NEBRASKA NITROGEN MANAGEMENT PRESENT AND FUTURE

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ABSTRACT

University of Nebraska faculty have been refining their N rate recommendation procedure since the 1970s. At that time, they introduced a procedure for predicting soil nitrate-N availability and effect on subsequent corn N needs. In the 1990's this procedure was refined based on 81 state wide N rate experiments. In 2003-2006 it was re-confirmed with 32 state wide irrigated corn trials. The current algorithm is the following: N need (lb/ac) = [35 + (1.2 x EY) - (8 x NO3-N ppm) - (0.14 x EY x OM) - other N credits] x $Price_{adj}$ x $NTiming_{adj}$. Where: EY = expected yield (bu/ac); NO3-N ppm = average nitrate-N concentration in the root zone (2-4 foot depth) in parts per million; OM = percent organic matter; other N credits include N from legumes, manure, other organic materials, and from irrigation water; $Price_{adj}$ = adjustment factor for prices of corn and $NTiming_{adj}$= adjustment factor for fall, spring and split applications. Over the last decade more emphasis has been placed on using sensing technology to make real-time decisions about how much nitrogen is needed at the V8-V11 stage. These one-time side dress procedures are currently being refined in the on-farm research Project Sense. Other work in the field and laboratory are working to find appropriate uses of enhanced fertilizer efficiency products.

INTRODUCTION

Nitrogen use for corn production is under continuous scrutiny. The farmer seeks to optimize its use for profit and efficiency. Many Nebraska Natural Resource Districts have had Nitrogen Management Plans for 25 or more years requiring periodic certification and reporting of soil N, fertilizer N application, irrigation water N content, water applied, and yield. Concern about surface water is highlighted by the recent lawsuit over nitrate-N in the Des Moines IA water supply. Several agricultural corporations have launched on-line tools to manage N throughout the season such as Climate Corp and Pioneer. Some consultants advise on N management using Adapt-N or a similar tool. Not all these private tools are completely documented, meaning that they do not publish the underlying assumptions and formulas used to estimate N use or loss.

The NRCS uses UNL recommendations as published in our NebGuides and Extension Circulars, as well as our experience and research data base to inform their recommendation and procedures. These publications are revised at least every five years with reinterpretation of past and new information although the history and rationale for changes are not documented in the Extension resources. This paper reviews our UNL recommendations and how farmers have reported their N use over the years (Ferguson, 2015).

This paper is authored by current UNL nutrient management Extension faculty but this is an ever changing group. In 2015 Dr. Gary Hergert retired, at least two others intend to retire before mid-2018. Dr. Ferguson will assume the role of Interim Department Head for the Department of

Agronomy and Horticulture in July, 2017. Drs' Shaver, Maharjan and Krienke are relatively recent to our group and plan to continue as UNL nutrient management specialists. Contributions of Agricultural Research Service and other UNL scientists have been and continue to be a valuable part of information supply for developing and refining recommendations.

The objective of this paper and the talk that will accompany it is a look back at how we have arrived at our present N recommendation procedures and a glimpse forward to where we think it might go. In addition, we have compiled a bibliography of N related publications from UNL soils faculty going back to 1952 (http://agronomy.unl.edu/nitrogen). In addition a similar paper was published as part of the Nebraska Extension Crop Production Clinic series (Shapiro et al., 2017)

HISTORY

Nebraska soil scientists have been working on use of soil generated and carry-over nitrate-N-N since at least 1958. A mimeographed publication dated 1958 discusses the potential yield increase from N fertilizer based on the 'nitrification rate' test, but not much other documentation is provided. With slightly more information, an unsigned Nebraska Extension chart dated 1962 describes soil nitrate determined by a 10 day incubation at 75^{o} F. Soil nitrate-N, derived from the incubation test, was separated into a range of levels (0 -27 ppm nitrate-N) and these levels were further subdivided based on rainfed soil conditions separated into three classes [below average (<2 ft moisture), average (2-4 ft moisture), above average (>4 ft moisture).] Based on this table of soil nitrate-N released and soil moisture, a N recommendations ranging from 0 to 100 lbs N/acre was given (for a corn yield goal of 125 bu/ac.)

In 1968 the Nebraska Soil Testing Laboratory introduced a 'new' nitrate-N test that measured soil nitrate-N rather than incubated nitrogen. The nitrate-N test accounted from recently produced nitrate-N and for the residual soil nitrate-N remaining after harvest which was often substantial due to high application rates of inexpensive fertilizer N (Schwartz, 1968). No guidelines for interpreting the nitrate-N test information into a N recommendation were provided.

As early as 1981, the UNL the corn fertilizer N algorithm or formula considered yield goal and residual soil nitrate-N based on available research at the time to achieve profitable yield (Knudson, 1981). Residual soil nitrate-N was inputted as pounds of N with an adjustment for sampling depth to estimate a credit for crop available N from the residual nitrate-N in the top 6 ft of soil. In addition to yield goal and residual soil nitrate-N, the formula accounted for the effects of previous crop, applied manure, and nitrate-N in irrigation water.

Recommended N in lbs/ac: $[(0.9 \times YG)/(1-0.0008*YG)] + 50 - \text{SoilN-lbs}$

with YG = Yield Goal and SoilN-lbs = soil nitrate in lbs N/6 ft depth

In the early 1980s, before any current soils faculty were hired, the soil fertility faculty generated a large dataset from 81 site years of N rate trials over several years under many field conditions which was analyzed by Dr. Gary Hergert who then proposed revisions of the corn N algorithm. These included:

1. The use of the weighted average for residual soil nitrate-N concentration (ppm and not lbs N/acre) for a soil sample depth of at least two feet;

2. Consideration of soil organic matter level with a formula for estimating the release of N from soil organic matter;
3. Revision of the soybean N credit.

The formula as of 1993 is similar to the current algorithm:

N rate (lbs N/acre) = [35 + (1.2 x EY) - (0.14 x EY x OM) - 8 x SoilN-ppm - Other credits] x f_A x f_R

EY = expected yield (105% of mean yield for past five years, bu/acre)
OM = organic matter (%, between 1 and 3%)
SoilN-ppm = weighted average soil nitrate-N test (min 2-ft) ideally before planting in spring
Other credits: legumes, manure, irrigation; not adjusted for depth as previously done.

Added after 2004 were
f_A = application timing adjustment factor
f_R = price ratio adjustment factor

These changes were accepted and the new formula was published in our corn NebGuide in the early 1990s. The credits for irrigation water N, manure N, and other previous crops remained with some revision over time. Default values for when measured values are not available are used for residual soil nitrate-N and for the amount of irrigation water applied when records of past years are inadequate.

Between 2002-2004, 32 site-years of research were conducted across Nebraska to evaluate high yield corn responses to N, P, K, and S through the project called the Nebraska Soil Fertility Project (NSFP). Results of NSFP were used to validate or update our recommendations for irrigated high yield situations. The earlier 81 site-years included both irrigated and rainfed sites, but NSFP sites were all irrigated and average yield with fertilizer applied was >230 bu/ac. The experimental procedures and major findings were reported in (Dobermann et al. 2010; Wortmann et al. 2010). These findings included:

1. The corn N formula estimated fertilizer N need very well on average but did not account for much of the year-to-year variation in the economically optimal N rate (EONR). The NSFP results did not indicate an opportunity to improve the predictive power of the corn N formula to better account these variations in EONR.
2. The corn N response curve differed for continuous corn compared with corn following soybean and the response to fertilizer N was less variable for corn following soybean (Figure 1). We have discussed using two procedures, one for corn on corn and one for corn on soybean ground, but this has not been developed.
3. We revised our corn nitrogen recommendations to account for the corn price: nitrogen price ratio. Therefore the recommended corn N rates are higher with low N cost relative to corn price, but lower when nitrogen is relatively more expensive (Table 1, factor Fr above.)

Table 1. Economic adjustment to the University of Nebraska Corn Nitrogen Recommendation algorithm.

Corn:N price ratio	5	6	7	8	9	10	11	12	13
f_R	0.78	0.87	0.94	1.00	1.05	1.10	1.13	1.16	1.19

f_R= price ratio adjustment factor = 1.311 (1 – $exp^{-0.181x}$);
x = Corn:N price ratio ($per bu corn/$ per lb N)

4. The corn N formula was revised to consider whether the time of N application adjusting fall, spring/preplant, or predominantly in-season with respective N rate adjustments of 105, 100, and 95% of the predicted N. Factor Fa above.

   The corn N calculator http://cropwatch.unl.edu/soils/software (download the Excel Spreadsheet 'Corn Nitrogen Recommendations Calculator') allows the user to enter data to calculate an N rate with and without the economic analysis. The details of the calculations and assumptions used are provided. The calculator was last updated in 2008 and is in need of several revisions.
5. The corn N calculator considers more information and does more detailed calculations compared with the published corn N formula in Extension Circulars EC117 and EC155. The main difference is it assumes different bulk density values for sandy and fine textured soil when converting soil nitrate-N from a concentration to weight. The corn N calculator differentiates the forage legume credit based on soil texture.
6. The corn N calculator does not calculate environmental implications that may result from greater recommendations for fall application.
7. At this point in time, the calculator does not make any adjustments for use of enhanced nitrogen efficiency products such as inhibitors and slow release fertilizers. There is a stand-alone spreadsheet that estimates various N losses and potential changes in N loss by the use of several management options and accompanying documentation (Wortmann et al., 2014; spreadsheet at: http://cropwatch.unl.edu/soils/software)

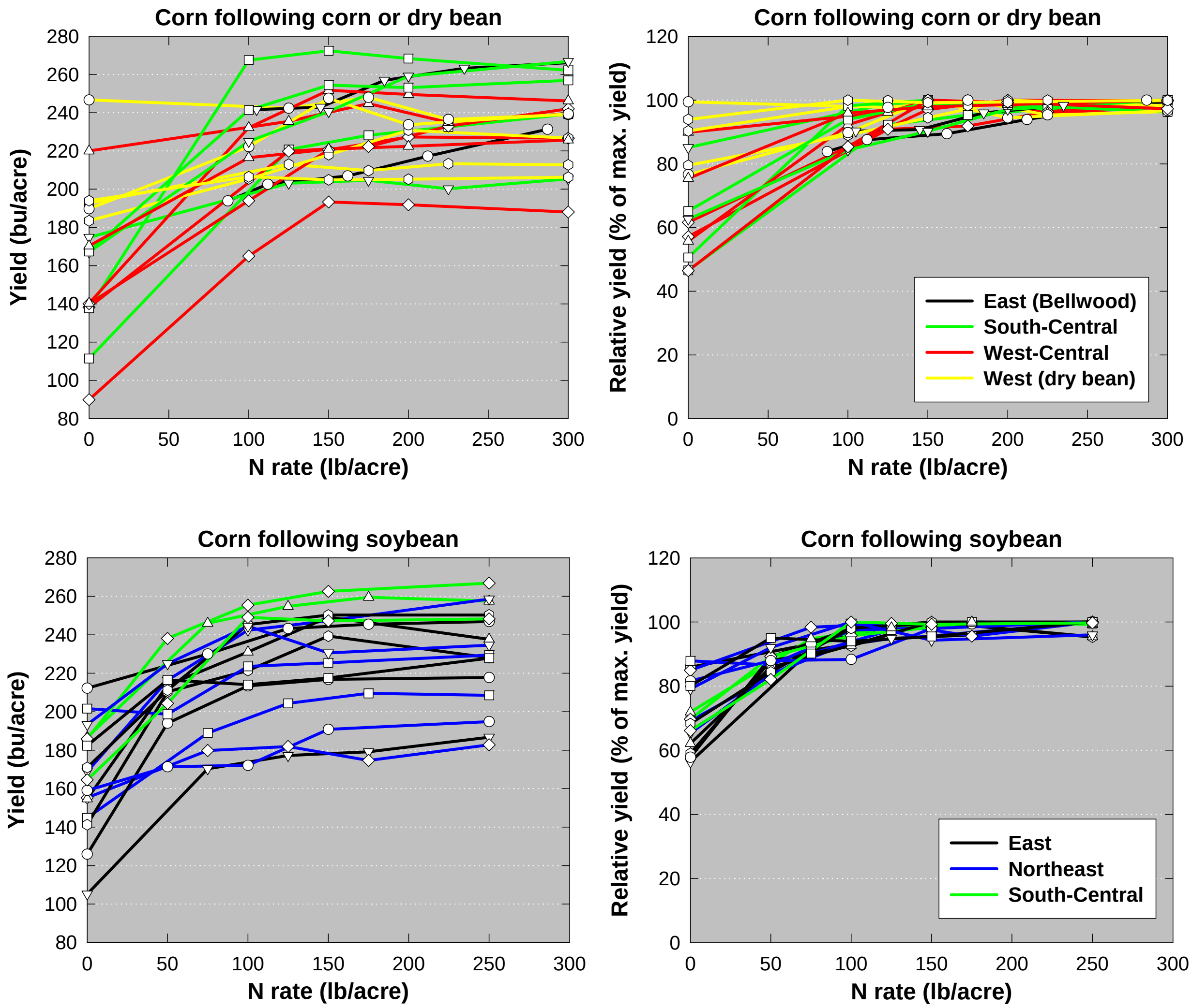

Figure 1. Corn response to N in absolute yield and relative yield for continuous corn and corn following soybeans. From the NSFP project 2002-2004.

Considering the four Rs of nutrient stewardship (timing, rate, source, placement), the above is focused on N rate, time of application, and nutrient source (fertilizer, manure, irrigation water, soil organic matter and residual nitrate-N). Results of research on fertilizer N use efficiency products (inhibitors and controlled release products); sensor guided in-season N application; and crop residue harvest management have not been integrated into the corn N algorithm but the principles and the interpretation of results for different production conditions are addressed through Extension activities.

In Nebraska in 2015, over 5 million acres were irrigated. Irrigation management is critical to nitrogen use efficiency on corn since over-irrigation can leach nitrates, and under irrigation will reduce yields. Much research has been conducted on irrigated fields to help optimize these two critical inputs (Ferguson et al., 1991). A comprehensive management guide to both nitrogen and irrigation management is available at: http://extensionpublications.unl.edu/assets/pdf/ec2008.pdf (Kranz et al., 2015).

The first NebGuide addressing use of crop canopy color to guide in-season N application addressed the use of a chlorophyll meter (Minolta SPAD 502), the precursor to the crop sensors that are more popular today. This work was conducted by the Agricultural Research Service division located at the University of Nebraska and was led by Dr. Jim Schepers, with help from Drs. Gary Varvel and Dennis Francis. Present recommendations using the SPAD meter are found in the NebGuide: Using a chlorophyll meter to improve nitrogen management (Shapiro et al., 2006).

Farmer adaptation of University of Nebraska Recommendations

Each NRD collects data on the N use of their farmers who irrigate. A brief summary of some overall N use in Nebraska is in section B of Kranz et al. (2015.) Based on the summary of six target areas, the average application rates was 172 lbs N/acre compared with the average recommended rate of 164 lbs N/acre but actual rates varied within and between fields and across the state. The average N use efficiency of fertilizer nitrogen was 1.1 bu of grain per lb of N; when all sources of N were accounted for the efficiency was 0.72 bu/lb of N. We generally discuss this metric in lbs N/bu which would be 1.4 lbs N per bushel of accountable N compared to 0.9 lbs fertilizer N/bu corn. The latter is closer to what is considered very efficient, but the 0.5 lb N discrepancy in efficiency considering total N credits (fertilizer, manure, organic matter, etc.) compared with applied N implies opportunity to greatly improve N use efficiency.

In another study of farmer reported N management, Ferguson (2015) discusses in-depth the behavior over time of farmers in the Central Platte Valley. Ferguson reports that N use efficiency in metric terms (kg grain/kg N) has remained steady (60-65 kg grain/kg N; 1.1 bu/lb applied N), although at the high end of the state average (in 2012, 67 kg grain/kg N.) Groundwater nitrate-N has decreased over the 1988-2012 period from 19 ppm to 15 ppm, attributed largely to the conversion from furrow to sprinkler irrigation. The data in this report suggests that N credits are not being fully taken and that there is more work to be done to determine if these credits are 'real' or ways to overcome the resistance to using them needs to be developed.

Future N management

The basic corn algorithm described above is part of a computer model, Maize-N (Setiyono et al., 2010.) Maize-N is much more comprehensive using historical weather, current season weather and the corn growth model, Hybrid-Maize (Yang et al., 2004; Yang et al., 2006.) While this tool is available for purchase, it is not widely used and is still being modified. It is expected to be useful in predicting in-season losses that will helpful in adjusting pre-season N rate during the season.

Sensor based technology is under continuous development. Thompson et al. (2015) compared the modeling and sensor approach and Ferguson et al. (2017) reported on bringing the technology to the farmer field level, in 2015 N applied with sensor use had 25% decreased N rates compared to the producer rates, and an increase in N use efficiency from 1.2 bu/lb N to 1.5 bu/lb N; these savings and increased productivity resulted in about $7.75 greater partial profit per acre.

Most sensor based research has been focused on a one-time adjustment near V11 corn growth stage, but other research is being conducted on periodic sensing and season long N additions if sensors indicate a need.

Nitrogen use efficiency has steadily increased since the 1960s, but much applied N is not accounted for by crop uptake and the pre-season ability to predict N need for a field in a given year remains weak. Opportunities for improving these deficiencies is expected through the use of models and the in-season assessment of corn N status.

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