

## Options for in-season adjustment of nitrogen rate for corn

John E. Sawyer, professor and Extension soil fertility specialist, Agronomy, Iowa State University

### Introduction

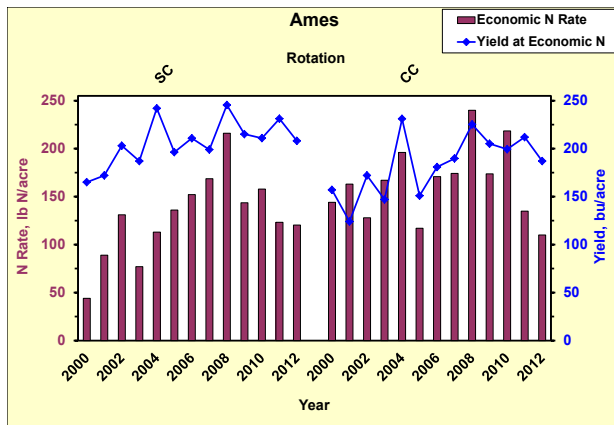
Periods of wetness and dryness extremes can have dramatic effects on available N supply from soil and loss of applied nitrogen (N) from fertilizer and manure. Such effects can happen quickly, as recently occurred with the large profile nitrate levels in the fall following the drought of 2012 and then the losses with excessive precipitation in the spring 2013. Compared to “normal” moisture and temperature conditions, seasonal differences can significantly reduce or increase needed N applications and cause variation in yearly optimal N rates (Fig. 1). Therefore, opportunity exists for seasonal refinement of N application rate. However, based on analysis of the Corn N Rate Calculator (<http://extension.agron.iastate.edu/soilfertility/nrate.aspx>) database for Iowa, the maximum added profit if the optimum N rate for each trial site could be applied instead of the MRTN rate would only be \$22/acre for corn following corn (CC) and \$16/acre for corn following soybean (SC); based on \$0.50/lb N and \$5.00/bu corn. Cost for site-specific N management (ex. information and N application) would subtract from the added profit.

Even if N is sidedressed after wet springtime conditions, wetness impact on soil derived N (residual nitrate and mineralized organic matter) influences needed fertilization rates. That is, excessively wet conditions before sidedress N is applied can result in increased needed fertilization rate. Similarly, if mid-to-late season conditions are more or less conducive to mineralization and nitrate retention in soil, then required N fertilization will be greater or smaller. Nitrogen processing in soil is dynamic, as is crop N use which further affects variation in N fertilization needs. Predicting season-long weather effects is difficult. There are several possible options to help assess N supply in-season and adjust N rate for corn, including soil nitrate testing, plant N stress sensing, and modeling.

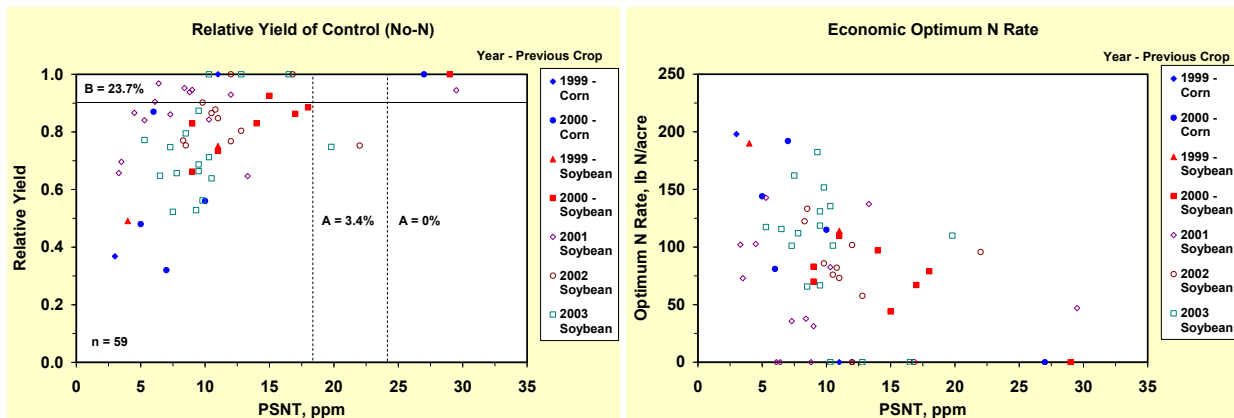
### Soil nitrate testing

The soil nitrate test utilized in Iowa is the Late Spring Soil Nitrate Test (LSNT) or Presidedress Soil Nitrate Test (PSNT) as it is called in other states. One-foot soil samples are collected when corn is 6 to 12 inches tall. Test concentrations are correlated to potential for yield response to added N, like a phosphorus or potassium test. Details of the test are found in ISU Extension and Outreach publication PM-1714 (<http://www.extension.iastate.edu/Publications/PM1714.pdf>). Soil nitrate can be sampled at other times and depths. For example, fall or spring preplant profile sampling to two feet or deeper (often 3 to 4 feet in dry or cold climatic areas) to determine the amount of nitrate-N in the soil profile. The LSNT timing is designed to measure nitrate-N concentration in the top foot as affected by residual nitrate, and early spring mineralized nitrate which fall or spring preplant sampling does not determine. Research in Iowa and the North Central Region (NCR publication 342, Bundy et al., 1999) did not find an advantage to deeper sidedress sampling. Also, there can be increased difficulty in obtaining a two-foot compared to a one-foot soil sample, although at times there can be significant nitrate-N below the top foot. As was found in the spring 2013, profile sampling in the fall or spring before planting in humid climates can have issues as significant nitrate movement and losses can occur after sampling.

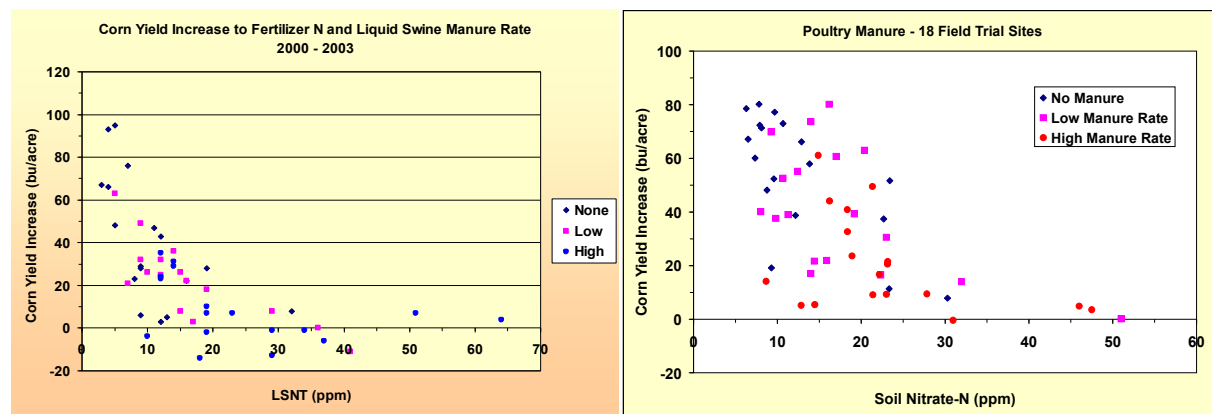
The LSNT is not perfect. While the desire is for test perfection because of corn yield sensitivity to N deficiency, as for any soil test the LSNT should not be expected to work correctly all the time. The error rate shown in Fig. 2 was approximately 27%, the same as a previous North Central Region evaluation project with the PSNT (NCR 342). Recent research in Iowa with swine and poultry manure also clearly indicated the potential for errors (Fig. 3). The greatest reliability has been when test results are above the critical value (20-25 ppm) where no corn yield response to additional N would be expected. More uncertainty occurs with tests below the critical value, when sometimes there is no or low yield response to additional N.



**Figure 1.** Variation in yearly corn economic optimal N rate and grain yield at one site at the Iowa State University Agricultural Engineering and Agronomy Farm, Ames, IA. The soil is a Clarion loam, with corn following soybean (SC) and corn following corn (CC) (J.E. Sawyer and D.W. Barker, 2012).



**Figure 2.** Correlation of the PSNT (LSNT) to corn relative yield when no fertilizer or manure was applied and relationship to optimal N fertilizer application rate. The A and B symbols indicate the type of test error (J.E. Sawyer and D.W. Barker, 2003).



**Figure 3.** Corn yield increase at different LSNT concentrations to fertilizer N applied in addition to liquid swine manure or poultry manure rate (adapted from Woli et al., 2013 and Ruiz Diaz et al., 2011).

### *Advantages*

- Season-specific information on needed in-season N fertilization rate.
- Sub-field specific information for rate decisions with detailed sampling.
- Feedback on preplant applied N sources.
- Interpretations can be specific for rotation and N source (such as corn following alfalfa).

### *Disadvantages*

- Requires one-foot soil sampling, sometimes with wet soil conditions.
- Time consuming to obtain enough samples for sub-field N application decisions.
- Time for sample analysis, although mobile labs can reduce this.
- Difficult to obtain test results that appropriately measure banded fertilizer or manure (requires many soil cores taken relative to the banded N). Sampling after recent fertilizer or manure application is unique for the LSNT, compared to the PSNT.
- Does not provide information on ammonium-N remaining from applied fertilizer or manure, which can cause erroneous low estimation of available N; especially an issue with high fertilizer and manure application rates and use of a nitrification inhibitor.
- Results only reflect soil nitrate-N at time of sampling, and soil nitrate-N concentration can change quickly after sampling.
- More than normal nitrate-N can be in the soil profile below one-foot.
- Leaching can be considerable and rapid in coarse textured soils.
- Test results are not calibrated to specific application rate; but provide general estimate for N rate – generally lower test results indicate higher required N rate (example in Fig. 2).

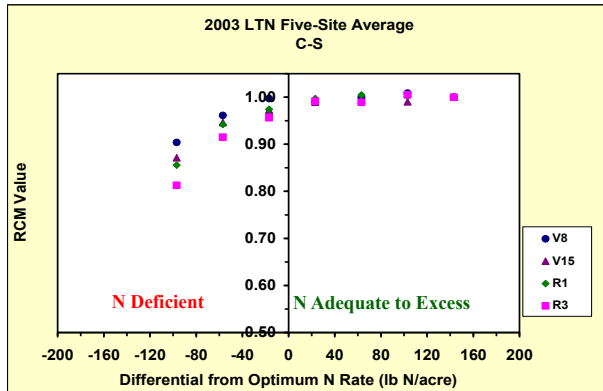
### **Mid-season corn sensing with active sensors**

There are two approaches to sensing corn plants to determine N stress (N status). One is using a device like the handheld Minolta SPAD chlorophyll meter to sample individual leaves. The second are the relatively new active canopy sensors that remotely monitor the corn plant canopy. Active sensors use modulated and specific wavelength emitted light, with measured intensity of light reflected back from the plant canopy to the sensor related to biomass and N status. Since the corn plant is used as the indicator of N stress deficiency or adequacy, the plant must have grown long enough, and taken up enough N, so that a potential N deficiency is expressed and can be measured. Otherwise, sensing systems will always indicate there is adequate N. Based on Iowa research, this means corn growth needs to be around the mid-vegetative V10 growth stage, and probably no earlier than V8 (Fig. 4).

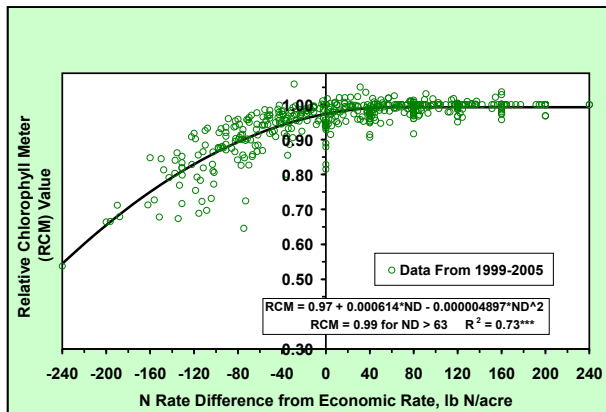
The Minolta SPAD meter is an active sensor as light is shown through a corn leaf; however, it is not a remote sensor as there is physical contact with the plant. The SPAD meter has been researched and calibrated in corn production since the early 1990's. Work in Nebraska indicated that a relative SPAD value of 0.95 (95%) or above (the critical value) indicated adequate N status of corn (relative SPAD means the SPAD reading is referenced against corn leaves from plants with known adequate N (i.e. not N stressed)). The referencing removes other potential factors that could affect corn leaf size and coloration, such as other nutrient deficiencies, different hybrid characteristics, moisture stress, etc. Research in Iowa indicated the critical value to be 0.97; with calibration data in Fig. 5. From the graph in Fig. 5, it is clear that the SPAD meter does not differentiate well slight N deficient situations (< 50 lb N/acre deficit) from adequate N. In fact, the SPAD meter and canopy sensors cannot tell when there is excess available N; that is, sensing values do not change as excess N is available to the plant. Details on use of the SPAD meter in corn are in ISU Extension and Outreach publication PM-2026 (<http://www.extension.iastate.edu/Publications/PM2026.pdf>).

There are several active canopy sensors in the marketplace. Examples include the GreenSeeker (Trimble), OptRx (Ag Leader), CropSpec (TOPCON), and Crop Circle (Holland Scientific). These sensors, when mounted on application equipment, provide canopy sensing on the go, and along with calibration (decision systems) provide real-time N

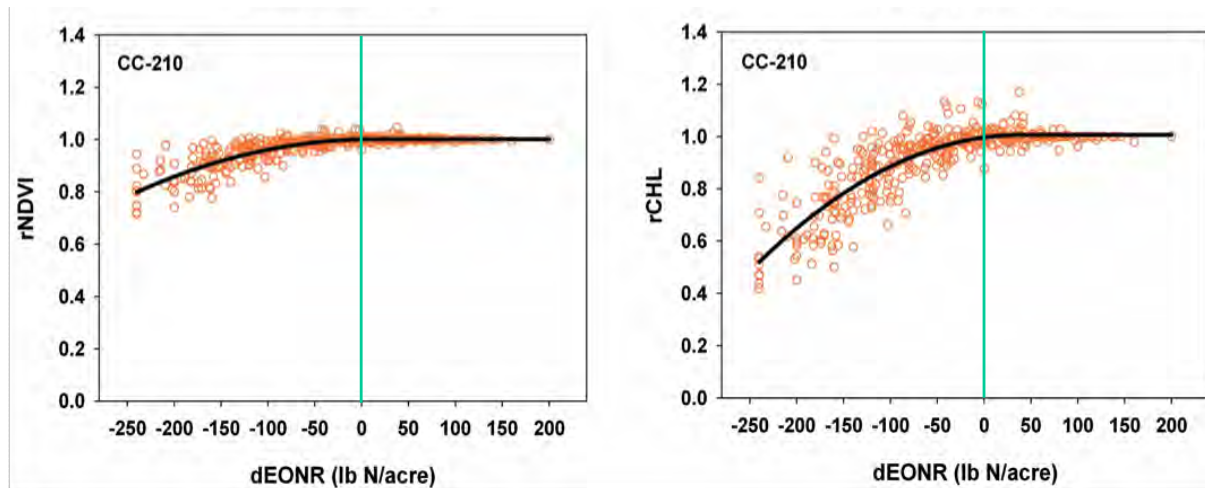
application rate decisions. Output from the sensor system can be any number of calculated indexes (calculated from the intensity of each wavelength measured), but commonly are NDVI (normalized differential vegetative index) or Chl (chlorophyll index). For example, NDVI index is calculated by  $(NIR-VIS)/(NIR+VIS)$  and Chl index by  $(NIR/VIS-1)$ . As with the SPAD meter, the output (index) of canopy sensors should be referenced against corn plant canopies that have known adequate N. Otherwise corn could be considered N deficient when there is actually another reason for a reduced canopy size or perceived N stress. Research in Iowa has shown that calibration is different for different indexes, but may be similar or different for different sensor systems (example calibration data in Fig. 6 for two indexes). Of importance is to use a calibration specific for the sensor and index (see manufacturer information) so the recommended N rate is correct.



**Figure 4.** Relative SPAD chlorophyll meter values (RCM) versus N rate difference from the optimum N rate at four corn growth stages (J.E. Sawyer and D.W. Barker, 2003).



**Figure 5.** Relative SPAD chlorophyll meter values versus N rate difference from the economic optimum N rate at the R1 corn growth stage (from Iowa State Univ. Extension and Outreach publication PM 2026).



**Figure 6.** Calibration of relative NDVI and Chl indexes with a Crop Circle 210 active canopy sensor relative to the difference from the economic optimum N rate (dEONR) (adapted from D.W. Barker and J.E. Sawyer, 2010).

### *Advantages*

- Uses the corn plant as an indicator of N stress; with the plant having time to integrate N availability across time.
- Provides instantaneous feedback on crop N status.
- Allows electronic integration to on-the-go N rate applications with sensors mounted on application equipment.
- Can provide site-specific (sub-field) N rate adjustment.
- If rainfall occurs shortly after in-season applications, corn can respond quickly and fully to applied N.

### *Disadvantages*

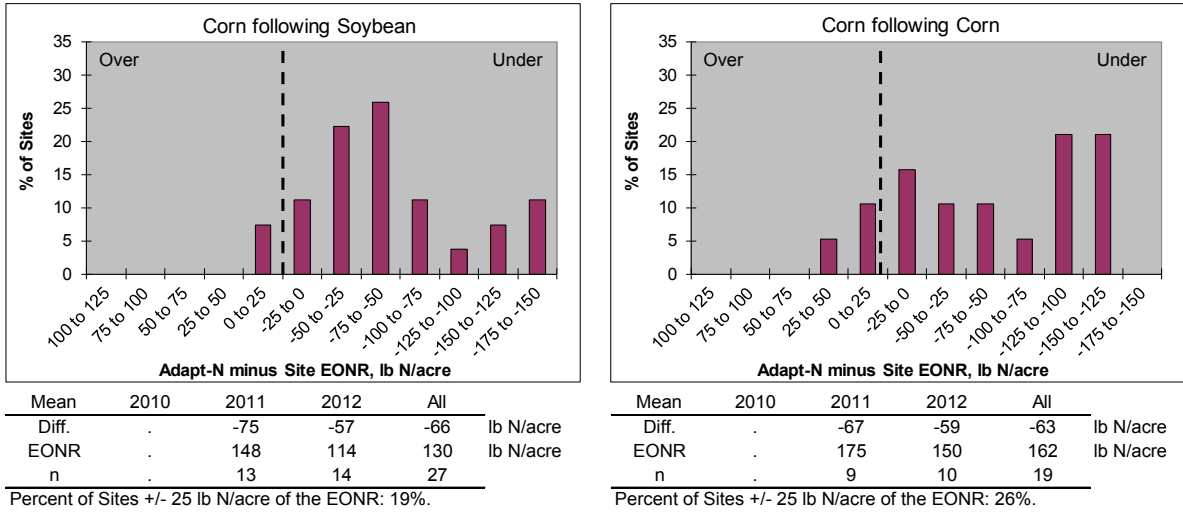
- Handheld sensors can be time consuming to obtain multiple readings; especially if sub-field rate adjustments are desired.
- Sensors must be employed using recommended operational methods; such as specific leaf and leaf area to be sensed (SPAD meter), relation to corn row and height range above the corn canopy (active sensors).
- Must have an “adequate or N rich” in-field reference system to properly determine N stress from other plant stresses or differences in calculated indexes. Nutrient deficiencies, like potassium and sulfur, will be “seen” by the sensor as N deficiency stress. Similar for hybrid differences, moisture stress, crop rotation, and specifically with canopy sensors plant stand.
- Sensor systems and output indexes must be calibrated to needed N fertilization rates.
- Corn plants must be of adequate size and have time for enough N uptake to express N stress that adequately relates to season-long N demand.
- Nitrogen sensing and applications typically occur after corn is too large for traditional sidedress equipment, thus needing to employ high clearance equipment.
- Mid-season N applications may occur during dry periods that limit plant uptake of applied N.
- Since corn plants must be N stressed to show N deficiency, yield potential loss can occur if the N stress is too great or persists for too long.
- If the corn canopy is too large, the sensor system may have a “saturated” light wavelength and not be able to detect N stress differences.

## On-line modeling

A relatively new approach to determining in-season N rate adjustments is use of model-based systems. One such system currently being promoted across the Midwest and Northeast U.S. is Adapt-N (<http://adapt-n.cals.cornell.edu/>). Adapt-N is an on-line system designed to use radar-interpolated rainfall, along with soil and crop models, to estimate sidedress N rate. The system uses a budget approach, with adjustments from an initial yield-based N rate. Input information for running the models include geo-referenced location, soil, rooting depth, slope, sod or soybean previous crop, soil organic matter, tillage system, corn hybrid maturity, planting date, plant population, expected yield range, any manure or fertilizer application date and placement, and in-season N run/application date. Expected yield is used to determine the base N rate for budget calculations. That amount is then adjusted for N currently in the crop, crop available N currently in the soil, N in soil after sidedressing, soybean credit if corn following soybean, losses after N applications, and an uncertainty of profit correction. The expected yield is assumed to be the economically optimum yield for the field, although as with all yield-based systems, the appropriate yield goal is nebulous. A recommended N rate and range is provided, with the range reflecting the uncertainty with post-application fertilizer losses. With the Adapt-N system designed to be year-specific for individual fields, refined calculation of early season potential losses via denitrification or leaching, and available N supply from soil mineralization, are of great importance.

Since Adapt-N is a new in-season recommendation system, an evaluation was conducted to compare N rate recommendations from Adapt-N to site-specific determined corn economic optimum N rate (EONR). The EONR from multiple N rate research trials in corn conducted across Iowa were used in the evaluation. There were 15 trials in 2011 and 21 in 2012, with CC and SC. The N fertilizer applications were sidedress from mid-May to early June at most sites as UAN solution, with a few sites having spring preplant urea application. Regression models were fit to the corn grain yield N response for each trial, and an EONR calculated at a 0.10 N:corn price ratio. For the Adapt-N recommended rate determination, each research site-specific information was used as input into the on-line Adapt-N. The recommendations were computed after harvest, but sidedress N timing (end date) was June 1. Each site-specific EONR was compared to the Adapt-N rate recommendation, with the EONR subtracted from the Adapt-N rate recommendation. Therefore, if a comparison to EONR was positive, then that recommended N rate was greater than the EONR; and if negative, the N rate was less than the EONR.

For the Adapt-N system rate recommendations, the distribution of rate differences from the EONR was shifted to an under-recommendation, with a mean across years difference of -66 and -63 lb N/acre, respectively, for SC and CC; with only 19 and 26% of sites that had a difference within +/- 25 lb N/acre of the EONR (Fig. 7). With Adapt-N providing a site-year specific N recommendation, it was surprising that the recommendations were not more closely related to the site EONR's (that is, "correct"), and did not result in a rate improvement (narrowing of the distribution range or centering close to the zero difference from the site-specific EONR's). It is unknown why Adapt-N recommendations were consistently lower than needed N application rates. Since the Adapt-N system uses a base N rate derived from expected yield, and appears to be a rate of approximately 1 lb N/bu, choosing a higher yield would increase the Adapt-N rate, but, increasing yield to the next higher range would only increase each recommendation by around 10-15 N/acre – not enough to shift the overall distribution to center around the zero mean difference from the EONR, and would not remove the distribution variation. The poor comparison results found could be due to many factors related to input information and model parameters used for factors such as rainfall distribution, soil properties, mineralization, nitrification, denitrification, leaching, N uptake, use efficiency, and lack of estimation for soil/plant N processing and losses after the Adapt-N recommendation timing. Estimating these model factors and interactions for an entire growing season is complex and difficult. The results indicate that perhaps the models and calculations within Adapt-N need calibration to Iowa soils, climate, and corn production conditions. This model-based approach to in-season N rate adjustment is new, and it is possible refinements in the future will improve field-specific recommendations.



**Figure 7.** Distribution of Adapt-N rate recommendations (sidedress timing) compared to site-specific economic optimum N rate (EONR).

### Summary

Above normal springtime precipitation has been a frequent occurrence in recent years. An extreme example was spring 2013. Excessively wet soil conditions affects soil N supply and puts applied fertilizer and manure N at risk; and makes in-season rate adjustment decisions an important part of ensuring adequate N for corn production. Several tools are available to help guide those decisions; including soil nitrate testing, crop N stress sensing, and on-line model calculation. Soil nitrate testing and plant sensing each have advantages and disadvantages, and best use occurs with an understanding of proper implementation and limitations. On-line models, such as Adapt-N, that incorporate weather information and soil/crop N processing are new, and thus should be used on a trial basis until more is known about reliability and success in improving N rate recommendations in Iowa conditions.