Active Crop Canopy Sensors

Robert W. Mullen
School of Environment and Natural Resources, Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691

Abstract

Active crop sensor usage for managing crop nitrogen inputs has been an area of intense research over the last decade. The question on the minds of producers, consultants, and policymakers is how well does the technology function in the field? And is it robust enough for commercial usage? The goal of this proceedings article and subsequent presentation and panel discussion is to provide a little background on current approaches, research successes and failures, and commercial prospects and challenges for crop sensor technology.

Current Approaches

From an engineering perspective, sensor technology potential for managing crop nitrogen (N) inputs has already been realized. Several active sensors exist to accurately and rapidly measure crop canopy reflectance. This includes GreenSeeker (NTech/Trimble), Crop Circle or OptRx (Holland Scientific/AgLeader), and CropSpec (TopCon). While these competing sensor technologies are similar in concept, there are differences. The biggest differences between the three sensor systems is the wavelengths of light used and the size of the target area from which reflectance information is collected. While each has its merits and drawbacks, they will not be discussed in detail here. Even with advancements in our ability to rapidly measure crop canopy reflectance, variable rate application does have limitations due to current fluid control systems on agricultural sprayers. Thus, even from an engineering perspective, there are areas of further advancement.

The ability to accurately, reliably, and rapidly measure crop reflectance is a technological achievement, but the translation of that information into an actual decision (in this case nitrogen rate) is the real challenge. There are agronomic realities that researchers have to face with regard to the measurement of sensor information, the need for a field calibration to accurately estimate N responsiveness, and crop nitrogen uptake patterns.

Current active sensors have limitations. Sensor information cannot be collected until an adequate amount of biomass has been accumulated. Each sensor has its own limitation with regard to how early reflectance information can be captured. Boom-mounted sensors would, by necessity, have to be used at later growth stages to capture reliable information about the plant, because the sensor is mounted right over the row. Small plants mean very little biomass to detect from a nadir position. Cab-mounted sensors that are further away and view the canopy from a side view could be used at earlier growth stages because the sensor is located at an off-nadir position and less influenced by soil reflectance.

Multiple confounding factors can influence crop performance throughout the growing season (water stress, temperature stress, disease stress, insect stress, other nutrient stresses, etc.); thus, assuming poor crop performance due solely to inadequate nitrogen is a naïve assumption. This reveals the need for reference strips as an in-field comparison to determine nitrogen responsiveness. Current algorithms differ, but the one constant is the need for a nitrogen reference strip in each field. Some have even proposed the use of a zero N reference to more accurately measure true N responsiveness (Mullen et al., 2007). Additional research has been conducted to derive pseudo estimates of N responsiveness in the absence of N reference strips (Kitchen et al., 2010a).

In addition to the fact that sensors cannot be utilized early in the growing season, agronomically speaking, crop nitrogen uptake has not occurred to a great extent prior to V7-V8 (Ritchie et al., 1997; Figure 1). Since the goal of canopy reflectance sensors is to assess crop nitrogen uptake and react to crop demand, collection of early season information does not make sense because the crop has not accumulated much nitrogen from the soil. This makes it difficult to measure differences in N accumulation early in the growing season. Identification of N response, even at later growth stages, can also be influenced by previous crop. Corn after corn is much more likely to exhibit earlier season N responsiveness than corn after soybean. It is imperative to delay sidedress N application to capture a better estimate of N demand. It is important to point out that N stress, even at early growth stage (prior to V8), can result in irrecoverable yield losses (Diedrick, 2010). Inclusion of early season N is critical to ensure the crop does not experience significant N stress.

Research Successes and Failures

Several peer-reviewed journal publications have been generated as a result of the research activity in this arena (Kitchen et al., 2010b; Raun et al., 2005; Roberts et al., 2010; Varvel et al., 2007). For ease of discussion I will only discuss what has been accomplished in Ohio with our current algorithm research program.

Ohio State University has been evaluating a variant of the Oklahoma State University yield potential algorithm (Raun et al., 2005) and the University of Missouri sufficiency-based algorithm (Kitchen et al., 2010b). A summary of field research conducted over the last 4 years reveals that our algorithm is performing relatively well, but it is not perfect (Table 1). There are environments where the algorithm may under- or overestimate N rate, and that is to be expected because N responsiveness can change after sensing and subsequent N application. The goal of our algorithm is to minimize the times that it underestimates optimum N rates to minimize the risk of yield loss to the producer.

Commercial Prospects and Challenges

While the potential certainly exists to utilize existing sensor-based technology today, there are agronomic and cultural hurdles to overcome to achieve widespread adoption. The first major challenge for much of the Corn Belt is to move to more sidedress application of N. Logistically speaking, this will be a challenge for retailers that service thousands of acres during a growing season. Not only do producers have to move from preplant N to sidedress, they need to move to later season sidedress N applications (approaching V8 or later). For much of the Corn Belt this is going to be a major challenge. Establishment of N reference strips (possibly including zero N references) is another cultural hurdle.

References

Diedrick, K.A. 2010. Field investigations of nitrogen fertility on corn. Ph.D. diss. Ohio State University, Columbus, OH.

Kitchen, N.R., K.A. Sudduth, and S.T. Drummond. 2010a. Is a nitrogen-rich reference needed for canopy sensor-based corn nitrogen applications? International Conference on Precision Agriculture, Denver, CO.

Kitchen, N.R., K.A. Sudduth, S.T. Drummond, P.C. Scharf, H.L. Palm, D.F. Roberts, and E.D. Vories. 2010b. Ground-based canopy reflectance sensing for variable-rate nitrogen corn fertilization. Agronomy Journal 102:71-84.

Mengel, D. 1995. Roots, growth, and nutrient uptake. AGRY#95-08.Purdue University Department of Agronomy. West Lafayette, IN.

Mullen, R.W., N.R. Kitchen, W.R. Raun, J.S. Schepers, W.E. Thomason, S.B. Phillips, and D.B. Mengel. 2007. Optical sensor based corn algorithm evaluation. *In* Agronomy Abstracts.ASA, 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.

Ritchie, S.W., J.J. Hanway, and G.O. Benson. 1997. How a corn plant develops. Spec. Publ. 48. Iowa State University, Coop. Ext. Serv., Ames, IA.

Roberts, D.F., N.R. Kitchen, P.C. Scharf, and K.A. Sudduth. 2010. Will variable-rate nitrogen fertilization using corn canopy reflectance sensing deliver environmental benefits? Agronomy Journal 102:85-95.

Varvel, G.E., W.W. Wilhelm, J.F. Shanahan, and J.S. Schepers. 2007. An algorithm for corn nitrogen recommendations using a chlorophyll meter based sufficiency index. Agronomy Journal 99:701-706.

Table 1. Performance of the Ohio State University algorithm across 11 site years at three locations in Ohio.

Location/year	EONR*, lb N/A	Yield @ EONR, bu/A	Algorithm rec, lb N/A	Yield @ algo rec, lb N/A	Control yield†, bu/A
Northwest 2006	180	195	36	119	173
Western 2006	86	227	105	227	227
Wooster 2006	27	96	36	96	105
Northwest 2007	67	164	70	164	172
Western 2007	0	195	42	195	181
Wooster 2007	124	184	200	185	200
Western 2008	84	180	159	180	200
Wooster 2008	130	174	147	166	177
Northwest 2009	113	174	36	161	181
Western 2009	122	219	63	204	215
Wooster 2009	26	209	50	209	227

*-determined by applying quadratic plateau regression model and only applies to sidedress N. All plots received 40 lbs N/A as a starter with the planter. Economic optimum N rate (EONR) determined based upon a corn price:N cost ratio of 10.

†-denotes yield achieved by applying 200 lbs N/A as a preplant broadcast application of ammonium nitrate.

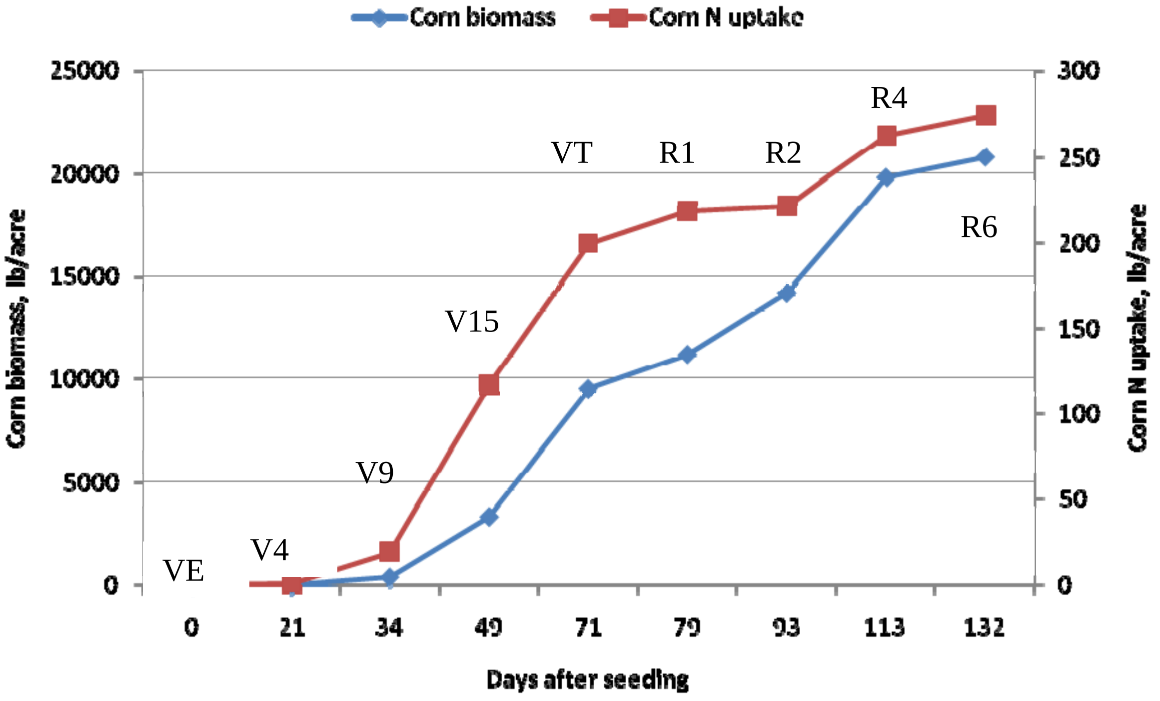

Figure 1. Corn biomass accumulation and N uptake as a function of days after seeding and growth stage (Mengel, 1995).

PROCEEDINGS OF THE

40th
NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 26

November 17-18, 2010
Holiday Inn Airport
Des Moines, IA

Program Chair:
Richard Ferguson
University of Nebraska - Lincoln
Lincoln, NE 68583
(402) 472-1144
rferguson@unl.edu

Published by:
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net