Using Active Sensors to Refine Nitrogen Rates in Corn

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The cost of nitrogen fertilizer has been increasing rapidly in recent years (NASS, 2006). Some producers are paying as much as $750 per ton for anhydrous ammonia for the spring of 2008. The old practice of adding insurance nitrogen to ensure good yields is now economically, as well as environmentally, unwise. Many producers are interested in fine-tuning their nitrogen rates and are looking to results from nitrogen rate trials for guidance. Recent trials in Indiana, however, demonstrate how variable grain yield response to nitrogen fertilizer can be, with economically optimum nitrogen rates for corn following soybeans varying from less than 100 pounds per acre to more than 200 pounds of nitrogen per acre. A summary of the field scale nitrogen trials for Indiana can be found at http://www.agry.purdue.edu/ext/corn/news/articles.07/NMgmtUpdate-1206.pdf. Although an accurate average recommendation is a step in the right direction, better recommendations would be field, cropping system and growing season specific. This paper summarizes recent research done in Indiana with an active sensor and examines the possibilities this technology may hold for N management strategies.

The potential solution to field specific nitrogen recommendations we chose to investigate involves the use of light emitting diodes and optical sensors that provide an indirect measurement of the nitrogen status of the corn crop. The amount of light reflected back to the sensor is determined by the size and greenness of the corn canopy which is related to nitrogen status. Greater leaf area results in more near-infrared light (NIR) being reflected back to the sensor while greener tissue contains more light absorbing chlorophyll which results in less visible light being reflected back to the sensor (Blackmer et al., 1994). The relative nitrogen status of the crop can be quantified by comparing the reflectance of the whole field to reflectance from an area of the field known to be adequate in nitrogen (usually referred to as the ‘reference strip’). It is hoped that the level of nitrogen deficiency detected by the sensor will be correlated with the rate of supplemental nitrogen fertilization needed to attain optimum economic corn yield.

The objectives of our research were to determine the relationship between chlorophyll meter readings, canopy reflectance and yield and whether these relationships could be used to determine optimum nitrogen fertilization rate. Assessing the effects of delayed nitrogen application on yield was another objective of our work.

MATERIALS AND METHODS

In 2006 and 2007 field scale experiments (12 rows by 300-900 feet long treatment plots) were conducted at seven Purdue University research farms throughout the state of Indiana (Table 1). A single hybrid was used each year, Pioneer 34A19 in 2006 and 34A20 in 2007. The two hybrids vary only in the addition of the Roundup Ready gene in 2007. All 2006 locations were corn grown after soybean (CS). In 2007 experiments were both CS and corn grown after corn (CC). Sidedress nitrogen treatments were applied at growth stage V3-V5 with urea ammonium nitrate solution (28% UAN) incorporated into the row middle. Sidedress nitrogen rate treatments ranged from 0 to approximately 200 lb N/acre in 40 or 50 lb N/acre increments. Most studies had additional small amounts of nitrogen applied preplant or at planting.

Table 1. Location and details of N rate trials conducted throughout Indiana during the 2006 and 2007 growing seasons.

Location	Soil Type[1]	O.M.[2]	Starter	Rotation[3]	AONR[4]	Yield
		%	lb N/acre		lb/acre	Bu/acre
Butlerville-2006	Cobbsfork SiL	1.2	25	CS	146	163
Columbia City-2006	Rawson SiL, Haskins L	1.8	24	CS	237	197
Farmland-2006	Blount SiL, Pewamo SiCL	3.1	0	CS	215	173
Fowler- 2006	Chalmers SiCL	4.4	0	CS	**	197
	TorontoSiL	3.5	0		**	196
	Wingate SiL	3.2	0		**	189
Vincennes-2006	Ade LFS, Lyles FSL	1.3	18	CS	217	123
Wanatah-2006	Sebewa L	2.9	24	CS	146	210
West Lafayette-2006	Chalmers SiCL, Raub SiL	2.9-4.1	22	CS	162	207
Butlerville-2007	Cobbsfork SiL	2.3	25	CS	142	178
		1.8	25	CC	144	139
Columbia City-2007	Rawson SL, Haskins L	1.8	29	CS	204	211
		1.8	18	CC	221	187
Farmland-2007	Blount SiL, Pewamo SiCL, Glynwood SiL	3.4	26	CS	160	145
		2.9	26	CC	206	114
Romney-2007	Toronto Millbrook, Drummer	3.0	21	CS	116	188
Vincennes-2007	Ade L fine S	1.3	18	Melon/rye	>250	178
Wanatah-2007	Sebewa L	2.9	24	CS	158	176
		2.9	24	CC	221	191
West Lafayette-2007	Chalmers SiCL, Raub SiL	2.9-4.1	22	CS	130	179
		2.9-4.1	22	CC	170	166
Romney*	Throckmorton SiL	2.9	21	CC	238	122
Wanatah*	Sebewa L	2.9	24	CS	175	196
West Lafayette*	Rockfield SiL	1.6-2.1	36	CC	205	142

1.Si refers to Silt, S is sand, C is clay, example: FSL is Fine Sandy Loam, SiCL is Silty Clay Loam
2. O.M. refers to Organic Matter.
3. CS is Corn planted following soybeans and CC is corn after corn.
4. AONR or Agronomic Optimum N rate is the N rate that will produce the maximum yield
* Locations featured delayed N applications. For more information see Table 2.
** AONR was not determined for this location because the number of N rates was too small to establish a response curve.

In 2007 an additional experiment was established at 3 locations to examine the effects of delayed nitrogen fertilizer application on grain yield. This experiment consisted of 3 treatments; a conventional sidedress nitrogen application at V3-V5, a nitrogen application delayed until V12, and 100 pounds of nitrogen per acre applied at planting plus a delayed application at V12. Sidedressed and delayed nitrogen application consisted of 7 nitrogen rates varying from 0 to 205 lb N/acre in 35 lb N/acre increments.

Several measurements were made during the growing season with a chlorophyll meter (Minolta SPAD 502), and at a single time with a Holland Scientific ACS 210 Crop Circle active sensor. There is another brand of sensor available from NTech industries called the

GreenSeeker. These two sensors are similar in concept but vary in the wavelengths used and optical footprint.

At approximate growth stage V12 two Crop Circle sensors were mounted on high clearance equipment and driven through the field. The sensors were positioned directly over the rows being sampled. Chlorophyll index [(NIR/VIS) - 1] (Gitelson et al., 2003) was calculated for all canopy reflectance readings and a SPAD reading of the most recently expanded leaf was taken within 2 days of the reflectance measurements. The earleaf was obtained at silking and total nitrogen determined. The middle 6 rows of each field scale plot were harvested while only 2 rows were harvested from the smaller delayed N application study. Grain moisture and yield were collected using a calibrated yield monitor and/or weigh wagon. Yield, chlorophyll index and SPAD readings were all evaluated on a relative basis-the value of each treatment divided by the value obtained with the highest N rate.

RESULTS AND DISCUSSION

By locating plots throughout the state we were able to evaluate the capabilities of the sensor across many growing environments. Data were gathered from 21 replicated trials over 2 years from both CC and CS rotations. A variety of soil types were included and maximum yields at each location ranged from 114 to 211 bu/acre (Table 1). Agronomic optimum N rates ranged from 116 to >250 lb/acre (Table 1).

Chlorophyll Meters and Canopy Reflectance

Relative SPAD and relative chlorophyll index had a high correlation across different soil types, cropping systems and growing seasons (Fig. 1). Although both tools indirectly measure chlorophyll concentration, the relationship was not certain because the SPAD reading is a measure of leaf transmittance on the newest expanded leaf and the sensor measures reflectance from the upper canopy. The wavelengths used to obtain the readings are also slightly different (590 and 880nm for the Crop Circle and 650 and 950 nm for the SPAD meter).

Canopy Reflectance and Yield

Relative chlorophyll index at approximate growth stage V12 was strongly correlated with relative yield (Fig. 2). This relationship takes into account two growing seasons, a wide range of soil types, and CC and CS rotations. By predicting relative yield we may be able to anticipate the plants' N requirement and fine-tune N recommendations late in the season and/or on the go. However, little research has been conducted to examine the effects of delayed N applications on corn yield under rainfed conditions in the eastern Corn Belt and this information is critical to evaluate this strategy of late season sensing to determine supplemental N application.

Delayed Nitrogen Application

Three experiments were conducted in 2007 to determine the effects of delayed nitrogen application on grain yield (Table 2). Unfortunately grain yield was severely reduced by delayed N application in this past growing season, in comparison to a pre-plant or traditional side-dress N application. The late N was not applied until the first week of July which coincided with a dry period in Indiana. At the West Lafayette site it was 3 weeks before any rainfall event totaled more than 0.1 inches. The Wanatah location received 0.3 inches the week after application and

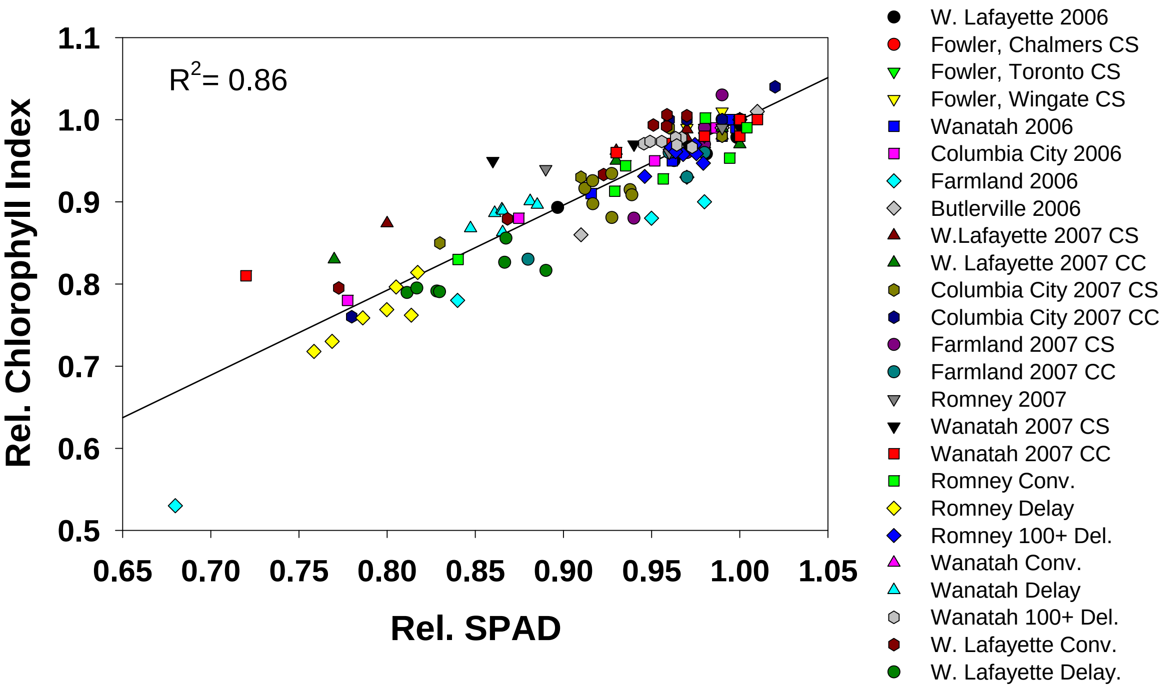

Figure 1. Relative SPAD reading and relative Crop Circle chlorophyll index were highly correlated across 21 experiments throughout Indiana during the 2006 and 2007 growing seasons.

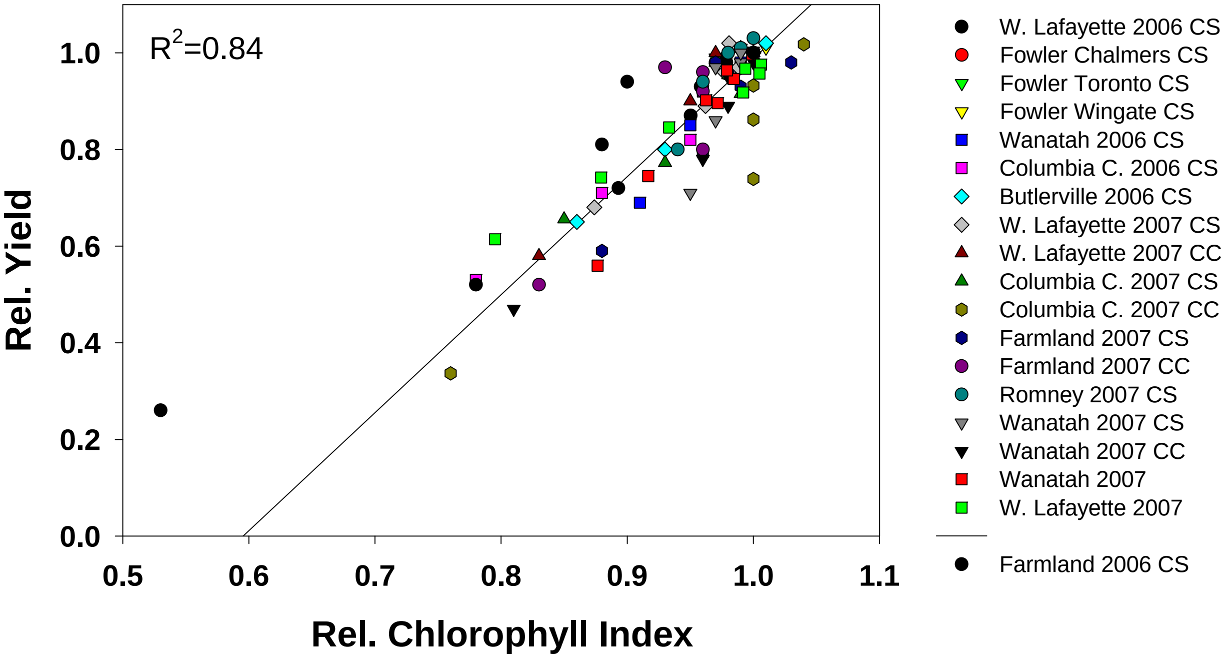

Figure 2. Relative yield and the relative chlorophyll index at approximate growth stage V12 are strongly related across 18 experiments. Note: data from Farmland 2006 was excluded from this analysis.

again the following week. Two weeks passed after the N application before any rain fell at the Romney location. At this location the precipitation total was 2 inches below normal for the month of July. This left the UAN on the soil surface where it was unavailable to the plant and prone to loss from volatilization. Precipitation of 0.5 inches would have been ideal for moving the N into the rootzone. Some commercial applicators have toolbars capable of injecting UAN behind a coulter in tall corn. In this situation N would be safely beneath the soil surface and available to the plant, but root injury could occur from the coulters. Avoiding plant stress and getting N into the rootzone are two large challenges for late applied N in rainfed corn production in the eastern Corn Belt.

Table 2. Location and details for delayed nitrogen application trials in 2007 growing season.

Location	**Predicted Max yield for Std. Sidedress**	**Yield Difference**	
		Delay	100 + Delay
	---bu/acre---		
Romney	122	-17	+8
Wanatah	196	-21	-8
West Lafayette	142	-8	+4

Nitrogen Management

After harvesting the delayed N studies, results show that delaying application of N when N deficiency is great can reduce yield. While the crop still responded to the late applied N, previous stress was too severe for full yield to be achieved. A more practical solution may be to make a sidedress application at a slightly reduced rate and use the sensor at growth stage V10-12 to ensure that the plant has an adequate amount of N. This approach could reduce N use as well as limit the chances of N deficiency and yield loss. In 2007 when 100 lb/acre was applied at planting and additional N was added in July, yields at each of the 3 sites were closer to yields obtained with traditional sidedressing.

CONCLUSIONS

The relative chlorophyll index of the upper canopy measured with a sensor was closely related to relative chlorophyll meter readings on the most recently expanded leaf, and grain yield. Relative chlorophyll index accurately predicted relative yield across a diverse range of environments, soil types, and yield levels in both corn-corn and corn-soybean rotations. Our research shows that active sensors can be effective at measuring differences in the N status of corn. However, data from the delayed N experiments show that yield potential was lost when delaying N application in a dry year. More research is needed to more fully explore the potential of sensor based recommendations and to examine alternative strategies for using the sensor to make delayed N applications.

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