Demonstration of In-Season Nitrogen Management Strategies For Corn Production

2006 Crop Year Report

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Introduction:

Water quality impairment related to nitrogen (N) continues to be an important issue in Iowa. Proposed Environmental Protection Agency surface water quality criteria for N could dictate strict guidance for N inputs to corn, which occupies large acreage and is important for economic vitality of Iowa farmers. This focus could even designate N use practices that require very high levels of management and risk, with unknown economic consequences. Therefore it is important to demonstrate emerging N management strategies that have potential to improve N use and economic return to corn production.

Rate of N application is an important N management factor in corn production related to increase in nitrate reaching surface and groundwater. Rate is also important in regard to economics of corn production. Application exceeding crop need increases the pool of nitrate remaining in soil after crop harvest – nitrate with the potential to move out of the soil profile. Excessive N application to corn also reduces a corn producer's profits. While applying only the needed fertilizer N rate in a given year will not stop nitrate from leaving cornfields, nor necessarily achieve proposed water quality criteria, it can result in reduced residual soil nitrate and help lessen corn production's impact on water quality. Therefore, it is possible that being able to assess corn N fertilization need differentially each season could improve corn N use efficiency and reduce nitrate susceptible to loss compared to application of an average agronomic rate each year.

Monitoring the corn plant to determine N status and seasonal N availability has advantages in that the plant integrates N supply over a wide period of time, and hence can reflect the soil N supply as affected by weather, soil processing, and fertilization. It can also reflect spatial variation. The longer the corn plant has grown, the larger the fraction of total N accumulated (corn accumulates approximately 50-65% of total N by the R1 growth stage). The total crop N need (and season-long soil N supply) is better reflected in the crop late in the season (after R1). This is a limitation with corn plant monitoring to determine N status as the best time to closely determine crop N need is likely after it is too late to apply and have N be accessible for plant uptake. The corn N uptake pattern also implies that small plants sensed early in the season will only indicate large N shortage and cannot differentiate total season N need, especially if available soil N plus preplant N is fairly high. A compromise is to sense the crop before the R1 stage, but after considerable N has been taken up. This might allow time for N to be effective if application is needed, and limit potential yield loss because of delayed application or crop N stress; however, if severe N stress develops unrecoverable yield loss may occur. The potential for irreversible yield loss can be reduced by applying preplant or early-sidedress N, monitoring for development of plant N deficiency, and making in-season applications timed before significant N stress occurs. Nitrogen can be applied with high clearance equipment and research has shown that N applied as late as the R1 growth stage can still add to the pool of N being accumulated during seed fill and improve yield if N supply is short.

Limitations to in-season monitoring and N application are dry surface soils where applied fertilizer is not accessible for uptake by active roots, or wet periods that limit field access. Also, to date sensors for assessing corn plant N status can only determine plant N stress (lack of adequate N). This means that to adjust seasonal N rates using this approach the corn crop must be showing N stress before an application need can be predicted. Having effective systems that allow N rate prediction and application later (later than traditional sidedress timing) into the growing season does provide a wider window for N application in corn.

Several emerging technologies now allow in-season N application and rate adjustment to be practiced. One, high clearance equipment can move through tall corn, some even at full growth height. Two, high clearance equipment has been developed that can inject urea-ammonium nitrate (UAN) fertilizer solutions into the soil (Hagie Manufacturing Co. NTB applicator; Miller Applications Technologies Co. NITRO toolbar applicator). Three, a plant chlorophyll sensor (Minolta SPAD 502 chlorophyll meter) is available and well-researched in regard to the relationship with N rate and N status. Other handheld, machine-mounted, and remote aerial sensors are being commercially developed, with research for determination of efficiency and N-rate prediction underway. Therefore, it is feasible for producers to begin investigating in-season N management systems based on plant monitoring. However, field-scale demonstration is needed to document and resolve several issues: integration into corn production systems, feasible strategy for in-season N management, corn productivity, and economics compared to preplant and early-sidedress N.

Objectives:

Objectives of this project include: one, demonstrate use of corn plant N deficiency/sufficiency monitoring (sensing) to determine need and rate of post-sensing N (hereafter referred to as post-N) application and effect on corn yield; two, demonstrate the impact of set preplant or early-sidedress N rates (hereafter referred to as pre-N) on corn plant N sufficiency and N stress development, frequency and rate of needed post-N application, total fertilizer N applied, and corn yield; and three, compare corn yield response and economic return using pre-N versus pre-N plus post-sensing N application.

Field Demonstration Description:

Demonstrations use cooperating producer fields, with fertilizer applications in replicated strips across field lengths. At each site cooperators are asked to avoid making broadcast applications of manure or N fertilizer to the site area, other than replicated N treatment strips. All other field activities are completed as normal by the cooperator, including grain harvest of treatment strips. Each demonstration strip is replicated three times in order to compare demonstration effects.

A summary of the application strategies is given in Table 1. Set pre-N rates are either fall- or spring-applied preplant or early-sidedress: 1) no-N control; 2) non-N limiting reference rate at 240 lb N/acre (corn after soybean) or 270 lb N/acre (corn after corn); 3) reduced N rate at 60 lb N/acre (corn after soybean) or 90 lb N/acre (corn after corn); 4) agronomic N rate at 120 lb N/acre (corn after soybean) or 180 lb N/acre (corn after corn). Post-sensing N applications vary and are determined from corn plant N stress sensing between V10 and VT vegetative growth stages: 5) reduced pre-N rate (see number 3 for rate) plus post-N applied before the R1 corn growth stage (applied if needed and rate determined from corn plant sensing); and 6) agronomic pre-N rate (see number 4 for rate) plus post-N applied before the R1 corn growth stage (applied if needed and rate determined from corn plant sensing). The post-N applications are applied to one of two strips of the reduced and agronomic pre rates in each replication. The in-season fertilizer N source is UAN solution surface-dribbled or coulter-injected with high-clearance equipment.

The agronomic N rate, set at 120 lb N/acre (corn following soybean) or 180 lb N/acre (corn following corn), is based on the approximate mid-point of current Iowa State University published recommended ranges for each rotation. Recent economic analysis of 200+ site-years of corn yield response data from across Iowa indicated an economic N rate near 125 lb N/acre for the corn-soybean rotation and 175 lb N/acre for corn following corn. This demonstration project allows for the following comparisons: 1) field response to applied N and relative magnitude of response with each strategy; 2) rates of application; 3) pre-N application and post-sensing application of additional N; 4) frequency and rate of needed post-N with each strategy; 5) timing of N deficiency development between pre-N rates; 6) ability of the monitoring system to determine needed post-N rate; and 7) economics of using pre-N rates versus pre-N rates plus post-sensing N application adjustment strategies.

Two pre-N rates are used to demonstrate two overall strategies of in-season monitoring and potential for post-N application by producers. One strategy is to apply an agronomic N rate and then monitor to see if a problem develops in regard to N sufficiency. This is a management strategy where in-season N applications might be infrequent across years; it allows producers to confidently use agronomic N rates while having a backup system available in case N deficiency problems develop during early vegetative growth (for example, high N loss or a year of greater than expected fertilizer N need). This approach does not allow for adjusting rates if less than an average agronomic rate would suffice in a particular year. The second strategy is to apply a reduced rate of N, expecting that more N will be applied in-season most years. This approach could allow for a closer match between corn N need and N application each year. Having some N pre applied can help limit severity of N stress and therefore potential development of irreversible yield loss.

Corn plants are sensed throughout each strip before post-N application to monitor N deficiency development and to determine post-N rate. A Minolta SPAD 502 chlorophyll meter is used to monitor N deficiency development. The SPAD chlorophyll meter is handheld, allows for determination of corn N deficiency in defined field areas, and provides instant feedback. The SPAD chlorophyll meter has been intensely researched, with well documented relationships to plant N and development of N deficiency in corn (ISU Extension Publication PM 2026). Work conducted in the Iowa Department of Agriculture, Division of Soil Conservation Integrated Farm/Livestock Management (IFLM) demonstration program project "Determining Corn Nitrogen Fertilization Requirements and Soil Carbon Status in Diverse Soil Nitrogen Supply Environments" has shown a positive relationship between relative (normalized) SPAD readings (RSPAD) and the average N rate difference (lb N/acre) between an applied rate and the economic N rate (ND). This relationship is described by the quadratic-plateau equation: $RSPAD = 0.97 + 0.00059ND - 0.00000499ND^2$ (plateau at 0.99 RSPAD at a ND of 59 lb N/acre; with the RSPAD being 0.97 when the average N rate is at the economic rate, ND=0). This equation is used to determine the post-N rate to be applied to each of the planned in-season strategies.

The non-N limiting reference N rate is included in the demonstration because research with chlorophyll meters and with remote imagery has shown that readings should be adjusted (normalized) to an adequately N-fertilized reference area to reduce color effects other than from N deficiency (drought, hybrid greenness differences, and diseases). Each strip is sensed after all N applications are completed (R3, corn milk growth stage) to monitor plant response to applied N.

Corn is harvested by cooperators using combines equipped with a yield monitor and GPS positioning equipment, with grain yields adjusted to 15.5% moisture. Combines equipped with GPS positioning equipment allow strip yield determination and comparison of within-field differences in response to applied N using GIS technology.

Thirteen demonstration sites were established with 10 cooperators in 10 Iowa counties in 2006 (Figure 1). Crop year 2006 demonstration sites varied in soil type, tillage system, yield history, recent N application rate history, and manure application history (Table 2). Nine crop year 2006 demonstration sites were corn following soybean (corn-soybean); four 2006 demonstration sites were corn following corn (corn-corn).

Planting dates at 2006 demonstration sites ranged from April 18 to April 27 (corn-soybean sites, Table 3; corn-corn sites, Table 4). Pre-N application timing at 2006 demonstration sites ranged from mid-November 2005 to June 15, 2006. Pre-N was applied at the Webster 2006 site via late fall (2005) applied anhydrous ammonia (no N-Serve® applied with the anhydrous ammonia). Pre-N was applied via early-sidedress at six 2006 demonstration sites (Dallas, Marshall, and Washington corn-soybean sites; Benton, Wright-1, and Wright-2 corn-corn sites). Pre-N source at three demonstration sites was anhydrous ammonia (one site late fall-applied, one site spring-applied, and one site early sidedress-applied); pre-N source at ten demonstration sites was UAN solution (three sites broadcast-applied and seven sites injected).

Preliminary 2006 Results:

Leaf Greenness Measurement and In-Season N Application Rates

Corn plant N status (leaf greenness) was monitored at all 2006 demonstration sites using a SPAD chlorophyll meter (Figure 2); preliminary chlorophyll meter data collection was targeted to begin at approximately V10 corn growth stage (uppermost leaf with a visible leaf collar was the tenth leaf on the majority of plants at a site). Chlorophyll meter (SPAD) readings were collected from twenty corn plants surrounding multiple pre-flagged points throughout the center of each treatment strip. Readings were collected from the uppermost developed leaf with a collar fully visible until the corn reached tassel emergence (VT), when readings were collected from the ear shoot leaf. Within each treatment strip, the average SPAD reading was calculated. Relative chlorophyll meter (RSPAD) values, normalized relative to chlorophyll meter readings collected from the 240 lb N/acre (corn-soybean sites) or 270 lb N/acre (corn-corn sites) reference treatment strips, were calculated for each treatment. As expected, leaf greenness readings at the vegetative stages increased with higher pre-N rates at most sites (Tables 5 and 6). The SPAD readings and leaf chlorophyll (leaf greenness) do not indicate excess N, but will show deficiency or N stress; therefore, readings do not increase once maximum greenness is reached, even with more N.

Post-sensing N application rates (60+ and 120+ at corn-soybean sites, 90+ and 180+ at corn-corn sites) were calculated for each site by entering RSPAD data into the aforementioned quadratic-plateau equation that describes the relationship between RSPAD readings and the average N rate difference (lb N/acre) between an applied N rate and the economic N rate. Equation-prescribed post-N application rates at 2006 corn-soybean demonstration sites ranged from 0 to 85 lb N/acre for the 60+ treatment (Table 3); equation-prescribed post-N application rates at 2006 corn-corn demonstration sites ranged from 0 to 30 lb N/acre for the 90+ treatment (Table 4). The 120 lb N/acre pre rate was indicated to be N-deficient at three of nine corn-soybean field sites in 2006; equation-prescribed post-N application rates at 2006 corn-soybean demonstration sites ranged from 35 to 45 lb N/acre for the 120+ treatment (Table 3). The 180 lb N/acre pre rates were estimated to be N-sufficient at all four corn-corn field sites in 2006; therefore, no 180+ treatment strips required post-N applications (Table 4).

At three of 13 demonstration sites (Dallas, Wright-1, and Wright-2 sites) high-clearance N toolbars equipped with coulter-injectors were used to apply post-N (UAN) treatments (Figure 3). At six other demonstration sites post-N was surface-applied using high-clearance spray booms equipped with drop nozzles to direct UAN solution below the leaf canopy and onto the soil surface. Chlorophyll meter readings suggested that no additional N was needed in 60+ or 120+ treatment strips at the Monona-1 and Webster corn-soybean sites; similarly, no additional N was needed in 90+ or 180+ treatment strips at the Benton and Mahaska corn-corn sites. Corn yellowing from N deficiency stress with no or low rate of applied N was quite apparent at some 2006 sites; Figure 4 illustrates an example of extreme deficiency in the zero N strips.

Corn response to post-N application was monitored at 2006 demonstration sites by collecting follow-up SPAD chlorophyll meter readings from the same pre-flagged strip points throughout each treatment strip. Follow-up chlorophyll meter data collection was targeted for the R3 corn reproductive stage (milky kernel stage). Late V-stage and R3 stage relative SPAD values (before and after post-N applications, respectively) are summarized for 2006 demonstration sites in Table 5 (corn-soybean sites) and Table 6 (corn-corn sites). Generally, post-N applications did not result in significant increases in corn leaf greenness; however, reductions in corn leaf greenness between early and late chlorophyll meter data collections were less where post-N was applied. Better retention of leaf greenness (indicating more-sufficient N levels) during the critical pollination and early reproductive growth stages may explain corn grain yield response to post-N application.

Growing Season Precipitation

Growing season (March 15 to October 15) precipitation totals and precipitation totals recorded two weeks before and two weeks after post-N application are summarized for all 2006 demonstration sites in Table 7. Precipitation records were used from nearby National Weather Service weather stations. Weather stations were generally within 5 to 10 miles of demonstration sites. Precipitation to maintain moist soil during the critical period two weeks before and after UAN application, and move applied N into the rooting zone, should increase response to post-N application. Based on that assumption, we might expect greater response to post-N at the Dallas, Shelby, and Washington field sites in 2006 relative to the Monona, Wright, and Jasper county sites, which received less precipitation during the two weeks after post-N application.

Corn Grain Yield Response to N Fertilizer Rate and Timing – 2006 Corn-Soybean Sites

Corn yield level and response to N fertilizer rate/timing varied among corn-soybean sites in 2006 (Table 8). Corn yield increase with pre-N application was statistically significant at all 2006 demonstration sites. Zero-N application (control) treatment strips yielded from 93 to 207 bu/acre, with an average yield of 148 bu/acre. Reduced pre-N application (60 lb N/acre) treatment strips yielded from 109 to 224 bu/acre, with an average yield of 177 bu/acre. Corn yield response to the first 60 lb N/acre was statistically significant ($P \leq 0.10$) at eight of nine demonstration sites, with yield increase at those sites ranging from 12 to 53 bu/acre. Agronomic pre-N application (120 lb N/acre) treatment strips yielded from 110 to 227 bu/acre, with an average yield of 187 bu/acre. Corn yield response to increasing pre-N from 60 to 120 lb N/acre was statistically significant ($P \leq 0.10$) at six of nine demonstration sites, with yield increase ranging from 2 to 31 bu/acre at those sites. Reference area pre-N application (240 lb N/acre) treatment strips yielded from 120 to 230 bu/acre, with an average yield of 192 bu/acre. Corn yield response to increasing pre-N from 120 to 240 lb N/acre was statistically significant at two demonstration sites (Dallas and Shelby-1), with yield increase at each site being 7 bu/acre. Overall, the Monona-1 (center pivot-irrigated) site was least N-responsive in 2006, with 13 bu/acre separating zero-N and adequate-N rate yield averages. The Jasper (73 bu/acre increase from zero-N to adequate-N rate yield averages) and Washington (70 bu/acre increase) sites were most N-responsive in 2006.

The 60+ treatment strips (post-N application average 54 lb N/acre, range 30 to 85 lb N/acre; total-N rate average 106 lb N/acre, range 90 to 145 lb N/acre) yielded from 116 to 224 bu/acre, with an average yield of 184 bu/acre. Post-N was applied to 60+ treatment strips at seven sites, as called for by plant N stress sensing. Corn yield response to post-N (versus pre-N application of 60 lb N/acre with no post-N) was statistically significant ($P \leq 0.10$) at three of seven sites; yield responses included 10 (Dallas and Marshall) and 17 bu/acre (Washington). The 60+ treatments yielded less than the 120 lb N/acre pre rate at three of seven sites in 2006 (average 10 bu/acre less). The need to apply post-N in addition to the 60 lb N/acre pre rate was correctly identified by plant N stress sensing at three of seven sites. Yield increase from post-N was significant at three of seven sites, and this strategy (60+ treatment) returned yield as high as the 120 lb N/acre pre rate at four of nine sites. This means full yield recovery from the N stress was achieved at four sites. There was minimal increase in yield with N rates above 60 lb N/acre at the Monona-2 (dryland) site, confirming that rainfall deficits near the time of post-N application and throughout the growing season limited corn yield potential and corn plant N uptake.

Plant N stress sensing in the 120+ treatment indicated need for post-N application at the Marshall (+35 lb N/acre; 155 lb total-N/acre), Monona-2 (+35 lb N/acre; 155 lb total-N/acre), and Shelby-1 (+45 lb N/acre; 165 lb total-N/acre) sites. Corn yield response to post-N was not statistically significant ($P \leq 0.10$) at any of the three sites (+3 to 6 bu/acre), suggesting that late V-stage SPAD measurements overestimated plant N stress. At six of nine sites, plant sensing of the 120 lb N/acre pre agronomic rate did not indicate additional N need. This was generally correct, as no statistical difference in yield was measured between the pre 120 and 240 reference N rates. Plant N stress sensing at the Dallas site incorrectly “missed” N stress in the 120 lb N/acre pre agronomic rate because there was a significant yield difference (7 bu/acre) measured between the pre 120 and 240 reference N rates.

Corn Grain Yield Response to N Fertilizer Rate and Timing – 2006 Corn-Corn Sites

Corn yield level and response to N fertilizer rate/timing varied among corn-corn sites in 2006 (Table 9). Corn yield increase with pre-N application was statistically significant at three of four 2006 demonstration sites. Zero-N application (control) treatment strips yielded from 93 to 207 bu/acre, with an average yield of 150 bu/acre. Reduced pre-N application (90 lb N/acre) treatment strips yielded from 159 to 228 bu/acre, with an average yield of 180 bu/acre. Corn yield response to the first 90 lb N/acre was statistically significant ($P \leq 0.10$) at three of four corn-corn demonstration sites, with yield increases ranging from 21 to 67 bu/acre. Agronomic pre-N application (180 lb N/acre) treatment strips yielded from 168 to 228 bu/acre, with an average yield of 192 bu/acre. Corn yield response to increasing pre-N from 90 to 180 lb N/acre was statistically significant ($P \leq 0.10$) at two of four demonstration sites, with yield increases of 17 and 20 bu/acre at those sites. Reference area pre-N application (270 lb N/acre) treatment strips yielded from 167 to 226 bu/acre, with an average yield of 192 bu/acre. Corn yield response to increasing pre-N beyond 180 lb N/acre was not statistically significant at any 2006 corn-corn demonstration site. Among 2006 corn-corn sites, the Mahaska corn-corn site was least N-responsive, with no statistically significant response to applied N (11 bu/acre separating zero-N and applied-N rate yield averages). The Wright-CC1 site was more N-responsive, with 38 bu/acre separating zero-N and adequate-N rate yield averages; however, yields did not respond to additional N beyond the 90 lb N/acre reduced pre-N rate. The 2006 Wright-CC2 site (87 bu/acre separating zero-N and adequate-N rate yield averages) was the most N-responsive corn-corn demonstration site. This was the second year of demonstration at this site, with the treatment strips in the same location. Therefore, the N supply would be expected to be more depleted in the control (zero-N) strips.

The 90+ treatment strips (post-sensing N was applied at 30 lb N/acre at the Wright-CC1 and Wright-CC2 sites, resulting in total-N rates of 120 lb N/acre) yielded from 158 to 221 bu/acre, with an average yield of 182 bu/acre. Corn yield response to post-N (versus pre-N application of 90 lb N/acre with no post-N) was not statistically significant ($P \leq 0.10$) at either Wright-CC site. The need to apply post-N to the 90 lb N/acre pre rate was incorrectly identified by plant N stress sensing at the Wright-CC1 and Wright-CC2 sites; since there was no increase in yield with N rates above 90 lb N/acre, the post-N application was not needed. At the Wright-CC2 site, additional N was needed beyond 90 lb N/acre (yield increase with the 180 lb N/acre pre rate and N stress indicating N deficiency with 90 lb N/acre), however, corn yield did not increase from the post-N application.

Plant sensing of the 180 lb N/acre pre agronomic rate did not indicate additional N need at any 2006 corn-corn sites, which was correct as no statistical difference in yield was measured between the pre 180 and 270 reference N rates.

Summary

One of our project objectives is to evaluate corn yield response and economic returns using strategies of pre-N rates versus pre rates plus post-N application. We will make economic analyses of N application strategies in our project final report; however, some preliminary conclusions can be drawn from 2006 results. Corn yield response to increasing the pre-N rate from 60 to 120 lb N/acre was statistically significant ($P \leq 0.10$) at six of nine corn-soybean demonstration sites, with yield increase averaging 13 bu/acre. At seven of nine demonstration sites the pre-N rate of 120 lb N/acre produced top yields, or yields that were statistically the same as the site's top-yielding N treatment. The 60+ treatments yielded less than the 120 lb N/acre pre rate at three of nine sites in 2006 (average 10 bu/acre less); at the four other sites where post-N was applied to the 60+ treatment in 2006, corn yield from 60+ and 120 lb N/acre pre rates were statistically similar. These 2006 results indicate an economic advantage to using the 120 lb N/acre preplant or early-sidedress application. These results indicate that a pre application of 120 lb N/acre may be more desirable with the strategy of N stress sensing in-season to determine if additional N is required.

Site history differences likely accounted for variable corn yield response to N at 2006 demonstration sites. The Benton corn-corn site, which was treated with dairy bedding (packed dry manure) in the fall of 2003, 2004, and 2005 demonstrated minimal response to N beyond 90 lb N/acre; similarly, the Mahaska corn-corn site, which had spring liquid swine manure applications in 2001-2004, demonstrated considerable leaf greenness and corn yield variability within individual N treatment strips and no response to applied N in 2006. Perhaps in-season plant N sensing can help identify or confirm those situations when corn N response in a particular field, or field area, is much different than expected because of previous years' management practices.

Education Component and Outreach Activity:

The following outreach activities occurred at the project sites in 2006. Field signs indicating the project name, program, and cooperating organizations were located at selected sites (Figure 5).

An important educational multiplier is the extensive use of the project information in extension programs. Since November 2004 the project leader has made presentations integrating information from this project to over 4000 people at ISU Extension and agribusiness meetings.

2006 Field Days

In cooperation with our Shelby County site cooperator and the Stine Seed Company a late summer field day was conducted at a Shelby County demonstration site on September 6, 2006. Local crop farmers, commercial fertilizer applicators, dealers, certified crop advisors (CCA's), and the general public attended the field day and viewed the demonstration site.

Expected Benefits:

One, producer recognition of the demonstration project and importance of corn N rate/timing management as a result of visibility through field signage and field days; two, multiple cooperating and neighboring producers consider use of in-season N application as a direct result of their participation in the project; and three, enhanced and refined information about corn response to N rate application by producers, crop consultants, and N suppliers across Iowa.

Several project outputs are expected: 1) increased awareness of demonstration activities that reinforce the economic and environmental importance of corn N management; 2) through a strong producer-extension field specialist-crop adviser-agribusiness-agency cooperative practice demonstration program, extensive outreach information transfer mechanism to producers and agbusiness via field days and meetings, promotion of experiences learned through the demonstration sites, and use of information learned for corn N management educational literature; and 3) improved understanding of corn yield response and economic return to in-season corn N management practices.

Additional Project Partners:

Iowa Crop Producers
Iowa State University and ISU Extension
Division of Soil Conservation, Iowa Department of Agriculture and Land Stewardship
HAGIE Manufacturing, Clarion, IA, providing HAGIE NTB High-Clearance N Toolbar
Platte Valley Equipment, Fremont, NE, providing NITRO High-Clearance N Toolbar
John Deere Ag Management Solutions, coordination of in-season aerial imaging efforts

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Figure 1. In-season corn nitrogen management strategies project demonstration sites, 2006.

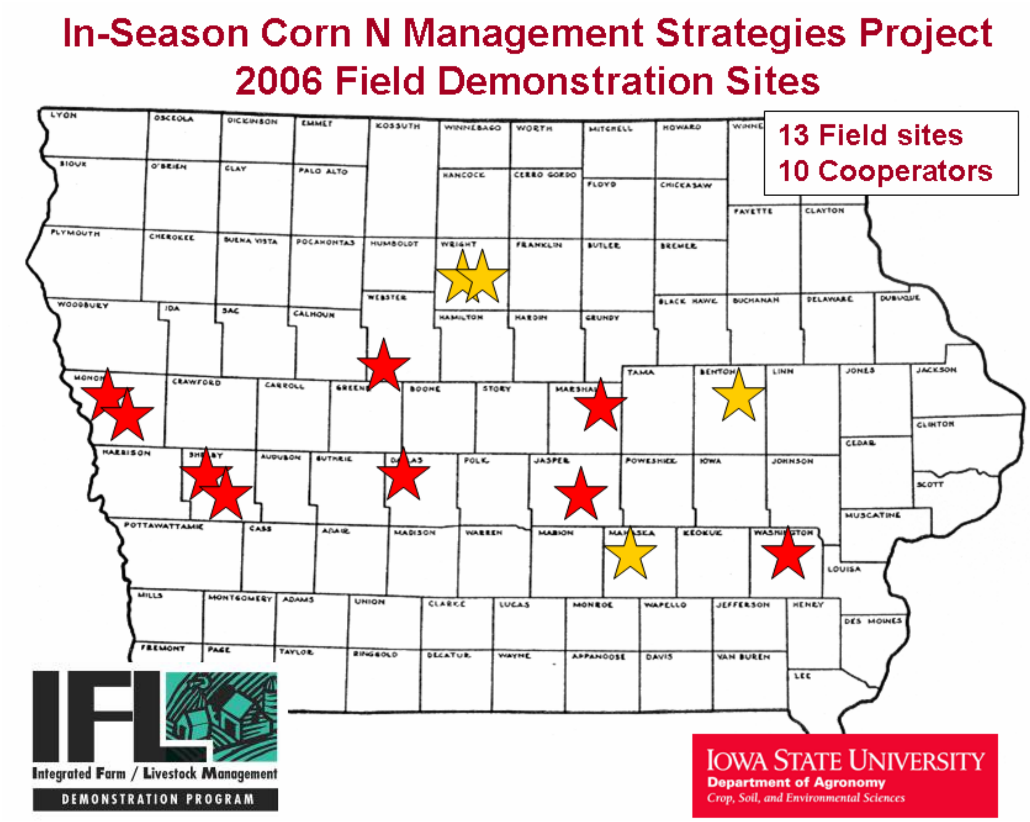

Figure 2. Demonstration of a SPAD chlorophyll meter measuring corn leaf greenness (N status).

Figure 3. Twelve row-wide, high-clearance nitrogen toolbars used to apply post-sensing N fertilizer in selected N treatment strips at project demonstration sites.

Figure 4. Mid-July view of corn response (leaf greenness) to field-length N rate strips.

Figure 5. Example project demonstration signage at a 2006 field site.

Table 1. Nitrogen application strategies, 2006 in-season corn N demonstration project.

Pre N rate[†]	Post-sensing N Application	N Application Treatment	Treatment Identifier
lb N/acre			
0	- - - - -	Control	0
60 (90)	- - - - -	Pre reduced N rate	60 (90)
60 (90)	At rate determined in-season	Pre reduced N + post-sensing N rate	60+ (90+)
120 (180)	- - - - -	Pre agronomic N rate	120 (180)
120 (180)	At rate determined in-season	Pre agronomic N + post-sensing N rate	120+ (180+)
240 (270)	- - - - -	Pre reference, non-N limiting rate	240 (270)

[†] Corn-soybean rotation N rate (corn-corn rotation N rate). Pre refers to N applied preplant or early sidedress.

Table 2. Site characteristics, management, recent years' corn N application rate and crop yield history, 2006 in-season corn N project sites.

County-Site	Soil(s)	Tillage[†]	Yield History[‡] Corn	Yield History[‡] Soybean	Average N-Rate History[§]	Manure History
			- - - bu/acre - - -		lb N/acre	
Dallas	Canisteo, Nicollet, Clarion	Conservation Tillage	190	52	155	None
Jasper	Tama	No-Tillage	178	57	160	None
Marshall	Tama	No-Tillage	177	54	120	None
Monona-1	Salix, Luton, Blencoe	No-Tillage	148	48	160	None
Monona-2	Blencoe, Salix, Luton	No-Tillage	132	43	160	None
Shelby-1	Monona	No-Tillage	185	50	100	Beef - Spring 1999
Shelby-2	Zook	Conservation Tillage	146	41	100	Beef - Fall 2000
Washington	Taintor, Mahaska, Kalona	No-Tillage	190	52	140	Liquid Swine - Fall 2003
Webster	Webster, Canisteo, Nicollet	Conservation Tillage	195	48	155	None
Benton-CC	Clyde, Aredale, Floyd	Conservation Tillage	190	50	180	Dairy Bedding - Fall 2003-2005
Mahaska-CC	Ladoga, Otley	Conservation Tillage	171	54	120	Liquid Swine - Spring 2001-2004
Wright-CC1	Canisteo, Webster, Nicollet	Conservation Tillage	183	43	173	None
Wright-CC2	Canisteo, Harps, Webster	Conservation Tillage	183	43	173	None

[†] Tillage system for the current crop year.

[‡] Yield history is average of last five to six crop years. Nine 2006 demonstration sites were corn following soybean; four 2006 demonstration sites were corn following corn (sites identified as "CC").

[§] Nitrogen application history for the last two or three corn crops.

Table 3. Planting dates, pre-sensing N and post-sensing N applications, 2006 in-season corn N project (corn-soybean) sites.

	Planting	Pre-Sensing N		Post-Sensing N (UAN solution) Application, lb N/acre		
County-Site	Date	Application Timing	N Source	Application Timing	60+	120+
Dallas	April 27	Early-sidedress, June 2 (V5)	Injected UAN solution	Coulter-injected July 7 (VT)	70	- - -
Jasper	April 24	Preplant, April 10	Anhydrous ammonia	Drop nozzle-applied July 7 (VT)	55	- - -
Marshall	April 24	Early-sidedress, June 15 (V5)	Injected UAN solution	Drop nozzle-applied July 13 (VT)	65	35
Monona-1	April 21	Post-emergence, May 23 (V3)	Broadcast UAN solution	No post-sensing N needed	- - -	- - -
Monona-2	April 22	Post-emergence, May 26 (V3)	Broadcast UAN solution	Drop nozzle-applied July 6 (V13)	50	35
Shelby-1	April 24	Pre-emergence, May 3	Broadcast UAN solution	Drop nozzle-applied July 5 (VT)	85	45
Shelby-2	April 27	Pre-emergence, May 4	Broadcast UAN solution	Drop nozzle-applied July 5 (VT)	30	- - -
Washington	April 21	Post-emergence, May 23 (V2)	Injected UAN solution	Drop nozzle-applied July 10 (VT)	75	- - -
Webster	April 18	Preplant, November 14, 2005	Anhydrous ammonia	No post-sensing N needed	- - -	- - -

Table 4. Planting dates, pre-sensing N and post-sensing N applications, 2006 in-season corn N project (corn-corn) sites.

	Planting	Pre-Sensing N		Post-Sensing N (UAN solution) Application, lb N/acre		
County-Site	Date	Application Timing	N Source	Application Timing	90+	180+
Benton-CC	April 24	Early-sidedress, June 5 (V5)	Anhydrous ammonia	No post-sensing N needed	- - -	- - -
Mahaska-CC	April 20	Post-emergence, May 18 (V1)	Broadcast UAN solution	No post-sensing N needed	- - -	- - -
Wright-CC1	April 26	Early-sidedress, June 9 (V5)	Injected UAN solution	Coulter-injected July 10 (V12)	30	- - -
Wright-CC2	April 26	Early-sidedress, June 9 (V5)	Injected UAN solution	Coulter-injected July 10 (V12)	30	- - -

Table 5. Effect of N application rate on average corn relative leaf greenness in field-length strips, 2006 in-season corn N demonstration project corn-soybean sites.

	N Application Treatment†					
Site, Corn Stage‡	None	60	60+	120	120+	240
	- - - - - - corn leaf greenness, relative to 240 lb reference N rate (%) - - - - - -					
Dallas, V11	88	93	91	96	96	100
Dallas, R3	81	94	93	97	97	100
Jasper, V10	72	94	87	97	95	100
Jasper, R3	65	88	93	97	101	100
Marshall, V14	82	91	92	95	95	100
Marshall, R3	76	89	93	97	98	100
Monona-1, V10	95	97	101	98	100	100
Monona-1, R4	88	98	97	97	100	100
Monona-2, V10	87	92	95	94	96	100
Monona-2, R3	- - -	- - -	- - -	- - -	- - -	- - -
Shelby-1, V11	77	88	92	94	94	100
Shelby-1, R3	87	94	99	97	98	100
Shelby-2, V11	92	96	95	99	98	100
Shelby-2, R3	91	97	97	99	99	100
Washington, V11	78	90	91	98	99	100
Washington, R3	66	76	91	96	97	100
Webster, V13	101	102	91	103	96	100
Webster, R3	- - -	- - -	- - -	- - -	- - -	- - -

† Refer to Tables 1 and 3 for description of N applications.

‡ Vegetative ("V") corn growth stages designate the number of fully-developed leaves present when "early" leaf chlorophyll meter data was collected; VT corn stage stage designates the tassel emergence stage. Reproductive ("R") corn growth stages designate the stage of reproductive grain development when "late" leaf chlorophyll meter data was collected.

Table 6. Effect of N application rate on average corn relative leaf greenness in field-length strips, 2006 in-season corn N demonstration project corn-corn sites.

	N Application Treatment[†]					
Site, Corn Stage[‡]	None	90	90+	180	180+	270
	------ corn leaf greenness, relative to 270 lb reference N rate (%) ------					
Benton-CC, V13	91	99	96	99	98	100
Benton-CC, R3	91	99	95	100	99	100
Mahaska-CC, V10	94	105	103	105	99	100
Mahaska-CC, R3	96	106	103	107	100	100
Wright-CC1, V10	87	97	97	99	99	100
Wright-CC1, R3	80	98	97	100	100	100
Wright-CC2, V11	78	95	97	98	98	100
Wright-CC2, R3	64	94	96	100	98	100

† Refer to Tables 1 and 3 for description of N applications.

‡ Vegetative ("V") corn growth stages designate the number of fully-developed leaves present when "early" leaf chlorophyll meter data was collected. Reproductive ("R") corn growth stages designate the stage of reproductive grain development when "late" leaf chlorophyll meter data was collected.

Table 7. Precipitation totals, 2006 in-season corn N project sites.

	Precipitation		
County-Site	2 weeks before Post-sensing N†	2 weeks after Post-sensing N‡	March 15 to October 15
	- - - - - - - - - - - - - - - -	inches	- - - - - - - - - - - - - - - -
Dallas	1.08	5.50	30.64
Jasper	0.82	0.64	24.31
Marshall	3.48	0.76	28.63
Monona-1	"no post-sensing N applied at this site"		22.63
Monona-2	0.53	0.32	22.63
Shelby-1	0.78	5.09	27.76
Shelby-2	0.78	5.09	27.76
Washington	0.54	2.63	21.68
Webster	"no post-sensing N applied at this site"		15.94
Benton-CC	"no post-sensing N applied at this site"		24.76
Mahaska-CC	"no post-sensing N applied at this site"		25.89
Wright-CC1	0.30	0.74	21.21
Wright-CC2	0.30	0.74	21.21

† Precipitation totals recorded at nearby weather stations during 2- week interval before post-sensing UAN application.

‡ Precipitation totals recorded at nearby weather stations during 2-week interval after post-sensing UAN application.

Table 8. Effect of nitrogen application rate on field-length strip corn grain yield, 2006 in-season corn N demonstration project corn-soybean sites.

	N Application Treatment†					
Site-Year	None	60	60+	120	120+	240
	- - - - - - - - - - - -	- - - - - -	- - - - - - bu/acre	- - - - - -	- - - - - -	- - - - - -
Dallas	152a‡	189b	199cd	196c	199cd	203d
Jasper	111a	164b	170b	184c	186c	188c
Marshall	161a	193b	203c	208cd	211d	211d
Monona-1	190a	202b	203bc	204cd	204cd	205d
Monona-2	93a	109b	116bc	110bc	116bc	120c
Shelby-1	160a	180b	182b	183b	186bc	190c
Shelby-2	207a	224bc	224c	227de	226cd	230e
Washington	106a	154b	171c	185d	176cd	185d
Webster	172ab	171ab	157a	179b	171ab	176ab

† Refer to Tables 1 and 3 for description of N applications.

‡ Yields at each site are not significantly different when followed by the same letter ($P \leq 0.10$).

Table 9. Effect of nitrogen application rate on field-length strip corn grain yield, 2006 in-season corn N demonstration project corn-corn sites.

	N Application Treatment†					
Site-Year	None	90	90+	180	180+	270
	- - - - - - - - - - - -	- - - - - -	- - - - - - bu/acre	- - - - - -	- - - - - -	- - - - - -
Benton-CC	207a‡	228c	221b	228c	226bc	226bc
Mahaska-CC	180ab	174a	186b	191b	190b	191b
Wright-CC1	120a	159b	158b	168b	172b	167b
Wright-CC2	93a	160b	163b	180c	181c	184c

† Refer to Tables 1 and 3 for description of N applications.

‡ Yields at each site are not significantly different when followed by the same letter ($P \leq 0.10$).