Addressing nitrogen controversies

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Objective:

The objective of this project is to collect data that will help to address several controversies about nitrogen management, including:

1) How do various nitrogen rate recommendation systems perform over multiple years?
2) Is foliar N more efficient than soil-applied N, and is Coron more efficient than UAN?
3) Among the range of new N products and N-enhancement products, which are profitable to use and how do they rank?

Accomplishments for 2010:

- Three separate small-plot experiments (addressing objectives 1, 2, and 3 listed above) were conducted as planned at Bradford Farm near Columbia. All experiments used corn as the test crop.

Long-term nitrogen rate recommendation systems experiment

- 2010 was, like 2009 and 2008, a very wet year, especially April and May.
- Pre-plant nitrogen treatments were applied on April 29 as broadcast ammonium nitrate. Planting was delayed until May 28 due to wet weather. Sidedress treatments were applied July 2 as surface between-row ammonium nitrate when corn was in the V7 stage.
- This experiment received 4.8 inches of rainfall between pre-plant treatments and planting and 3.3 inches more rainfall was received from planting to the time of sidedress. The pre-plant nitrogen was exposed to total of 8.1 inches more rainfall than the sidedress nitrogen.
- This wet weather apparently caused loss of much of the soil & pre-plant nitrogen. By early August, all of the treatments with pre-plant nitrogen appeared severely nitrogen-deficient over the entire plant (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.

FIG. 2

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

- **Nitrogen timing had a large effect on yield in this experiment.**
  - Plots receiving pre-plant N had an average yield of 38 bu/acre (see table next page).
  - Plots receiving sidedress N had an average yield of 119 bu/acre, an advantage of more than 80 bu/acre.
  - 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.
  - 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).

- **After four years, the most profitable systems are the two systems in which in-season N rate is based on corn color** (Minolta chlorophyll meter and Crop Circle sensor).
  - 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.

- Among pre-plant treatments, the high-rate treatment (180 lb N/acre) gave the highest yields and highest profits both in 2010 and over a four-year span.
  - With adverse weather causing N loss, all preplant treatments were N-deficient, and the high rate treatment was the least deficient.
  - Yield of the high-rate preplant treatment in 2010 was still 80 bushels below the average of the two color-based sidedress treatments.

- 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.

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 (lb/ac)	2010 Yield (bu/ac)[3]	2007-2010 Ave. N rate (lb/ac)	2007-2010 Ave. yield (bu/ac)	2007-2010 Ave. gross (Yield-N) ($/ac/year)[4]
Chlorophyll meter	V7	197	130	171	146	481
Crop Circle sensor	V7	220,182,168 219,202,203[2] avg. rate = 199	122	149	142	479
Sidedress 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, $0.60/lb N as estimates of average corn price and N cost during these four years.

<u>Foliar N efficiency experiment</u>

- This experiment was designed to compare the ability of different foliar N sources to deliver N to corn, and to compare foliar applications with soil applications at the same rate and timing.
- A total N rate of 80 lb N/acre was used. This rate was chosen with the expectation that corn would be N-stressed and the ability of treatments to deliver N would be directly reflected in yield.
- The 80 lb was divided into three applications, 40 lb N preplant and two in-season applications of 20 lb N/acre.
  - We wanted to test the ability of foliar treatments to deliver an amount of N that could make a substantial difference in yield when serious N deficiency occurs.
  - Initially we chose 50 lb N/acre, divided into two applications to reduce burn, as a rate that could address serious N deficiency.
  - In the first year of the study this approach produced marginally unacceptable leaf burn.
  - For subsequent years we have reduced the in-season N applications to 40 lb N/acre, divided into two applications, and increased the preplant rate to keep the total the same.
- All treatments received a broadcast application of preplant N at a rate of 40 lb N/acre.
- All treatments except the check received two equal in-season applications of N. Applications were made on June16 (stage V10, waist high) and again on June 24 (V13, shoulder high).
- In-season nitrogen treatments were:
  - foliar CoRoN, study rate (8 gal/ac)
  - foliar CoRoN, manufacture's rate (3 gal/ac)
  - foliar UAN
  - foliar urea
  - dribbled UAN (between rows)
  - broadcast ammonium nitrate
  - broadcast urea with Agrotain
  - check (no in-season N)

- Average yield response to 40 lb in-season N/acre was 24 bu/acre. This shows that in-season N applications can produce good yield response in N-deficient corn.
  - However, yield response to in-season N was much lower than in 2008, when 50 lb/acre of in-season N produced an average yield response of 54 bu/acre.
  - N stress was less in the check treatment this year (94 bu/acre) than in 2008 (69 bu/acre).
  - Top-side yield potential was also less this year, as reflected in state-average yields, although the reasons for this are not clear.
- **Foliar treatments did not show superior ability to deliver in-season N to a corn crop relative to soil-applied treatments.** See Table 3.
  - Average yield with foliar N (excluding the lower-rate CoRoN treatment) was 115 bu/acre, with soil-applied N was 121 bu/acre.
  - A similar pattern was seen in 2008.
  - High soil moisture and frequent rainfall throughout the summer contributed to efficient use of soil-applied N. Water to deliver soil-applied N to roots was plentiful.

- Foliar UAN gave the highest burn rating (see photo in Figure 3) and lowest yield among treatments receiving a total of 80 lb N/acre, as it also did in 2008. UAN solution is not an ideal N source for foliar applications.

Table 3. Corn yields with foliar or dry N sources. All treatments were applied at a rate of 20 lb N/acre at V10 and again at V13 except for the check and manufacturer rec rate CoRoN treatments. Urea-ammonium nitrate solution was broadcast on all plots preplant at a rate of 40 lb N/acre and incorporated with light tillage.

In-season source	2010 Ave. Yield (Bu/ac)[1]	2010 Ave. Burn Rating[2]	2008 Yield Bu./ac	2008 Ave. Burn Rating[2]	2 yr Yield Bu./ac	2 yr. Ave. Burn Rating[2]
Urea with Agrotain(dry)	128	0.75	133	1	131	0.9
Foliar Urea	118	4.4	130	7.5	124	6.0
Ammonium Nitrate(dry)	119	1.8	126	4.5	123	3.2
UAN dribbled	117	0.0[3]	122	0.0[3]	120	0.0
Foliar CoRoN Study rate	115	3.6	116	4.0	116	3.8
Foliar UAN	111	8.3	112	8.5	112	8.4
Foliar CoRoN 3 gal/acre (Manufacturer recommended rate)	107	1.0	---	1.0	---	1.0
No in-season N	94		69	0	82	0

[1] Yields are different than each other if they are 9 or more bushels apart. (95% confidence)

[2] Burn rating shown is the average of ratings 7 days after each application (V10 and V13). (10 = Severe, 0 = None) I

[3] Leaf burn = 0, Some cosmetic burn on plant stalk from application splash

- Broadcast dry urea with Agrotain gave significantly higher yield than any other N source/placement.
  - In both years, this treatment gave the lowest burn rating except for the dribbled UAN treatment. This agrees with our earlier research showing lower burn potential for urea than for other N sources.
- Other N sources gave yields that were not statistically different than each other when applied at the full study rate (total 80 lb N/acre).
- The lower (manufacturer's recommended) rate of CoRoN gave a significant yield response (applied twice), but still yielded 11 bushels less than foliar urea (with 95% confidence). It also yielded less, statistically, than all three soil-applied N treatments.
  - The beneficial properties of CoRoN are not enough to compensate for low N rates.
  - Claims that CoRoN is more effective per lb of N than other N sources were not supported by this study. These claims also go against established scientific principles.

Due to the loss of our 2009 foliar N experiment (farm crew accidentally harvested it as bulk corn), we will continue this experiment for one more year. The final report for the whole project will be completed at the end of 2011.

New N products and N-enhancement products experiment

- This experiment was designed to test the new N products ESN, Calcium Ammonium Nitrate, and Nurea, the new N-enhancement product Nutrisphere, and the established N-enhancement product Agrotain. All treatments are dry surface applied N products.
- Soybean was the previous crop. This field received some light tillage to level seedbed as a damp soybean harvest had left some tire tracks.
- Corn was planted on April 21.
- A nitrogen rate of 140 lb N/acre was used for all treatments.
- Emergence was slow and vigor weak as over 4.5" of rainfall was received within days of planting and treatment application was delayed. Over 8" rainfall had been received since planting when treatments were applied to V3-4 corn on May 26.
- Effectiveness of N delivery was not tested well this year. The check treatment with no N yielded 110 bu/acre, and the highest-yield N treatment yielded 133. This is a yield response of only 23 bu/acre to 140 lb N/acre applied. Clearly another factor other than N availability was limiting yield, but we don't know what it was. We did not observe any pest or crop growth problems that could explain the modest yields despite plentiful soil water.
- Thus it is likely that the observed 'treatment differences' are not real, since even a very poor-performing treatment should have been able to deliver enough N to support a 23

bu/ac yield response.

- **Over the three years of this study, ESN stands out as the new N product that performed most successfully.** Average yield with ESN was 20 bushels higher than with normal urea. This was partly a product of the wet spring weather during all three years. ESN is a coated urea product and releases the urea slowly from the coating; while still inside the coating, the N is protected from loss processes.
- Agrotain is a volatilization inhibitor that has been shown for decades to reduce loss of ammonia from surface-applied urea products. Its application to dry urea gave an average yield benefit of 9 bushels/acre over the three study years.
- Nutrisphere may have also given a yield increase of 7 bushels/acre during the study period. The mode of action of this product appears to be unknown, so I would recommend interpreting these results with caution.
- The new N products Nurea and calcium ammonium nitrate performed adequately but not well enough to justify using them in place of standard N sources.

Table 2. Yields with new N sources or N additives compared to standard dry N products.

Nitrogen source	2010 yield[1]	2009 yield	2008 yield	3-yr ave. yield
ESN	132	140	124	132
Urea + Agrotain	131	126	107	121
Urea + Nutrisphere	128	126	104	119
Ammonium nitrate	133	115	102	117
Urea	122	120	93	112
Calcium ammonium nitrate	119	108	106	111
Nurea	127	122	84	111
Check (0 N)	110	74	----[2]	----[2]

[1] Yields are different from each other if they are 11 or more bushels apart. (95%confidence)

[2] Check treatment omitted in 2008.

Table 3. Details of experimental procedures for the three experiments in this project.			
Description	Long Term N	Foliar N	New Sources of Dry N
Previous Crop	Corn 70-75% Residue cover	Soybean 20-25% Residue cover	
Pre-plant Soil Sampling	4/7/2010	none	
Tillage	No-till	Pre-plant tillage - light field cultivation and mulcher to remove harvest tracks	
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	Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/20/2010	Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/20/2010
Early Nitrogen Application	3 Fixed rate treatments & MO pre-plant soil test treatment 4/29/2010	All plots, 40 lbs/ac N UAN added to above herbicide mix, incorporated with mulcher 4/20/2010	All treatments applied 5/26/2010
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 – Slow 4/21/2010	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 – Slow 4/21/2010
Weed Control Clean – up Broadcast Herbicide Application	Round-up 32 oz./ac+ AMS 20 gal water/ac 6/16/2010	none	none
Sidedress Treatment Applications	Spad, Holland & Soil nitrate test Sidedress treatment applied 7/2/2010	1st foliar application 20 lbs./ac N 6/16/2010 2nd foliar application 20 lbs./ac N 6/24/2010	none
Harvest	10/4/2010	9/29-30/2010	9/29/2010