USE OF CORN HEIGHT TO IMPROVE THE RELATIONSHIP BETWEEN ACTIVE OPTICAL SENSOR READINGS AND YIELD ESTIMATES

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Abstract

Pre-season and early in-season loss of N continues to be a problem in corn (*Zea mays*, L.). One method to improve nitrogen use efficiency is to fertilize based on in-season crop foliage sensors. The objective of this study was to evaluate two different ground-based, active-optical sensors and explore the use of corn height with sensor readings for improved relationship with corn yield. Two different ground-based active-optical sensors (Greenseeker®, Trimble, Sunnydale, CA; and Holland Crop Circle ACS 470 Sensor®, Holland Scientific, Lincoln, NE) were used within established corn N-rate trials in North Dakota at two different growth stages. A corn height measurement was also recorded the date of sensor data collection. At the 6-leaf growth stage of corn, the Greenseeker® (GS) relationship to yield and the INSEY (in-season estimate of yield) value was improved when the sensor reading was multiplied times corn height. At the 10-12 leaf stage, about 10-14 days later using the GS, the INSEY relationship with yield was also generally increased. The Holland Crop Circle Sensor® (CC) INSEY relationship with yield was increased only at the first sensor date, but not with the second. The second CC sensor INSEY relationship with yield was maximized using sensor reading only.

Splitting the thirteen site data set into the five sites with high clay surface textures (clay or silty clay loam) and the eight sites with a medium texture (loam to sandy loam) improved all INSEY relationships compared to pooling all thirteen sites.

Introduction

Nitrogen use efficiency of corn (*Zea mays*, L) is generally low (Raun and Schepers, 2008). One method of increasing nitrogen use efficiency is in-season detection and fertilization based on reflected/emitted light from corn foliage (Raun and Schepers, 2008). Algorithms to relate expected corn yield with both the Greenseeker® (Trimble, Sunnyvale, CA) and Holland Scientific Crop Circle Sensor® ACS 470 (Holland Scientific, Lincoln, NE) measurements taken early in the growing season have been developed for a number of regions. The Greenseeker® algorithm developed for corn by Raun et al. (2005) related corn yields measured in field experiments with 'in-season estimate of yield' or 'INSEY'. The INSEY number is derived from the Greenseeker® NDVI measurement, divided by number of days with positive growing degree days from the date of planting. The algorithm described by the regression relationship between corn yield and INSEY is then used to vary the rate of N to corn, using an estimate of the difference in corn yield predicted and the corn yield predicted from a nitrogen-rich strip within variety and field of interest, multiplied times the 1.25% N in corn grain estimate divided by a nitrogen fertilizer application efficiency factor.

The Holland Scientific Crop Circle Sensor® algorithms (Holland and Schepers, 2010) also include an estimate of yield based on comparison of sensor readings of an N-enriched strip within the field of interest with an unknown part of the field and information regarding early-season N application or estimates of N release following certain previous crops. Both sensor algorithms used to vary in-season rely on relationships of sensor readings and crop yield.

Crop height has been used to alone and with sensor readings to estimate yield and other harvest parameters. Sugar beet height multiplied times a Greenseeker reading was used in Minnesota to better estimate leaf N concentration, sugar beet top N content and dry matter yield (Franzen et al., 2003). Corn height measured early in the season was also related to final yield (Yin et al., 2011a, Yin et al. 2011b).

There are no published studies that use a combination of corn plant height and sensor readings. The purpose of this study was to explore the combination of corn plant height at two growth stages with either the Greenseeker® sensor reading or the Holland Scientific Crop Circle Sensor® ACS 470 readings.

Materials and Methods

A total of thirteen sites in southeastern North Dakota were used to conduct N rate trials on field corn in 2011. Three sites were located in Sargent County, five in Richland County and five in Cass County. The sites were established within larger farm fields. The experimental area did not receive supplemental N from the cooperator, but were planted by the cooperator and received herbicide applications at their discretion along with the rest of the field. Each field was planted with a corn variety chosen by the farmer for the entire field, so no two sites were planted to the same corn variety. The experimental design at each site was a randomized complete block with four replications and six treatments; check (no added N), 40, 80, 120, 160 and 200 lb N/acre, applied as ammonium nitrate by hand preplant within a week of planting. Individual plot size was 20 feet long by 10 feet wide. An interior row (6-m in length) of the plot was hand harvested, dried to about 10 per cent moisture and then shelled using an Almaco® corn sheller. Moisture at shelling was determined on a grain subsample using a Dickey-John moisture-test weight instrument.

Both Greenseeker® readings (GS) and Holland Scientific Crop Circle Sensor® ACS-470 (CC) readings were obtained when the corn was about 6-leaf stage and again about 10 days to 2 weeks later when the corn reached the 10-12 leaf stage. Readings were taken over the top of the corn whirls on the identical interior row of each plot. The GS measurement consisted of the NDVI measurement (Chung et al., 2008), while the CC measurement was:

(760nm (near infrared) – 730nm (red-edge))/(760nm+730nm)

A tape measure was used to measure corn height from the soil surface to about 5 centimeters above the corn whirl base. The measurement was subjectively taken from an estimate of a ‘typical’ corn plant within the 6-m of row from each plot. Only a single measurement from each plot was used for this comparison.

The GS and CC readings consisted of a mean of between 30-50 individual readings from each plot. Means within a treatment were determined using in-house programs for GS and CC raw data developed for Excel by Franzen (2012). Means for each N treatment of sensor readings and yield were calculated using SAS 9.1 for windows. The value for sensor reading and corn height was calculated using the sensor reading multiplied by the corn height in inches. Regression to show relationships between sensor readings and yield, and sensor/corn height and yield were conducted within Excel, and figures were generated in Excel.

Results and Discussion

The formula for INSEY using either the Greenseeker sensor (GS) or the Crop Circle sensor (CC) is:

INSEY = (sensor reading)/(growing degree days after planting)

The formula for INSEY using either the GS or CC with corn height considered (INSEYH):

INSEYH = INSEY x (corn height inches)

The r^2 values for INSEY using both the GS sensor and the CS sensor were lower at the first reading compared to the r^2 values at the second reading (Table 1) for all sites. Using data from all sites, the GS INSEY relationship was increased using INSEYH (Figure 1). The GS INSEY and INSEYH r^2 at the 6-leaf stage of corn were higher than the CC INSEY and INSEYH. At the 10-12 corn leaf stage, CC INSEY and CC INSEYH were both more highly related to corn yield compared to the GS. The CC INSEY at the 10-12 corn leaf stage had the highest r^2 of any comparison using all sites. Within the scatter diagrams of INSEY with corn yield, there was evidence for the presence of different populations within the data set. Given the independence of yield and crop response (Raun et al., 2010), it is not surprising that different soils would have different sets of crop response to N. For that reason five sites were analyzed separately from the other eight sites based on surface soil texture difference. Five sites consisted of textures with higher clay content than the other eight sites. These five sites were classified as clay or silty clay loam textures (high clay), while the other eight sites were loams to sandy loams (medium).

Within the high clay sites, GS and CC INSEY and INSEYH relationships were similar. There was no advantage of the use of INSEYH over INSEY without the height component. At the second sensor measurement date, the CC held an advantage over the GS measurements (Figure 2). The highest r^2 was for the CC second date INSEY.

Within the medium texture sites, the CC INSEY measurements were higher than their GS INSEY counterparts. However, the relationships using GS INSEYH were similar to CCINSEY and CCINSEYH relationships. The GS benefited more from including a corn height measurement compared to the CC.

The differences in response between the high clay sites and the medium texture sites might be related to early season wetness. In 2011 rainfall totals between April 1 and July 1 were about 10 cm higher than normal, combined with one of the largest snowmelts on record (NDAWN records, online). Most of the high clay sites were saturated with water, but not covered with water for about 6 weeks. Early season denitrification from these locations was likely very high. In contrast, the medium textured soils tended to dry between rains due to better internal drainage and N losses were probably much lower. Differences in denitrification potential may be a reason why these soils needed to be separated in this data set, and why they may need to be separated in the future.

Table 1. Relationship (r2) of INSEY (in-season estimate of yield) and INSEYH (in-season estimate of yield with height component) using the Greenseeker (GS) sensor or the Holland Crop Circle (CC) sensor. INSEY is the sensor reading divided by growing degree days from planting date. INSEYH is the INSEY calculation multiplied times the corn height in centimeters.

	Sensor source	**INSEY**	**INSEYH**
Soil class	**and timing**	**r^2**	
High clay	GS 1*	0.40	0.46
	GS 2	0.44	0.40
	CC 1	0.34	0.38
	CC 2	0.87	0.70
Medium	GS 1	0.25	0.43
	GS 2	0.18	0.35
	CC 1	0.38	0.47
	CC 2	0.39	0.29
All	GS 1	0.14	0.28
	GS 2	0.24	0.33
	CC 1	0.05	0.20
	CC 2	0.64	0.46

* ‘1’ designates readings conducted when corn was about 6-leaf. ‘2’ designates readings conducted 10-14 days after the first reading, when the corn was in the 10-12 leaf stage.

The GS readings at the 6-leaf growth stage of corn were more highly related to corn yield than CC measurements taken at the same growth stage. At the 10-12 leaf growth stage taken about 2 weeks later, the CC measurements held the advantage over all sites and particularly in the high clay soil sites. However, in the medium texture sites, using INSEYH with the GS resulted in a similar relationship to that using the CC.

Conclusions

Including a plant height measurement with Greenseeker NDVI generally increased the relationship between sensor reading and corn yield estimates. Including a corn height measurement with Holland Crop Circle red edge NDVI increased the relationship between the sensor reading and the corn yield estimates at the 6-leaf stage, but not at the 10-12 leaf stage.

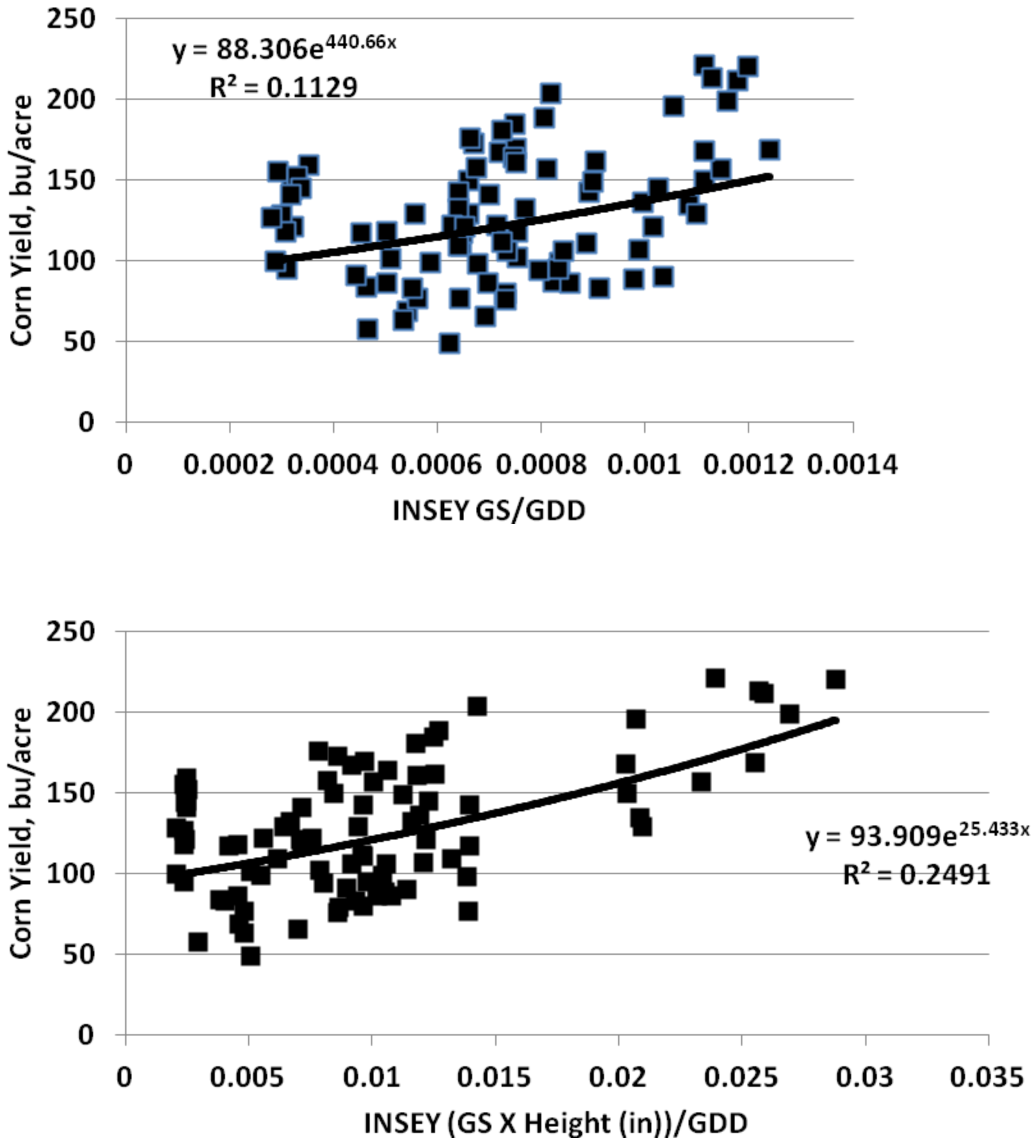
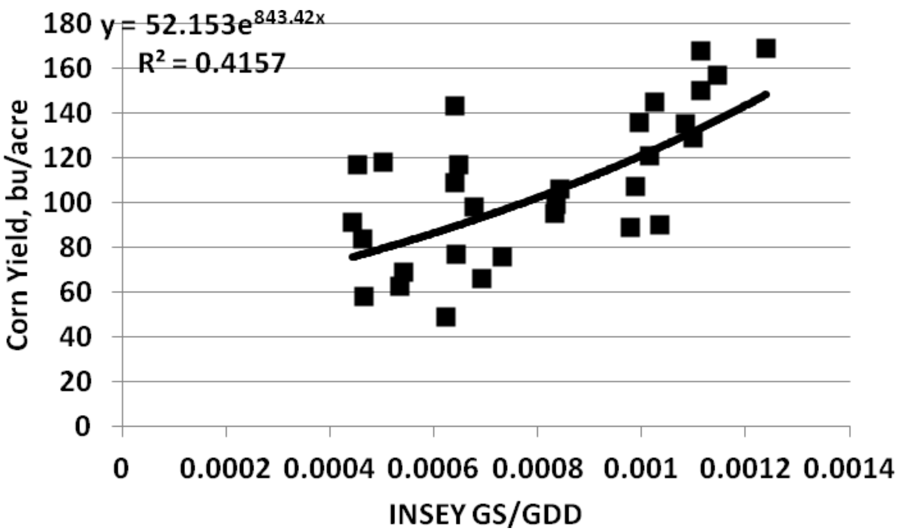


Figure 1. Relationship between GS-INSEY at the 6-leaf growth stage of corn and corn yield (top) using all sites. Relationship between GS-INSEYH at the 6-leaf growth stage of corn and corn yield (bottom) using all sites.



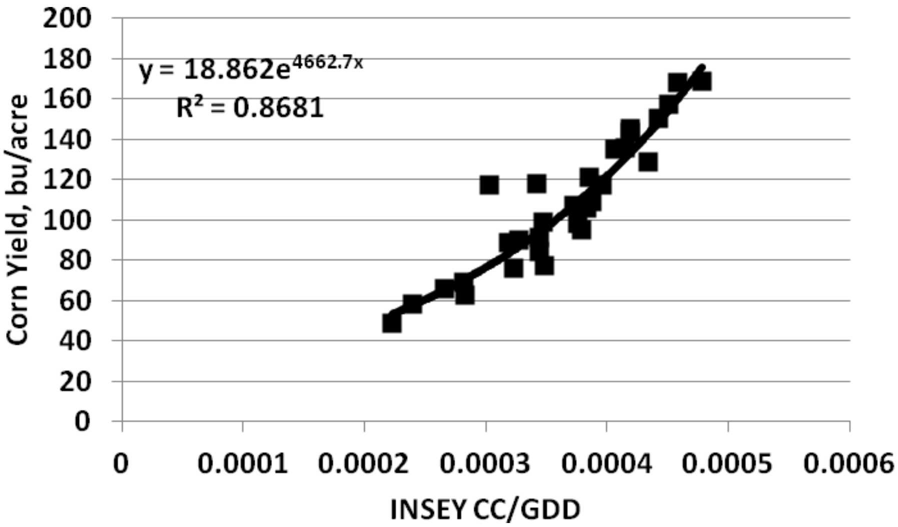


Figure 2. Greenseeker relationship at the 10-12 corn growth stage using INSEY (top) compared to CC at the same growth stage using INSEY (bottom) using high clay soil sites only.

References

Chung, B., K. Girma, K.L. Marin, B.S. Tubana, D.B. Arnall, O. Walsh and W.R. Raun. 2008. Determination of optimum resolution for predicting corn grain yield using sensor measurements. Archives of Agronomy and Soil Science. 54:481-491.

Franzen, M. 2012. Program for initial analysis of Greenseeker and Holland Crop Circle Sensor raw data within Excel. Unpublished program. Fargo, ND.

Franzen, D.W., G. Wagner, and A. Sims. 2003. Application of a ground-based sensor to determine N credits from sugarbeet. *In* p. 119-123. 2003 Sugarbeet Research and Extension

Reports. Vol. 34. Sugarbeet Research and Education Board of Minnesota and North Dakota. Fargo, ND.
Holland, K.H., and J.S. Schepers. 2010. Derivation of a variable rate nitrogen application method for in-season fertilization of corn. Agronomy Journal 102:1415-1424.
Raun, W.R. and J.S. Schepers. 2008. Nitrogen management for improved efficiency. p. 675-694. In Nitrogen in Agricultural Systems. Agronomy Monograph No. 50. J.S. Schepers and W.R. Raun, eds. ASA-CSSA-SSSA, Madison, WI.
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. Communications in Soil Science and Plant Analysis. 36:2759-2781.
Raun, W.R., J.B. Solie, and M.L. Stone. 2010. Independence of yield potential and crop nitrogen response. Precision Agriculture Journal DOI 10.1007/s11119-010-9196. Published on-line.
Yin, X., N. Jaja, and M. A. McClure. 2011a. Comparison of models in assessing relationship of corn yield with plant height measured during early- to mid-season. Journal of Agricultural Science 3:14-24.
Yin, X., A. McClure, N. Jaja, D.D. Tyler, and R.M. Hayes. 2011b. In-season prediction of corn yield using plant height under major production systems. Agronomy Journal 103:923-929.

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