Sensor-based variable rate N: Long-term performance in corn and cotton

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Objective:

The objective of this project is to evaluate long-term performance of sensor-based variable N rate recommendations for corn and cotton. Sensor-based N will be compared with typical producer N management and with other N rate decision systems.

Accomplishments for 2010:

- Two small-plot corn experiments were conducted as planned at Bradford Farm near Columbia.
- One small-plot cotton experiment was conducted as planned at the Delta Center near Portageville.

Sensor-based variable rate N: Long-term performance in corn

Experiment 1: Long-term impact of nitrogen rate recommendation systems

- This experiment uses the following systems to evaluate corn nitrogen need.

  Pre-Plant Systems

  1. Fixed Rate
     A. 0 lbs.N/acre
     B. 100 lbs.N/acre
     C. 140 lbs.N/acre
     D. 180 lbs.N/acre
  2. Missouri Pre-plant Soil N Test

  In-Season Systems

  3. Sensor Based
     A. Crop Circle Sensor (Variable Rate)
     B. Chlorophyll meter
  4. Iowa Side-dress Soil Test

- 2010 is the fourth year of this study. It has been previously funded by the Fertilizer & Lime grants program as part of the project 'Addressing Nitrogen Controversies'. Reports on years 1 to 3 are available under this title.
- Part of the reason for focusing this project on long-term performance of sensor-based N management is that it was the most profitable system (of eight tested) after three years of study in corn.
- Continuous no-till corn is grown in this study, and N timing and rate decision systems remain the same on each plot every year. This tests the cumulative effect of using these different N rate and timing systems.
- 2010 was, like 2009 and 2008, a very wet year, especially April and May.

- Pre-plant nitrogen treatments were applied on April 29 as surface broadcast ammonium nitrate. Planting was delayed until May 28 due to wet weather. Side-dress treatments were applied July 2 when corn was in the V7 stage as surface in-row ammonium nitrate.
- This experiment received 4.8” of rainfall between pre-plant treatments and planting and 3.3” more rainfall was received from planting to the time of side-dress. The pre-plant nitrogen was exposed to total of 8.1” more of rainfall than the side-dress nitrogen.
- The wet weather apparently caused loss of much of the pre-plant nitrogen. By early August, all of the treatments with pre-plant nitrogen appeared severely nitrogen-deficient over the entire plant (see Fig.1). We observed the classic V-shaped nitrogen deficiency burn up the midrib on all plants in these treatments, usually up to the leaf below the ear.

- All side-dress nitrogen treatments had much better leaf color (see Fig. 2). In early August these treatments were green right down to their lowest leaves.

Table 1.
Nitrogen rates recommended and corn yields produced by eight different recommendation systems in 2010 and 2007-2010.

Nitrogen Recommendation System	Nitrogen Application Timing[1]	2010 Nitrogen Rates lbs./ac[2]	2010 Yields bu./ac[3]	2007-2010 Ave. rate lbs N/ac	2007-2010 Ave. yield bu/ac	Gross (Yield-N) $/ac[4]
Chlorophyll meter	V7	197	130	171	146	481
Crop Circle sensor	V7	[220,182,168 219,202,203] avg. rate = 199	122	149	142	479
Side-dress soil test	V7	147	105	123	131	450
High	Pre-plant	180	46	180	98	284
Yield goal/ MRTN	Pre-plant	140	39	140	86	260
Pre-plant soil test	Pre-plant	124	38	134	84	256
Low	Pre-plant	100	27	100	76	244
Check	Pre-plant	0	8	0	47	188

[1] Growth stage V7 is about knee high corn
[2] A different N rate was applied in each of 6 replications for this treatment. It is feasible to use this sensor to change N rate automatically while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot Separately.
[3] 2010 yields are different from each other (95% confidence) if they are more than 19 bushels apart
[4] Gross calculated using $4/bu. corn price, $0.60/lb. N cost as estimates of average corn Prices and N cost during these years.

- **In 2010, the N rate systems based on corn color again gave the highest yields (Table 1). This had also been true for the combined 2007-2009 results.**
  - Average yield for these two systems was 88 bushels more than the average of the four preplant N treatments, and 19 bushels more than sidedress N rate based on a soil nitrate test.
  - The Crop Circle sensor is designed to support variable-rate N applications based on crop color measured during fertilizer application.
  - The Minolta chlorophyll meter is hand-held and can diagnose N rate for whole fields or zones before fertilizer application begins.

- **The color-based N rate recommendation systems are also the most profitable systems after four years of testing (Table 1).**
  - These systems gave profits $195/acre/year above the profits given by the most profitable pre-plant N management system.
    - ✓ This is due to the poor yields with pre-plant N in 2008, 2009 and 2010. These years all had excessive spring rainfall.
  - The color-based systems also out-performed sidedress N management based on a sidedress soil nitrate test (Iowa State University interpretations) by about $30/acre/year.
    - ✓ This is probably due to the higher N rates recommended by the color-based systems, which appeared to more successfully compensate for high losses of soil N.
    - ✓ Profit was higher with color-based management than soil-nitrate-based management in 3 out of 4 years. All sidedress treatments were within a few dollars of one another in 2009.
  - The chlorophyll meter system recommended an average of 22 lb N/acre more than the reflectance sensor system, and yielded an average of 4 bu/acre higher, resulting in virtually identical estimates of profitability.

- **Crop sensors appear to be a feasible long-term nitrogen management option for corn based on results to date.**
  - Yields have been maintained at higher levels than all other N rate and timing systems tested except the chlorophyll meter-based system.
    - ✓ This has been accomplished while applying only 149 lb N/acre
      - This rate is just slightly above the MRTN (Maximum Return to Nitrogen) N rate of 140 lb N/acre for Missouri.
      - Environmentally this is preferable to making the same profit while applying 22 extra lb N/acre, as happened with chlorophyll meter-based N rates.

- **Nitrogen timing had a large effect on yield in this experiment.**
  - Plots receiving pre-plant N had an average yield of 38 bu/acre (Table 1).
  - Plots receiving sidedress N had an average yield of 119 bu/acre, an advantage of 81 bu/acre.
  - This large yield difference suggests that a large proportion of N applied pre-plant was lost.
  - All yields were surprisingly low given the good moisture availability throughout the season. Some anthracnose and diplodia were observed, but not enough to expect a major yield impact. No weed or insect problems were observed. One possibility is that the corn was never able to fully recover from the effects of the extended waterlogging early in the season.
    - ✓ Nitrogen loss even with sidedress N application could potentially explain the limited yields, but no deficiency symptoms were visible in mid-August to support this idea (Figure 2).
  - This is the third year in a row with an unusually wet spring and a large yield advantage to sidedress N timing.

- This experiment is continuous no-till corn. High levels of corn residue on the surface lead to wetter soil conditions than in other rotations and tillage systems. In wet years, this system will be more vulnerable to N loss than other systems.
- Part of the yield advantage to sidedress N timing is due to the fairly high N rates recommended by all three sidedress recommendation systems in this wet year. Even so, the lowest sidedress rate (147 lb N/acre) out-yielded the highest pre-plant N rate (180 lb N/acre) by 59 bushels.
- Nitrogen timing appeared to influence the number of kernels on an ear. We did not collect data on kernel number, but many of the ears in plots receiving pre-plant N could be seen to have low kernel number. This could have been due to poor pollination or to kernel abortion.
- The large yield advantage to sidedress N timing is in agreement with the appearance of the plants as shown in the photos (Figures 1 and 2).

❍ The check treatment that received no N fertilizer yielded only 8 bu/acre. This shows how severely depleted the soil N supply was, both by N loss due to wet weather and by four years of removal without replenishment by fertilizer.

Experiment 2: Effect of pre-plant nitrogen on sensor-based N rate performance

❍ One concern that arose with sensor-based N recommendations and the design of Experiment 1 was the potential for early-season N deficiency.
- Sidedress treatments in Experiment 1 receive no pre-plant N.
- N stress experienced before sidedress could potentially reduce yield.
- Various members of the agricultural community have expressed concern about whether sensor-based sidedressing with no N applied pre-plant is a viable system.

❍ Experiment 2 is designed to express that concern.
- 2010 is the first year for Experiment 2.
- The key treatment is 50 lb N/ac applied pre-plant, followed by sidedress N at rates diagnosed by the Crop Circle sensor.
  - ✓ Results from this treatment can be compared to pre-plant N management (140 and 180 lb N rates) and sensor-based sidedress with no N pre-plant to evaluate its relative performance.
  - ✓ Any N stress experienced with the sidedress-only treatments should be avoided.
- Experiment 2 is designed to complement experiment 1 and is therefore as similar as possible.
  - ✓ It is right next to Experiment 1, so soils and weather are very similar.
    - However, in this first year of the study, previous crop is sweet corn instead of corn. Residue cover was lower than in experiment 1 (Table 3).
  - ✓ Same seed, same herbicide, same planting date, same application dates.
  - ✓ Three of the four treatments are the same as in Experiment 1.

❍ All corn in this experiment was taller and greener than the corn in Experiment 1 early in the season.
- This is likely due to a previous crop of sweet corn, resulting in lower residue cover, warmer soil temperatures, and greater nitrogen availability.

❍ Experiment 2 corn did show the same growing pattern as experiment 1:
- Pre-plant N treatments were taller and greener than sidedress treatments early in the season
- Sidedress treatments were greener than preplant treatments later in the season.
- However, the visual N stress symptoms in preplant N treatments of experiment 2 were far less severe than in experiment 1.
- This again ties to greater soil N availability (compared to Experiment 1) resulting from a previous crop of sweet corn.
- Experiment 2 will, like Experiment 1, be cropped continuously to corn from now on.

❍ **Early-season N stress did not appear to be a problem when all N was sidedressed on knee-high corn at rates recommended by crop sensors.**
- Yield was 4 bushels higher with sensor-based sidedressing when 50 lb N/acre was applied preplant than when none was applied (Table 2).
- Statistically, there is only a 24% likelihood that this yield difference is real. There is a 76% chance that it is due to random experimental error.
- Even if it is real, it barely covers the cost of the higher total N rate applied (an extra 23 lb N/acre).
- We will continue to evaluate whether using a modest pre-plant N rate enhances the performance of sensor-based N management.

Table 2. Nitrogen rates and yields for four N rate/timing systems in Experiment 2 in corn.

Nitrogen Recommendation System	Nitrogen Application Timing[1]	Nitrogen Rates[2] lbs N/ac	Yield bu/ac	Gross (Yield-N)[3] $/ac
50 lbs N/ac preplant + Crop Circle sensor	Pre-plant + V8	50 pre + [60,74,60 157,160,96] avg. rate = 151	139	$465
Crop Circle sensor	V8	[135,113,108 84,163,167] avg. rate = 128	135	$463
High	Pre-plant	180	107	$320
Yield goal/ MRTN	Pre-plant	140	104	$332

[1] Stage V8 is usually knee- to thigh-high corn
[2] A different N rate was applied in each of 6 replications for this treatment. It is feasible to use this sensor to change N rate automatically while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot separately.
[3] Prices used were $4/bushel and $0.60/lb N

❍ As in Experiment 1, sensor-based sidedress N treatments out-yielded pre-plant treatments by a considerable margin.
- In Experiment 2, this margin was about 30 bu/ac (Table 2).
- In Experiment 1, it was about 80 bu/ac.
- This agrees with the much milder N deficiency symptoms seen in the pre-plant

treatments in Experiment 2.

- ✓ Three wet years with continuous corn have depleted the N soil reserves in Experiment 1.
- ✓ A previous crop of sweet corn in this first year of Experiment 2 also contributed lower cover, higher temperatures, and higher soil N release. This area had been in fertilized sweet corn or fallow during the last three years.

❍ Experiment 2 also had greater variability in soil N supply as indicated by the wider range of N rates recommended by the sensors.

- The highest and lowest N rates based on sensors were only 51 lb N/acre apart in Experiment 1.
- In experiment 2, the range of N rates was 100 lb N/acre in one sensor treatment, and 83 lb N/acre in the other.
- This variability is caused in part by landscape position. This plot area is a summit position and tends to drain poorly and has areas where water pools, affecting N availability. (Fig. 3)

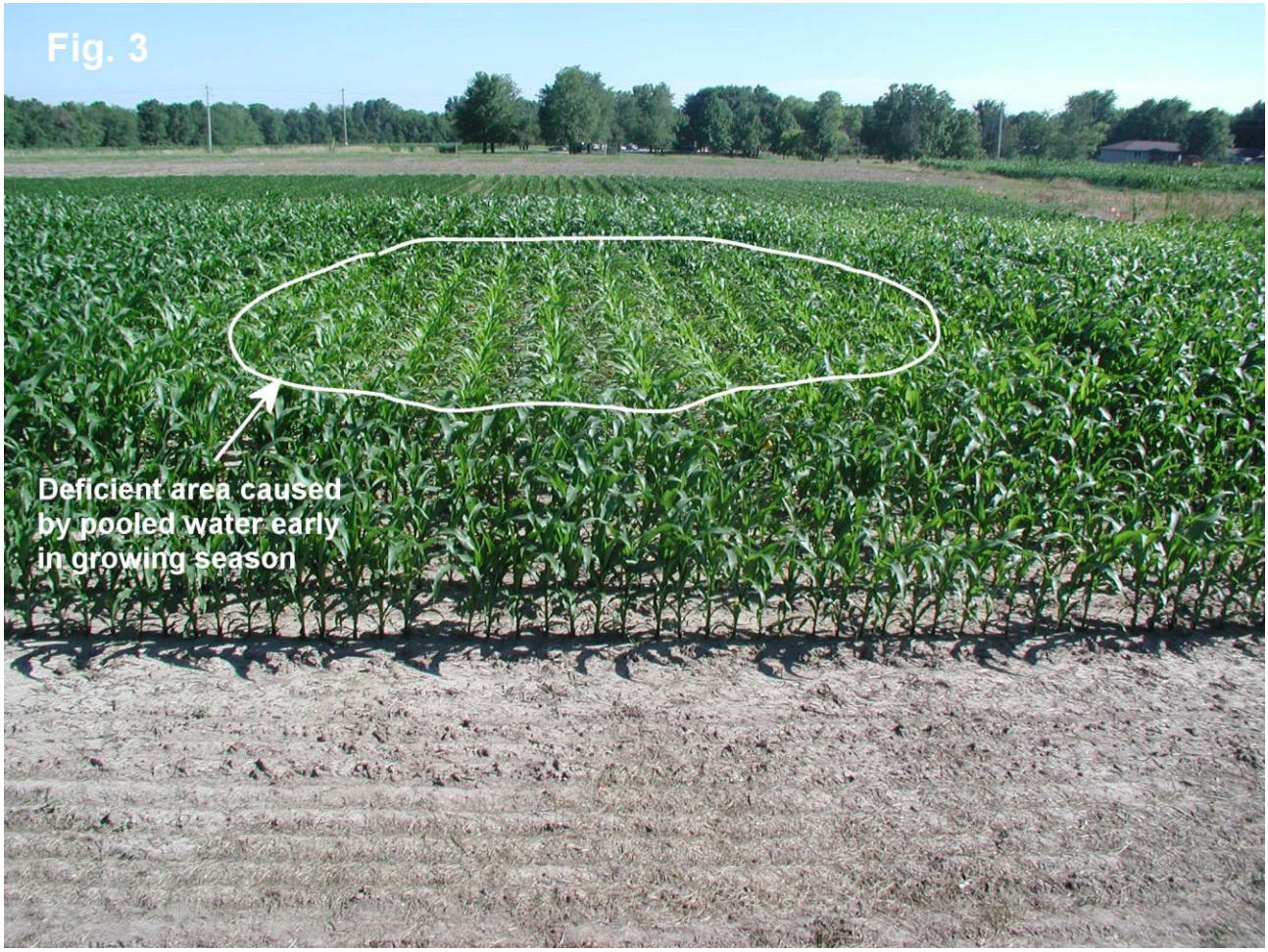

Table 3.
Procedures for long-term corn sensor N experiments

Description	Experiment 1	Experiment 2
Previous Crop	Corn 70-75% Residue cover	Sweet Corn, 150 lbs.N/ac 50-55% Residue cover
Pre-plant Soil Sampling	4/08/10	none
Tillage	No-till	No-till
Weed Control Broadcast Herbicide Application	Burn down Round-up 32 oz./ac Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/19/2010	Burn down Round-up 32 oz./ac Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/19/2010
Early Nitrogen Application	3 Fixed rate treatments & Mo pre-plant soil test treatment 4/29/2010	2 Fixed rate treatments & 1 Fixed rate treatment Pre-plant for sensor based 4/29/2010
Plant Plots	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculex xtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25” – 1.50” Conditions: Good Emergence – Good 5/28/2010	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculex xtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25” – 1.50” Conditions: Good Emergence – Good 5/28/2010
In-Season Soil Sampling	6/24/20/10	none
WeedControl Clean – up Broadcast Herbicide Application	Round-up 32 oz./ac+ AMS 20 gal water/ac 6/16/2010	Round-up 32 oz./ac+ AMS 20 gal water/ac 6/16/2010
Sidedress Treatment Applications	Chlorophyll meter, sensor, & sidedress soil nitrate test treatments applied 7/02/2010	sensor sidedress treatment applied 7/02/2010
Harvest	10/4/2010	10/4/2010

Sensor-based variable rate N: Long-term performance in cotton

❍ Recent experiments in Missouri and other states have shown that:
- Optimal N rate for cotton varies widely from field to field
- Crop sensors can provide relatively reliable estimates of optimal N rate

❍ This has created a need to evaluate how sensor-based N rates perform when used routinely and on the same land over an extended period.

❍ We initiated this experiment in 2010 to meet that need.

❍ This experiment is designed to look at sensor-based N performance both with and without N applied preplant. Treatments used include:
- Sensor-based N applied at mid-square stage
- 30 lb N/acre applied pre-plant, then sensor-based N applied at mid-square stage
- Standard N management: 50 lb N/acre preplant, 50 lb N/acre early square
- Standard N management with credit for soil nitrate test
- 50 lb N/acre preplant, followed by additional N if petiole nitrate is below critical value
- High rate: 50 lb N/acre preplant + 80 lb N/acre early square
- Low rate: 20 lb N/acre preplant + 50 lb N/acre early square
- Check treatment: no N applied

❍ Yields have not yet been analyzed for spatial trends and are not ready to present until this step is completed. However, a few points emerge from the initial yield analysis that will probably hold true in the final analysis:
- Yield in the zero-N (check) treatment was 1230 lb lint/acre. This is a very good yield and indicates that the soil supplied a substantial amount of N to the crop.
- Yield in the fertilized treatments averaged 1320 lb lint/acre, an average yield response of only 90 lb lint/acre.
  - ✓ Any of the N treatments should have been able to supply enough N to the crop to support a 90 lb response
  - ✓ Differences in yield from plot to plot under these conditions are probably due mostly to spatial variability in the soil where the experiment is planted, rather than to the effectiveness of the treatments.
- In this situation there is potential for N applications to hurt yields, quality, or harvestability.
- The best treatment under these conditions will probably be the one with the lowest N rate applied, partly due to savings on N and partly due to reduced risk that excess N will cause yield, quality, or harvestability problems.
- By this criterion, the sensor-based N (with no N applied pre-plant) treatment is the best treatment, since only 22 lb N/acre was applied.
- **The sensors correctly diagnosed that the soil was supplying a high level of N and that minimal fertilization was needed.**
- However, fiber strength was significantly lower with the sensor-only treatment (33.6) than with standard N management (34.8) in the preliminary analysis. This is a disadvantage.

Objectives for 2011

Our objective for 2011 is to repeat these three experiments in the same locations, and with the same treatments on the same plots. This will help us to assess the long-term effects of sensor-based N management relative to other N rate and timing approaches.

Budget for 2011

Labor & benefits, corn experiment	$8,000
Labor & benefits, cotton experiment	$8,000
Labor & benefits, data & website	$ 500
Soil & petiole sample analyses	$ 500
Field supplies & fuel	$ 500
Total	**$17,500**