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Sensor-based nitrogen applications out-performed producer-chosen rates for corn in on-farm demonstrations

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Abstract. *Optimal nitrogen fertilizer rate for corn 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 $42 ha-1 (P = 0.0007) and yield by 110 kg ha-1 (P = 0.18) while reducing N use by 16 kg N ha-1 (P = 0.015). This represents a 24 to 26% reduction 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.*

Keywords. *EONR (economically optimal nitrogen rate), canopy sensor, reflectance sensor, spatial variability, variable-rate nitrogen application.*

Economically optimal nitrogen (N) fertilizer rate (EONR) for corn (*Zea mays* L.) and other crops can vary substantially within fields (Schmidt et al., 2002; Mamo et al., 2003; Scharf et al., 2005; Kitchen et al., 2010). Lighter leaf color indicates need for a larger amount of N fertilizer across a range of measurement platforms (Scharf and Lory, 2002; Scharf et al., 2006; Scharf and Lory, 2009). Canopy reflectance sensors offer the opportunity to translate this concept into a practical management tool to optimize N fertilizer rate across landscapes for corn and other crops.

Methods

55 experiments were carried out from 2004 to 2008 on commercial farms in Missouri, U.S.A. Elements in common over all 55 experiments include:

1. A producer-chosen N fertilizer rate was compared with variable-rate N application based on crop canopy sensors.
2. Variable-rate N application was carried out in real time based on crop canopy reflectance readings, with fertilizer rates adjusted each second.
3. On each farm, only one N fertilizer source and one N fertilizer timing were used for these two treatments.
4. At least three replications were used, with an average of 5.6 replications.
5. A high-N reference area was established at least 4 weeks prior to sensing and fertilization.
6. A reference reflectance value from this high-N area was measured before variable-rate N application, and used in the equation for calculating N rate.

Urea-ammonium nitrate solution (either injected or dribbled) was used as the N source in more than half of the experiments; broadcast urea was also used as the N source in some experiments, and injected anhydrous ammonia in others. Time of application ranged from stage V6 to stage V16. Average plot length was 450 m, and average plot width was 10.7 m.

Crop Circle ACS-210 sensors were used in most experiments (Figure 1), but Greenseeker 505 sensors were also used in some experiments. Equations used to translate reflectance measurements to N fertilizer rates are given in Scharf et al. (2011). System N efficiency was defined as nitrogen removed in grain divided by nitrogen applied as fertilizer and manure. Partial profit was defined as (grain yield x grain price) – (N rate x N price). Other experimental methods not given here can also be found in this reference.

Figure 1. Crop Circle ACS-210 sensors on dry fertilizer spreader, variably applying N based on crop color.

Results

Average N fertilizer rate chosen by the producer was 194 kg N ha^{-1} over the 55 on-farm experiments. This includes estimated manure-N contributions. Average N fertilizer rate when using crop sensors to control variable-rate N application was 178 kg N ha^{-1}, a reduction of 16 kg N ha^{-1} ($p = 0.015$).

Reducing N rate usually increases N efficiency, but sometimes at the cost of yield. In these 55 fields, the evidence was that this reduction in N rate was accompanied by, if anything, an increase in yield. Yield with sensor-based N rate was 110 kg ha^{-1} higher ($p = 0.18$) than with the N rates chosen by producers. Although this is weak evidence, it is corroborated by weather and individual-year analyses. 2008 was a wet year, resulting in loss of soil N and preplant N. It is also the only year in which sensor-based N rates exceeded producer-chosen N rates, resulting in 526 kg ha^{-1} higher ($p = 0.007$) yield. There was no evidence that sensor-based N management increased yield in other years in which N loss was minimal; however, in these years, N rate was reduced without yield penalty.

The combination of lower N use and higher yield resulted in both higher N efficiency (78% vs 68%, $p = 0.0011$) and higher profitability ($42 ha^{-1} advantage, $p = 0.0007$). This is the elusive win-win outcome, with the producer making more money while less N is available to escape to other locations where it has undesirable effects.

Summary

Variable-rate N fertilizer applications based on canopy reflectance sensors out-performed N rates chosen by corn producers in every metric:

1. Higher profit
2. Lower N rate
3. Higher yield
4. Higher N efficiency

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