggregated results of all sites showed 21 lbs acre^{-1} more N and decreased normalized difference red edge (NDRE) of 0.0870 for the passive sensor treatments compared to the active sensor treatments. The results support a difference in reflectance values recorded by the type sensors, yield data still needs to be analyzed to understand the effect on production of either yield or nitrogen use efficiency (NUE)

INTRODUCTION:

Precision application of nitrogen (N) fertilizer for corn production is an area of growing interest for many corn growers. Precision farming can help reduce costs by enabling proper placement of fertilizer as well as proper timing of the fertilizer application. Farming by soil type was one of the first ways precision farming was introduced to growers and has now advanced to crop canopy sensing (Mulla 2013). Crop Canopy sensors use electromagnetic radiation in specific bands to detect and quantify crop reflectance. Vegetation indices created from the specific bands of radiation received by the sensors relate crop health to measured reflectance values.

Multiple crop canopy sensors are available for collection of Normalized Different Red Edge NDRE) data and thus can be used for N application prescriptions. A main difference between crop canopy sensors being a passive sensor or an active sensor. Passive crop canopy sensors use electromagnetic radiation from the sun that has been reflected from the crop canopy as their source of light. Most passive sensors will have calibration panels and irradiance sensors to help calibrate for the amount of radiation provided by the sun. Active crop canopy sensors emit their own light source by way a modulated light emitting diodes (LED). This eliminates the need for calibration outside of a lab and can be used during the growing season with constant measurements.

The objective of this study was to determine the correlation between N management by remote sensing using a passive sensor and N management using proximal sensing with an active sensors. Active crop canopy sensors have shown to reduce nitrogen inputs while the corn yield is maintained compared to the growers standard nitrogen management practice. This has improved the NUE of these fields compared to a grower's standard practice. If a passive sensor carried by a drone can create a nitrogen prescription map as effective as an active sensor can prescribe nitrogen a passive sensor could be used in place of the active sensor and logistics for in-season nitrogen application by sensors could be improved.

MATERALS AND METHODS:

Split applications of N occurred on two treatments: SENSE treatment and Drone treatment. Participating corn growers used their equipment to apply the first application of N near planting of the crop and a Hagie DTS 10 high clearance applicator with an Ag Leader® Integra monitor was used to apply the in-season application of the treatments. A pulse width modulation (PWM) system by Capstan was installed to control rate changes. In-season N applications occurred between tenth leaf and twelfth leaf (V10 – V12) growth stages of corn. Differences between treatment types were from the type of sensor used to direct the application of variable rate N. SENSE treatments used the OptRx® sensors to direct in-season nitrogen management. The OptRx® sensor is an active sensor that emits a modulated light and is detected by optical sensors. The optical sensors are outfitted with filters to read reflectance of electromagnetic radiation (EMR) in near Infrared (NIR), red edge (RE), and red (R) wavelengths. Drone treatments used the Sequoia sensor to direct in-season nitrogen management. The Sequoia is a passive sensor that reads reflectance that is produced from EMR emitted from the sun. Wavelength filters the Sequoia uses to record reflectance of EMR are NIR, RE, R, and green (G) wavelengths. The Vegetation indices of normalized different red edge (NDRE) is created by these sensor (equation 1) to be used in an algorithm based on the Holland-Shepers sensor algorithm (Holland and Schepers, 2010).

Equation 1

$$NDRE = \frac{NIR - Red\ Edge}{NIR + Red\ Edge}$$

Where: NDRE is the normalized difference vegetation index
NIR is near infrared light reflectance
RE is red-edge light reflectance

Treatments were set up with five replicates of three field length treatments in complete randomized block design. Following is a description of each treatment and how the treatments were managed.

SENSE treatments were applied by variable rate application based on NDRE readings of the crop in real-time. A NDRE reference was created by operating the OptRx® for 5 minutes over a representative portion of the field in relation to crop canopy color. After the 5 minute data collection was done the 95th percentile of the data was calculated by the Integra monitor and used as the NDRE reference. A sufficiency index (SI) was calculated by using the currently view crops NDRE and the NDRE reference (equation 2). The SI was then used in the modified Holland-Shepers sensor algorithm to determine a N rate. Inputs needed to determine a N rate are input into the Integra monitor. These parameters are minimum N rate, maximum N rate, economic optimum nitrogen rate (EONR), N credits, pre-applied N. For all sites Minimum N rate was set to 30 lbs acre^{-1} N, Maximum N rate was set 300 lbs acre^{-1} N. Economic optimum nitrogen rate was calculated by the use of Maize N

Equation 2

$$SI = \frac{VI_{Sensed\ Crop}}{VI_{Reference}}$$

Where: SI is sufficiency index
VI is vegetation index
Target VI is the area receiving N application
Reference VI is the reference value

program (Setiyano et al., 2011). Pre-applied N was the base rate of N applied prior to the in-season application. Nitrogen within irrigation water were used as N credits.

Drone treatments were had variable rate N prescription applied with the same high clearance applicator. The N prescription was created from reflectance images collected by the Sequoia sensor. The Sequoia sensor was carried by the eBee SQ which is an unmanned aerial system

(UAS). The eBee SQ was flown at an altitude of 380 ft above ground level and collected reflectance images at a resolution of 4.31 inches per pixel. The reflectance images were collected one day to six days in advance of the application dependent on weather. After reflectance data was collected using the Sequoia camera and eBee SQ the images were geotagged in eMotion Ag 3.3.1 (senseFly SA, Lausanne, Switzerland) and stitched in Pix4D V. 3.3.29 (Pix4D SA, Lausanne, Switzerland). Near infrared (NIR) and RE maps were used to create a NDRE map of the field. The NDRE map was loaded into R studio as well as shapefiles of the Drone treatment replicates. The Drone treatment replicates were divided into 10 ft polygons by the width of the treatment at the respected site to extract NDRE data by average of the pixels within the divided polygons. The extracted NDRE values were then used to create a NDRE reference by calculating the 95th percentile of the dataset. A SI map was created for all polygons using the NDRE reference and the respective NDRE value of the polygon of interest. The SI values were used with the modified Holland-Shepers sensor algorithm to create a nitrogen (N) prescription map. The parameters used in the algorithm were the same as the parameters used in the SENSE treatments for the respected site. Spatial Management System V. 16.5 (Ag Leader®, Ames, IA) was used to create a file compatible prescription map for the Integra monitor. Applications of the Drone treatments occurred the same day as the SENSE treatments. Drone treatment NDRE values were recorded by the OptRx® sensors during the application of N on the Drone treatment. Aerial imagery was collected over all treatments multiple times throughout the season by the Sequoia sensor.

Initial data analysis was conducted in SAS V. 9.3 (SAS, Cary, NC) using the GLIMMIX procedure. Statistical difference for NDRE and N rate were calculated using an alpha = 0.05. Yield will be used to determine the effect of nitrogen application on production. Yield will be collected and analyzed after harvest is completed.

RESULTS AND DISCUSSION:

Results of treatment averages indicate that NDRE values are greater for the SENSE treatment compared to the Drone treatment by 0.0870. Nitrogen rate on average were lower for the SENSE treatments by 21 lbs acre^{-1} N compared to the Drone treatments. Average results by sites are presented in Table 1 results by replicate are presented in Table 2 and Table 3.

*Table 1: Difference between Drone and SENSE treatment reported for N rate and NDRE values [1]Numbers in this column with * are significantly different at the 95% confidence level (alpha=0.05)*

Difference (Drone - SENSE)		
	N Rate (lbs N $acre^{-1}$)	NDRE
Site 1	-9.8*	-0.15436*
Site 2	39.75*	-0.00703
Site 3	36*	-0.12064*
Site 4	22.6*	-0.05*
All Sites	21	-0.08701*

Table 2: NDRE from SENSE treatments and Drone treatments reported by site and replicate

		SENSE NDRE	Drone NDRE
Site	Replicate	OptRx	Sequoia
Site 1	1	0.3392	0.1833
Site 1	2	0.3296	0.1864
Site 1	3	0.3556	0.1878
Site 1	4	0.3425	0.1994
Site 1	5	0.3551	0.1933
Site 2	1	0.3838	0.3686
Site 2	2	0.3791	0.3737
Site 2	3	0.3920	0.3880
Site 2	4	0.3883	0.3848
Site 3	1	0.3459	0.2169
Site 3	2	0.3302	0.2183
Site 3	3	0.3241	0.2169
Site 3	4	0.3241	0.2122
Site 3	5	0.3385	0.1953
Site 4	1	0.2966	0.2571
Site 4	2	0.2996	0.2582
Site 4	3	0.3203	0.2603
Site 4	4	0.3207	0.2673
Site 4	5	0.3254	0.2697
All Sites		0.3416	0.2546

Table 3: N rate reported by Base Rate and Sidedress rate by SENSE treatment and Drone Treatment

Site	Replicate	SENSE Base Rate	SENSE Sidedress	Drone Base Rate	Drone Sidedress	Timing of Sidedress
		(lb acre⁻¹)				
Site 1	1	130	50	130	49	V11
Site 1	2	130	48	130	44	V11
Site 1	3	130	57	130	44	V11
Site 1	4	130	45	130	30	V11
Site 1	5	130	54	130	38	V11
Site 2	1	75	65	75	120	V11
Site 2	2	75	76	75	105	V11
Site 2	3	75	46	75	87	V11
Site 2	4	75	58	75	92	V11
Site 3	1	39	32	39	66	V11
Site 3	2	39	31	39	64	V11
Site 3	3	39	35	39	63	V11
Site 3	4	39	28	39	65	V11
Site 3	5	39	34	39	82	V11
Site 4	1	101	165	101	176	V11
Site 4	2	101	162	101	173	V11
Site 4	3	101	135	101	177	V11
Site 4	4	101	136	101	156	V11
Site 4	5	101	126	101	155	V11
All Sites		86	73	86	94	V11

When NDRE by treatment is considered with replicate of treatment in mind the NDRE varies greatly. Site 1 and Site 4 were both flown a day in advanced of the application. Site 1 has a larger difference between the SENSE treatments and the Drone treatments with a larger NDRE value from the SENSE treatments Compared to Site 4. Nitrogen rates for Site 1 are lower in each replicate for the Drone treatments compared to the SENSE treatments N rates. This is opposite for Site 4 where NDRE values are closer in relation. Site 4 has a higher N rate in the Drone treatments when compared to the N rates in the SENSE treatments. The time setting when the drone imagery was taken could have effect the NDRE values that were received. Site 4 was imaged around 5:00 pm the day before the application took place compared Site 1 being imaged around 3:00 pm the day before the application took place. Site 2 was imaged 3 days before the application took place and by replicate between treatments has the most similar NDRE values. Site 2 was flown at 10:00 am on a clear and slightly windy day. The field had the most crop biomass, determined by the height of the crop, compared to the other sites when it was imaged. Site 3 was imaged 6 days prior to the application. Weather affected when the application could take place after the field was imaged. The field was imaged when the crop was between the ninth and tenth leaf (V9 – V10) growth stage of the crop. The application occurred when the crop had matured to the eleventh leaf (V11) growth stage. Nitrogen rates for the Drone treatments had larger differences compared to the N rates for the SENSE treatments when the

NDRE were closest in value between treatment types. During the sidedress application Site 2 had the greatest difference between treatment N application rates with the Drone treatments on average receiving 40 lbs acre $^{-1}$ N more than the SENSE treatments. Site 1 had the lowest difference in sidedress rates when comparing treatments and also had the greatest difference in NDRE values between treatments. With the high base rate of 130 lbs acre^{-1} N at site 1 the amount of N need at sidedress would be lower initially compared to other sites. This will play a role in the nitrogen rates being more similar since both systems were using the same algorithm.

CONSLUSION:

Initial comparison of reflectance data concluded that NDRE values between treatments were different. This means reflectance data between passive and active sensors are different based on the average of treatment values. A spatial look could show more variability and possible areas where reflectance data is similar between sensors. Nitrogen rates are different between the SENSE and Drone treatments in relation to the difference of the NDRE values. A closer look at how the sufficiency index might affect these results is needed. Finally yield needs to be collected and analyzed to confirm if one treatment preformed better in either yield or nitrogen use efficiency.

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