4R Management: Differentiating Nitrogen Management Categories on Corn in Iowa

By Peter M. Kyveryga and Tracy M. Blackmer

Results of two large-scale on-farm evaluation studies are summarized where farmers used later-season digital aerial imagery, corn stalk nitrate tests (CSNT) and yield monitoring technology to quantify differences between five major N management categories—formed by combining different application timings and N fertilizer sources.

The role of N fertilizer source and its timing of application in corn production is often emphasized in many soil fertility textbooks as major factors determining the economic efficiency of N fertilization as well as the risk of N loss from excessive soil moisture. In practice, however, the effects of common timings and sources on economic optimum N rates are difficult to quantify, complicating development of fertilizer N recommendations (Sawyer et al., 2006).

Historically in Iowa, farmers could apply N in fall, spring, as a sidedress and could use at least four N sources, including manure. To study the effects of these timing and source options, traditional yield response studies were required to include several (e.g. 3 by 4) treatment combinations at a single location. Moreover, studying the common interaction between rainfall, timing and N source required a relatively large number of trial locations. Even with this large number of environmental replications, studying these effects was often both impractical and cost prohibitive.

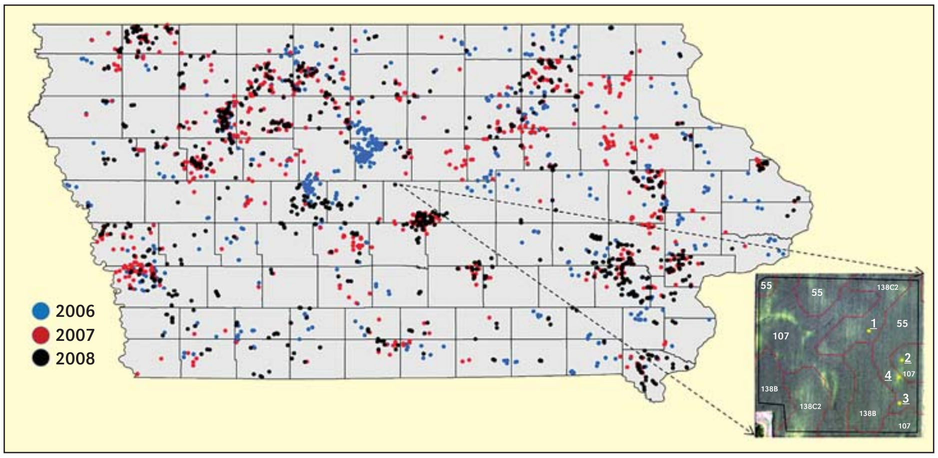

Figure 1. Locations of on-farm evaluations of late-season corn N status using digital aerial imagery of the corn canopy and CSNT across Iowa. Corn stalk samples were collected within the three predominant soil types and within a targeted deficient "Area 4" in each of > 2,300 corn fields during 3 years.

A renewed focus on using the best timing and sources of N application has been recently discussed in the 4R (Right source, Right rate, Right time and Right place) Nutrient Stewardship framework (IPNI, 2012). Using a variety of precision agriculture tools (i.e. yield monitoring, remote sensing and GPS) farmers can conduct studies on their own farms to collect data to quantify the effects of N timing and source on corn N status and corn yields across relatively large areas.

We summarize two types of on-farm studies conducted by farmers in Iowa to identify differences among five major N management categories—Fall AA, Fall Manure, Spring AA, Spring UAN (broadcast and incorporated in the majority of trials), and SD UAN or AA (referred to hereafter as just SD UAN)—created by combining common N timing and source applications in corn.

Interactive Effects of Rainfall and N Management Categories on the Size of N Deficient Areas within Fields

A 3-year survey was conducted within 683 farm fields in 2006, 824 fields in 2007, and within 828 fields in 2008 across Iowa (**Figure 1**). Using late-season digital aerial imagery of the corn canopy, four sampling areas were selected within each corn field to conduct a CSNT. Three stalk samples (10 individual stalks in each) were collected within the three predominant soil types to characterize the field-average corn N status. A fourth targeted sample was collected in an area that exhibited a lighter colored corn canopy in the aerial imagery, which we interpreted as a N deficient area of the field. The stalk sample collection and test interpretations were done according to the previous CSNT test interpretations in Iowa (Blackmer and Mallarino, 1996).

Digital aerial imagery (comprised of blue, green, red, and near-infrared bands) of the corn canopy was acquired in late August or early September. Green band reflectance values of the imagery and stalk nitrate values were used to estimate the size (%) of N deficient and sufficient areas within each field. The estimated N deficient areas corresponded to the deficient category (< 250 ppm) and the N sufficient areas (> 250 ppm) corresponded to the marginal, optimal, and excessive categories of the CSNT results. Kyveryga et al. (2011; 2012) describes more information about the properties of digital aerial imagery and the methods of normalization of the imagery, and estimation of the areas (%) within fields with different N status. The size of the N deficient area and summary statistics of N rates that corresponded to the optimal corn N status were compared among the five N management categories (Fall AA, Fall Manure, Spring AA, Spring UAN, and SD UAN).

The average estimated N deficient area for corn after soybean in 2007 (relatively wet) and 2008 (extremely wet), was from 45 to 300% higher than that in 2006, a relatively dry

Common abbreviations and notes: N = nitrogen; Fall AA = fall-applied anhydrous ammonia; Fall Manure = fall-injected liquid swine manure; Spring AA = spring-applied anhydrous ammonia; Spring UAN = spring-applied urea-ammonium nitrate solution; SD UAN = sidedress UAN; GPS = global positioning system; ppm = parts per million.

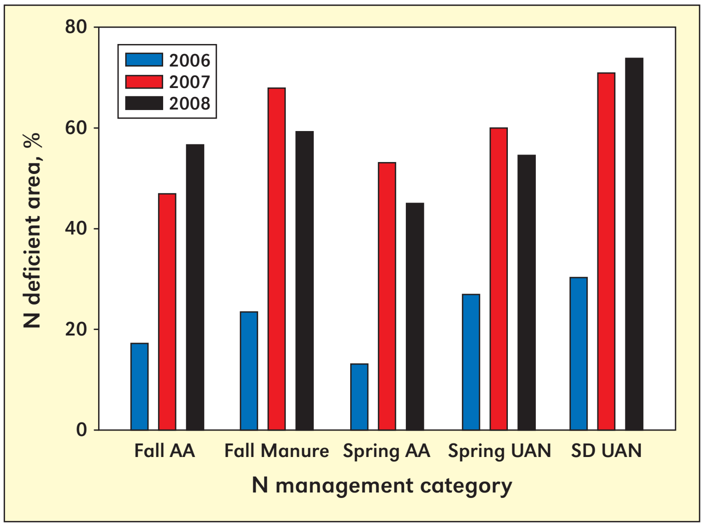

Figure 2. Estimated average N deficient areas within cornfields for five N management categories for corn after soybean in relatively dry 2006, wet 2007, and extremely wet 2008 growing seasons. Only fields (565 in 2006, 240 in 2007, and 311 in 2008) that did not have extensive flooded areas, terraces, waterways and more than one corn hybrid were used in the analysis.

year (**Figure 2**). More than 50% of the field area in some N management categories was estimated as N deficient in 2007 and 2008, with about 75% of the SD UAN areas being deficient in 2008. In 2006, Spring UAN and SD UAN management had larger N deficient areas than where other fall or spring N management categories were used, mostly due to limited soil moisture and lower N availability. In 2007 and 2008, average N deficient areas for Fall AA, Fall Manure and Spring UAN were significantly larger than those for Spring AA. Assessments of spatial variability in the corn canopy reflectance for Spring AA also indicated that N losses were lower under this management category. In fact, Spring AA had the smallest percentage N deficient areas of all the timing and source combinations tested in relatively dry 2006.

Observed N Rates Corresponding to the Optimal Corn N Status

In each year, more N from Fall Manure was required to reach the optimal CSNT status than from any other N source or application timing (**Figure 3**). This could be explained by relatively larger N losses, the larger uncertainty in estimated N rates applied by farmers, and/or by smaller than expected N availability from liquid swine manure. Fall AA required the second highest amount of N for optimal stalk nitrate status while spring and sidedress N applications consistently required the lowest amount of N. Most of the CSNT samples from the SD UAN management category were N deficient in extremely wet 2008 (**Figure 2** and **3**).

Differences in Critical CSNT Values between N Management Categories

In 125 on-farm trials conducted from 2007 to 2010 across Iowa, farmers compared their normal N rates to those that were one-third or 50 lb N/A higher or lower (**Figure 4**). Each corn after corn or corn after soybean trial consisted of two non-randomized alternating N treatments (normal and normal plus

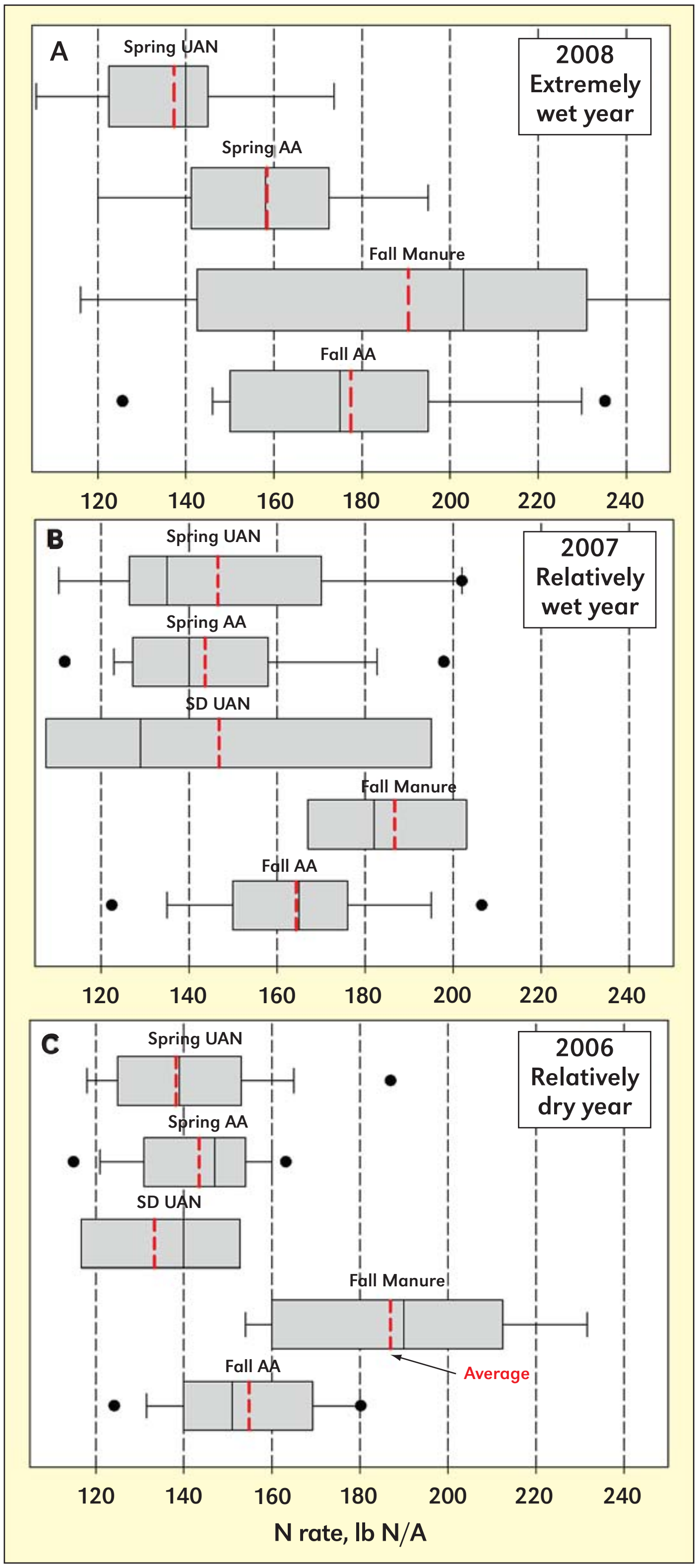

Figure 3. Box plots showing summary statistics for observed N rates corresponding to the optimal category of CSNT for five N management categories for > 1,400 corn-after-soybean fields evaluated during the 3 years. The boxes indicate 25th and 75th percentiles, the black vertical line represents the median, the red vertical line is the average, and whisker bars indicate 5th and 95th percentiles. The summary for applied N rates for SD UAN in 2008 is not shown because most of the fields with SD applications tested below the optimal.

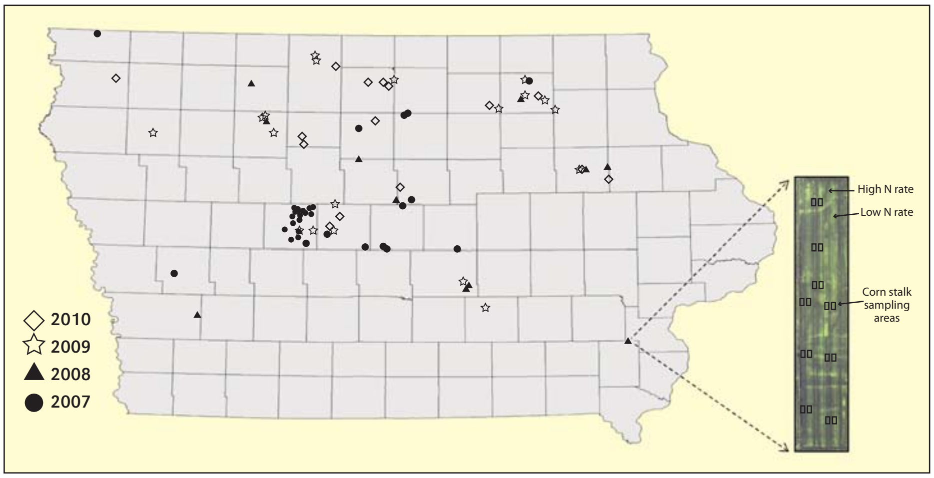

Figure 4. Locations of 125 on-farm two-treatment N evaluation trials conducted during 4 years. Each trial had the farmer's normal N fertilizer rate compared to a rate that was one-third or 50 lb N/A higher or lower. Nine sampling areas were used to collect CSNT samples within fertilizer strips which received the lower N rates.

or minus 50 lb N/A) replicated at least three times within an area > 20 acres. The risk of potential bias from not randomizing N fertilizer treatments in these multi-location trials is relatively small compared with small-plot trials, which are often conducted at one or at very few locations (Kyveryga et al., 2013). The treatments were harvested with combines equipped with yield monitors and GPS. Categorical economic (profitable and non-profitable) yield response was related to CSNT values collected within nine sampling areas from the lower N rate in each trial. A yield response of > 5 bu/A was considered profitable from application of an additional 50 lb N/A. Using estimated probabilities of a profitable yield response to the additional N, critical CSNT values were estimated for each N management category using multilevel binary (profitable and non profitable) categorical analysis from the data across 4 years.

The probability of receiving a profitable yield response (> 5 bu/A) to an additional 50 lb N/A applied in the near-optimal range of fertilization and the critical CSNT values for the five N management categories for corn after corn and corn after soybean are shown in **Figure 5**. The critical values separated deficient samples (those with probabilities > 0.51) from N sufficient samples (those with probabilities < 0.49). The critical CSNT value for Fall Manure was about 3,500 ppm, which was about 1,500 ppm higher than is currently recommended for the upper end of the optimal CSNT category in Iowa (Blackmer and Mallarino, 1996). Also, the critical CSNT value for Fall Manure was about 3,000 ppm higher than CSNT values for Fall AA, Spring UAN and SD UAN or AA. The estimated probability values for Fall Manure were also consistently higher across all N sufficiency ranges. These observations confirmed the results of the 3-year survey shown in **Figure 3**. Despite the higher amount of N applied, a category of Fall Manure is characterized by larger uncertainty and variability in corn N status than N management categories with commercial N sources used in Iowa.

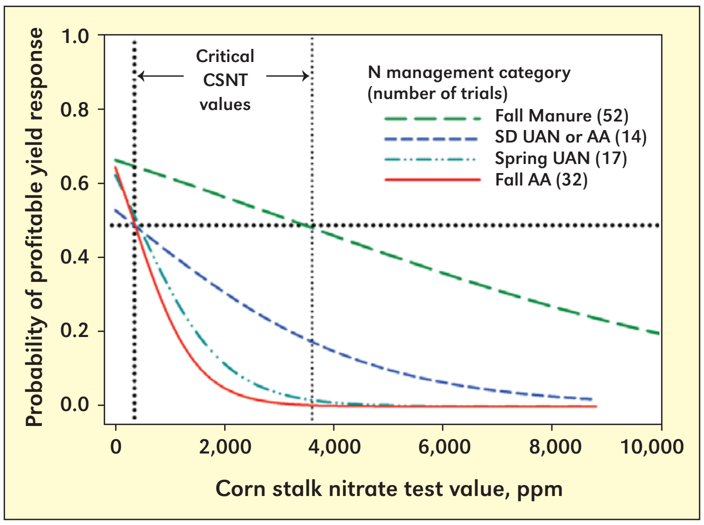

Figure 5. Critical CSNT values separating N deficient and sufficient categories for the five N management categories for corn after corn and corn after soybean, based on 125 two-treatment on-farm N evaluation trials.

Summary

Two large-scale on-farm evaluation studies confirmed the importance of considering interactions between rainfall, N timing and N sources in Iowa cornfields. Commonly used N management categories showed differences in the size of N deficient areas within fields, average N rates corresponding to the optimal corn N status, and the probability of receiving a profitable yield response to additional N applied in the near-optimal range. The described field methodology and data analysis can be used to focus more on collecting local data to study the complex interactive effects of rainfall, application timing and N fertilizer sources on corn N status and yields. These on-farm research approaches can be used to support guidance on fertilizer best management practices to increase the economic efficiency of applied N while reducing its potential negative impacts on the environment. Assessment of the risk associated with reducing normal N rates applied by farmers can also be estimated using similar on-farm evaluations conducted at different spatial and temporal scales (Kyveryga et al., 2013). BC

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