CROP SENSOR-BASED N RATES OUT-PERFORMED PRODUCER-CHOSEN N RATES

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Abstract

Optimal N fertilizer rate for corn (Zea mays L.) and other crops can vary substantially within and among fields. Current N management practices do not address this variability. Crop reflectance sensors offer the potential to diagnose crop N need and control N application rates at a fine spatial scale. Our objective was to evaluate the performance of sensor-based variable-rate N applications to corn, relative to constant N rates chosen by the producer. Fifty-five replicated on-farm demonstrations were conducted from 2004 to 2008. Sensors were installed on the producer's N application equipment and used to direct variable-rate sidedress N applications to corn at growth stages ranging from V6 to V16. A fixed N rate chosen by the cooperating producer was also applied. Relative to the producer's N rate, sensors increased partial profit by \$17/acre (P = 0.0007) and yield by 2 bushels/acre (P = 0.18) while reducing N use by 14 lb N/acre (P = 0.015). This represents a reduction of approximately 25% in the amount of N applied beyond what was removed in the grain, thus reducing unused N that can move to water or air. Our results confirm that sensors can choose N rates for corn that perform better than rates chosen by producers.

Materials and Methods

Fifty-five on-farm demonstrations were conducted from 2004 to 2008. These demonstrations were distributed widely across the corn-growing regions of Missouri (Fig. 1). Cooperating producers were chosen based on their interest in the technology and availability of sidedress/topdress equipment with an appropriate controller.

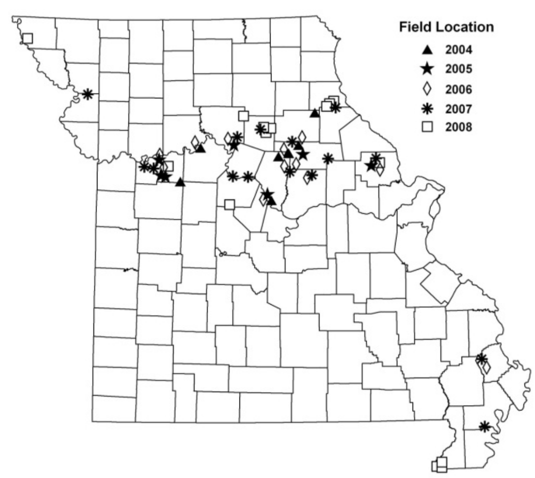


Figure 1. Locations of demonstration fields comparing N rates chosen by producers with variable-rate N controlled by reflectance sensors.

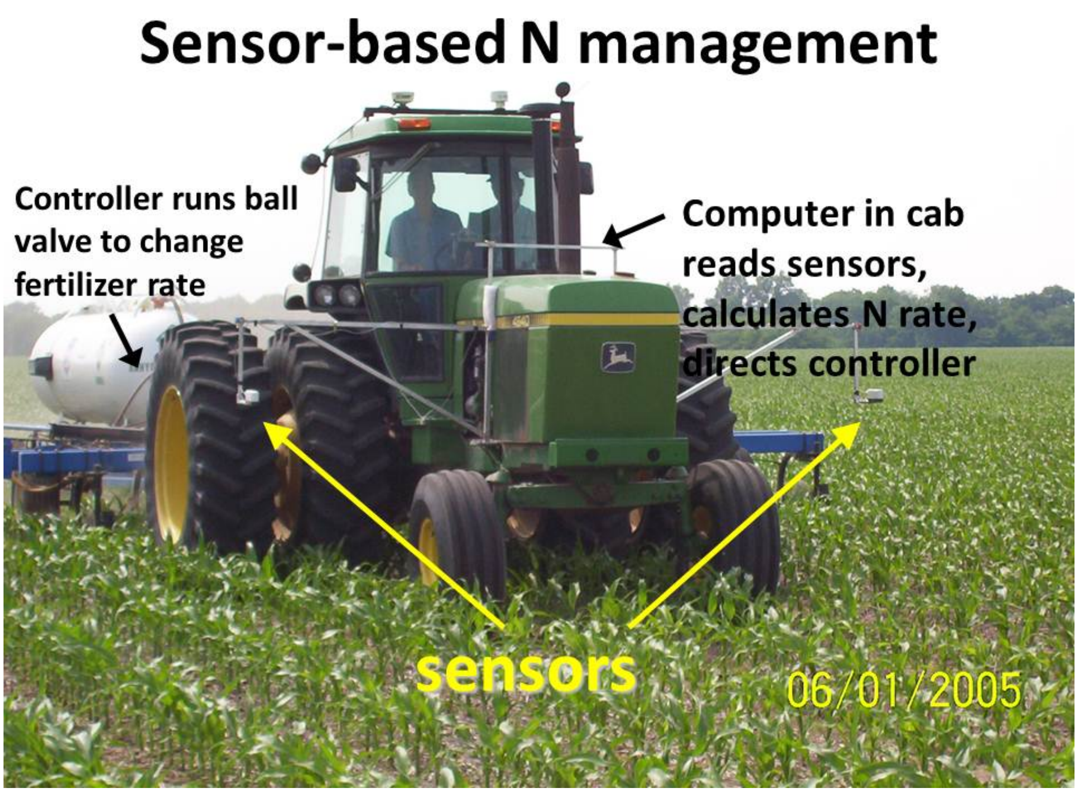
Preplant N rate was chosen by the cooperating producer and varied from 0 to 150 lb N/acre, with an average value of 45 lb N/acre.

High-N reference areas were created in all demonstration fields between 4 and 8 weeks before sidedress N application. Some reference areas were field-length strips, while others were small areas in which the N was applied by hand. Usually the N rate in these reference areas was 200 lb N/acre.

Nitrogen was applied in 19 of the fields as dribbled urea-ammonium nitrate (UAN) solution with a Spra-Coupe sprayer that we transported to the field. This applicator was set up to apply N only to 6 rows (15 feet). In 36 of the fields, nitrogen was applied with an applicator owned by the producer or their fertilizer dealer. Among these, nitrogen was applied as injected UAN solution in 19 fields, dribbled UAN solution in 10 fields, injected anhydrous ammonia in 5 fields, and broadcast urea in 2 fields.

There were two treatments common to all 55 demonstration fields: an N rate chosen by the producer, and a variable-rate treatment based on canopy reflectance sensors. These treatments were replicated in a complete block design a minimum of 3 times in each field, and up to 15 times in some fields. The average number of replications was 5.6. Plots were field length (average 1450 feet) and one applicator width wide (average 35 feet).

Two or three crop canopy reflectance sensors were installed on the N application equipment and used to direct variable-rate sidedress N applications to corn at growth stages ranging from V6 to V16 (average V9). Sensors were positioned on the front of the applicator and directly over the corn row at a height of 20 inches above the canopy.



Two types of crop reflectance sensor were used: Crop Circle 210 (Holland Scientific) and Greenseeker (Trimble). Nitrogen rate equations were different for each sensor and also were different for different growth stages. Equations used are available at:
http://www.mo.nrcs.usda.gov/technical/agronomy/out/Agronomy%20Technical%20Note%20MO-35.pdf

Average reflectance value was first measured from the high-N reference area, and this value was used in the equation used to control N rate in the sensor treatments. Custom software was used to compile and average sensor values, discard readings from bare soil, and calculate N rate based on the above equations.

Results

Averaged over all 55 fields, sensors reduced N use by an average of 14 lb N/acre and increased yield by an average of 2 bushels/acre. Average yield was 158 bushels/acre when N rates were variable and based on reflectance sensor measurements of the canopy. With $5/bushel corn and $0.60/lb N, this came to an average economic benefit of $17/acre.

Outcomes in 2008 were different than during 2004-2007 due to widespread and extensive rainfall during the spring of 2008. Eleven of 14 fields received more than 16 inches of rain from April through June 2008. In this wet year, when soil and preplant fertilizer N were likely lost prior to the sidedress N applications, N rates based on reflectance sensors averaged 15 lb N/acre more than N rates chosen by producers, and yields were 8 bushels/acre higher.

By contrast, N rates based on reflectance sensors were 24 lb N/acre less than rates chosen by producers for the period 2004-2007, with 0 bushels/acre yield difference between the two treatments.

In all years, there were individual fields where the average N rate based on sensors was higher than the N rate chosen by the producer, and there were individual fields where the average N rate based on sensors was lower than the N rate chosen by the producer.

The sensor interpretations that we used produced, on average, N rate decisions that were economically superior to the rates chosen by the producer both when they recommended more N and when they recommended less N than the producer's rate.

Profitability of sensor use to determine N rate was also not affected by the growth stage of the corn from V6 to V16.

Less of the applied N was unused when sensors were used to guide N rates. Total N applied minus estimated N removed in grain was 58 lb N/acre with N rates chosen by producers and 40 lb N/acre when N rates were based on sensors, a 26% reduction.

Other Lessons Learned

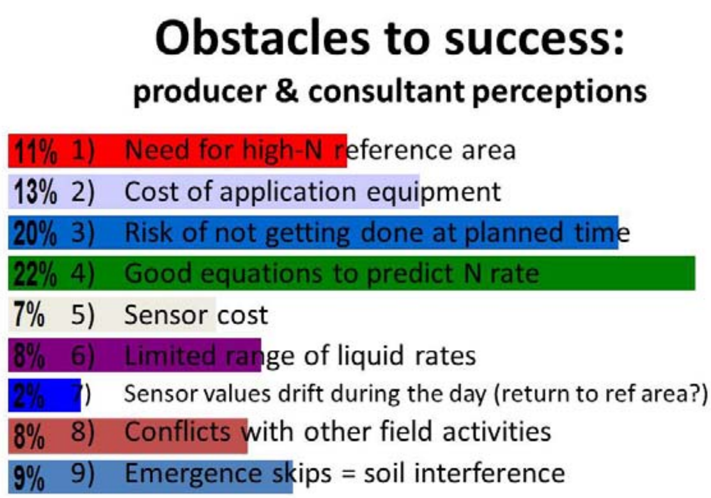
We had several demonstration fields that were not successful for reasons apparent at the time of the demonstration:

- High-N reference area applied less than 2 weeks before sensing/fertilization (5 fields)
- Corn V4 or V5 (2 fields)
- Weeds large and dense and sprayed with Roundup a week or so before sensing/fertilization (weeds not dead yet) (2 fields)

These fields are not included in the 55 fields described above. In none of these fields did the sensor-based N treatment out-perform the producer-chosen N rate.

We also discovered that sensor values change from morning to night when we stopped halfway through a field at nightfall. Nitrogen rates the next morning were considerably lower than they had been the evening before. Dew on the leaves probably contributed to this observation, and re-reading the high-N reference would have probably corrected for this effect. More detailed study subsequently revealed that sensor values tend to gradually drift, that Greenseeker sensor measurements changed much more (and in a predictable way) during the course of a day than Crop Circle or Cropscan sensors, and that dew or water sprayed on leaves results in higher NDVI readings. We now recommend re-measuring the reflectance value of the high-N reference area every two hours for Crop Circle (probably also would apply to OptRx) or Cropscan sensors, and every one hour for Greenseeker sensors. Greenseeker personnel have recently said that this problem is fixed but that they can't reveal how. Independent verification is needed for this claim.

Sensor interpretations still vary widely from source to source. Some of these differences probably appropriately reflect regional differences in production of corn (and other crops). It is likely that some differences reflect imperfections in research approach or size of the supporting dataset. Additional effort is needed to optimize and evaluate the equations used to translate sensor values to N rates. The new interpretations for OptRx sensors introduced with the Integra display seem to give especially high N rates. At a meeting of cooperating producers, consultants, retailers, and Extension and NRCS personnel, this was identified as the biggest obstacle to success for sensor-based variable-rate N using a 'clicker' survey.



Risk of not getting done at the planned time was identified as the second-biggest concern in this survey. We never failed to complete a planned demonstration of sensor-based N application, but we were usually doing the last field or two for each cooperating producer. Doing all of a producer's fields would require excellent logistics, especially if the plan is to do all N applications with tractor-based applicators. Availability of high-clearance N applicators, or prioritization of only some fields to receive sensor-based N applications, would reduce this risk.

We found that it is difficult to get a wide range of N rates for UAN with standard application equipment. Addition of spring-loaded nozzle bodies such as Veriflow made it much easier to achieve a wide range of N rates.

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