INDEPENDENCE OF CROP YIELD AND NITROGEN RATE ACROSS SITES

D.W. Franzen, L.K. Sharma, H. Bu, E.C. Schultz, J. Breker, and A. Denton
North Dakota State University, Fargo, ND
david.franzen@ndsu.edu

ABSTRACT

Historically soil fertility specialists in the North Central States of the USA have constructed nitrogen (N) rate recommendations based on 'yield goals' or 'expected yield'. Within the past ten years, there has been a general realization by soil fertility researchers that within a site or field there is a relationship between N rate and yield; however, because of soil and weather differences between sites there is no relationship in N rate studies with a large number of sites between yield and N rate. Reexamination of spring wheat, corn, and sunflower N rate data sets in North Dakota indicates that the current trend towards 'maximum return to N' used as a basis for recommendations in several North Central State, without regard to expected yield, is a valid and necessary approach to fertilization.

INTRODUCTION

Historically, soil fertility specialists of the North Central States of the USA have constructed N application rate recommendations based on 'yield goals' (Dahnke et al., 1992; Hoeft and Peck, 2002; Warncke et al., 2004) or 'expected yields' (Vitosh et al., 1995). The yield-based approach perhaps made sense when high-yield corn was 80 bushels per acre, as it was in North Dakota in the 1970's, or 150 bushels per acre, as it was in Illinois during the 1970's. These early N recommendations also did not consider economics, which was understandable given the rate of grain surpluses in the US during the late 1970's through the mid-1980's and the subsequent narrow range of prices paid to farmers for those crops. In addition, from the mid-1970's through the early 1990's, the range of fertilizer prices was similarly narrow. From the drought years of 1988 through the early 1990's when high rainfall and subsequent small grain diseases devastated the northern plains wheat crops, the surplus of grain disappeared, natural gas prices rose, and the prices for crops and for fertilizer inputs became much more volatile.

From the N research side, it became increasingly more difficult to justify a yield-based approach. The yield-based approach psychologically drove farmers to increase N rates because the formula implied that higher N rates meant greater yields. In most studies, yield was not limited by N, but it was limited by too much rain, not enough rain, and soil differences that either enhanced the efficiency of water and nutrient use or made poor use of water and/or nutrients. Due to increased economic volatility, and also due to the frustration by soil fertility specialists and researchers in their N recommendation system deficiencies, a regional approach was advanced based on accumulated data from each participating state. The factors incorporated into the new N recommendations were yield responses to N rate, and economics of the application. Several states within the North Central Region now have a version of the Maximum Return to N (MRTN) concept explained by Sawyer and Nafziger (2005) at this conference eleven years ago.

Although not specifically stated, the MRTN approach contains little consideration of yield expectations. The researchers seemed to recognize that yield was not driven by N rate, but were instead driven by other factors. Recently, studies have examined long-term data from N-rate experiments and have shown that there is no relationship between N rate and yield achieved between these experiments (Raun et al., 2011; Arnall et al., 2013; Franzen et al., 2016).

North Dakota State University wheat N rate recommendations have been based on the MRTN approach since 2010 (https://www.ndsu.edu/pubweb/soils/wheat/), corn N rate recommendations since 2014 (https://www.ndsu.edu/pubweb/soils/corn/), and sunflower recommendations since April, 2016 (https://www.ndsu.edu/pubweb/soils/sunflower/). During a presentation in Fargo at the annual Soil and Soil Water Workshop to regional certified crop advisors (CCA's) in January, 2016, a respected consultant asked how we could establish N rate recommendations for sunflower when the relationship between available N and yield was so poor. The question struck me, because having found a strong relationship between available N and sunflower yield at each location, the combined relationship was significant, but was related statistically more poorly than within any individual site. Therefore, a reexamination of the data was conducted to determine whether recognizing the independence of N rate and yield over sites through normalizing the yields within each site would result in stronger relationships between N rate and relative yield.

METHODS

Over 100 spring wheat/durum wheat N rate site data sets, over 100 corn sites, and 30 sunflower sites were reexamined in the summer of 2016. Each site was a randomized complete block design with 4 to 8 N-rate treatments. Within the corn data, there were 9 sites from southern Manitoba, over 20 sites from northwest Minnesota, and 6 sites from the northern counties of South Dakota, all provided to the N recalibration in corn project by respective researchers and used with their permission. The data sets were separated into categories that were previously identified through regression analysis as being different than other categories. These categories include region and tillage (long-term no-till vs conventional till) within all crops, and separation of high clay soils with other (medium texture sites) within the corn data set. Within the data in each site, the yields were divided by the greatest within-site yield. The results were values within each site from 0.0 to 1.0. Total known available N is the sum of residual soil test nitrate-N, consideration of any previous crop N credits and fertilizer N rate. Long-term no-till is defined as continuous no-till for 6 or more years.

RESULTS AND DISCUSSION

Figures 1a and 1b depict the same data set of spring wheat/durum wheat yields from N rate trials conducted west of the Missouri River, where the climate is more arid and the soils developed from much older parent materials compared to sites east of the river. Although the r^2 of the original data in Figure 1a are significant, the r^2 increased greatly when the yields were normalized within each site. The increase of r^2 would only be possible if the N rate and yields between sites were not independent.

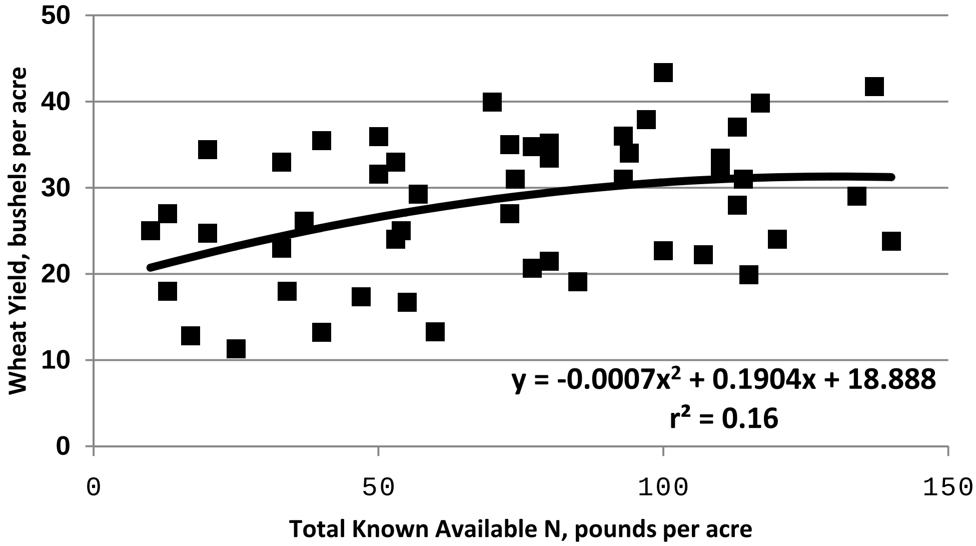

Figure 1a. North Dakota spring wheat/durum yields, west of the Missouri River, compared with total known available N, conventional tillage.

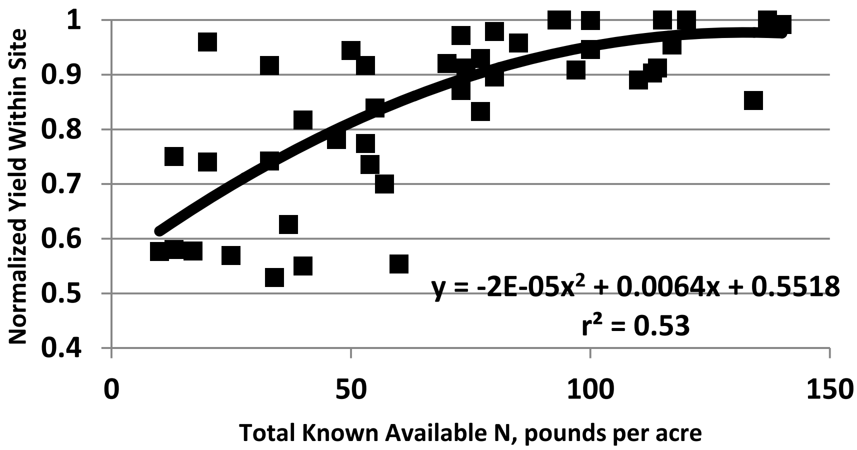

Figure 1b. North Dakota normalized spring wheat/durum yields, west of the Missouri River, compared with total known available N, conventional tillage.

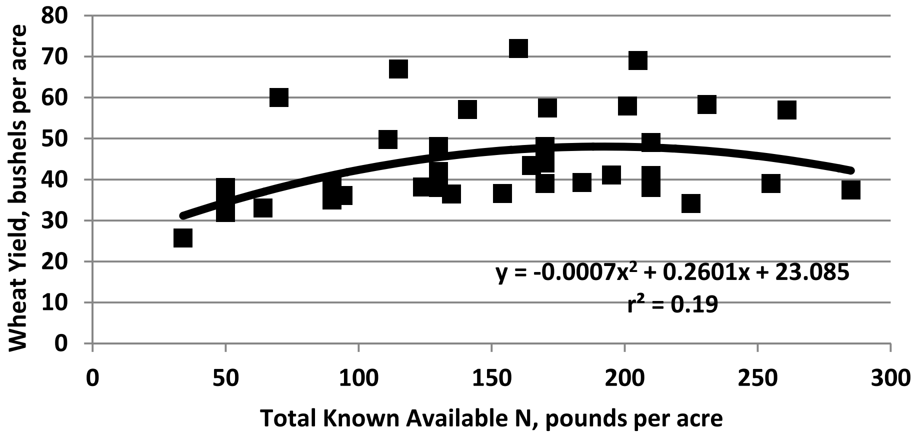

Figure 2a. North Dakota spring wheat/durum yields, west of the Missouri River, compared with total known available N, long-term no-till sites.

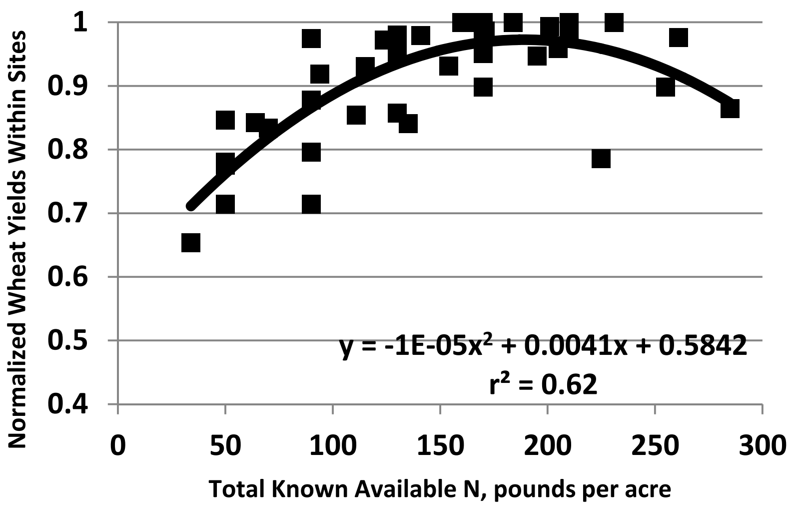

Figure 2b. Spring wheat and durum wheat yields, normalized within each site, compared with total known available N, west of the Missouri River, long-term no-till sites.

Figure 2a tends to illustrate why graphing original yields tends to blur the relationship between N rate and yield; in this figure, one can make out individual site responses to N. The aggregate graph appears scattered, although the shape of individual site data is similar. The normalized data in Figure 2b represents a common response of each of the site, although the maximum yield achieved due to environment was different.

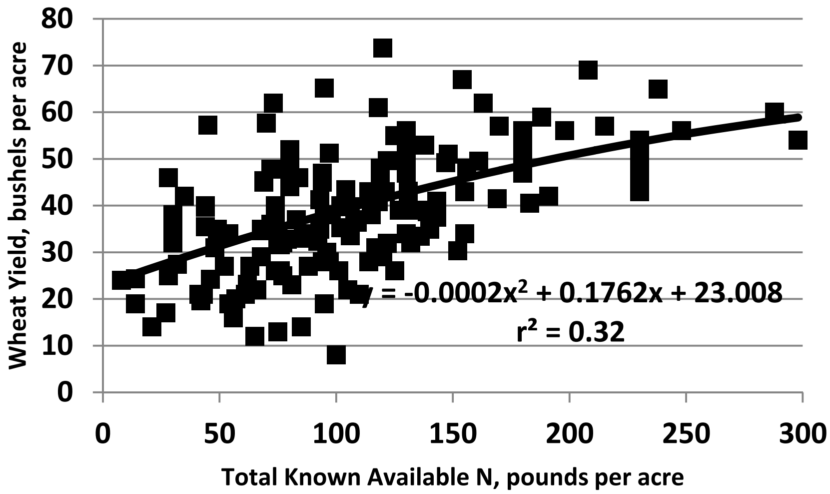

Figure 3a. Spring wheat and durum wheat yields compared with total known available N, east of the Missouri River, conventional tillage sites.

Figures 3a and 3b illustrate that some relationships are misrepresented by using the original data. Figure 3a suggests that recommended N rate is not achieved even at 300 pounds N per acre. However, using the normalized yield approach (Figure 3b), the optimum N rate without economics considered is the peak of the curve, which is 245 lb N per acre according to the regression equation. In Figures 4a and 4b, the comparison between wheat yield and available N relationship in eastern North Dakota is illustrated between original yield and normalized yield within site. The r^2 of the normalized yield with total known available N is about twice the value of the r^2 of the original yield relationship.

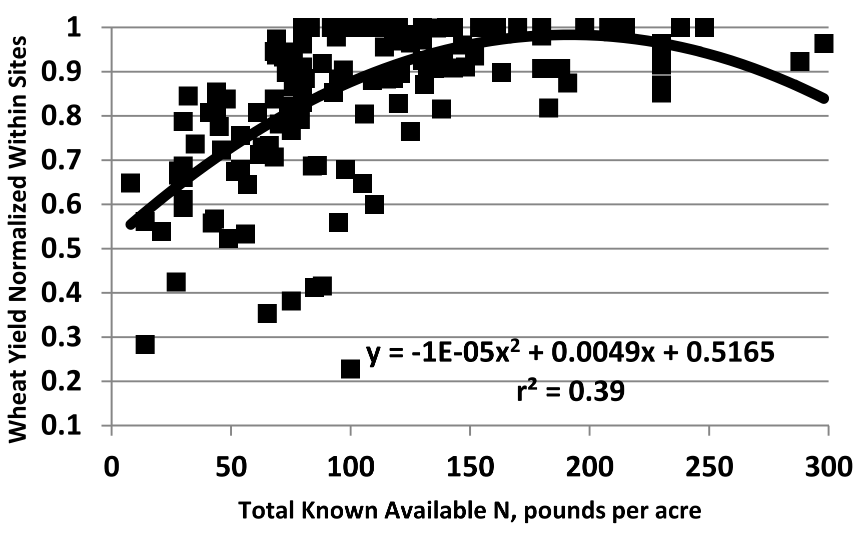

Figure 3b. Spring wheat and durum wheat yields, normalized, compared with total known available N, east of the Missouri River, conventional tillage sites.

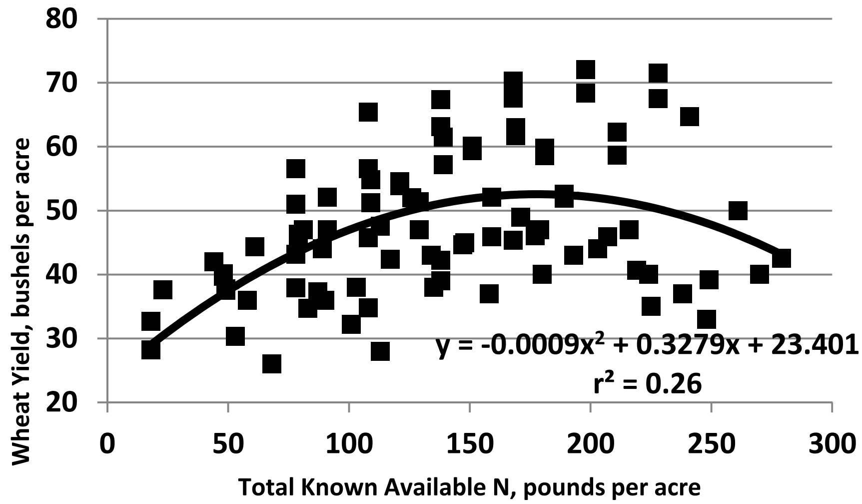

Figure 4a. Spring wheat and durum wheat yields, compared with total known available N, east of the Missouri River, long-term no-till sites.

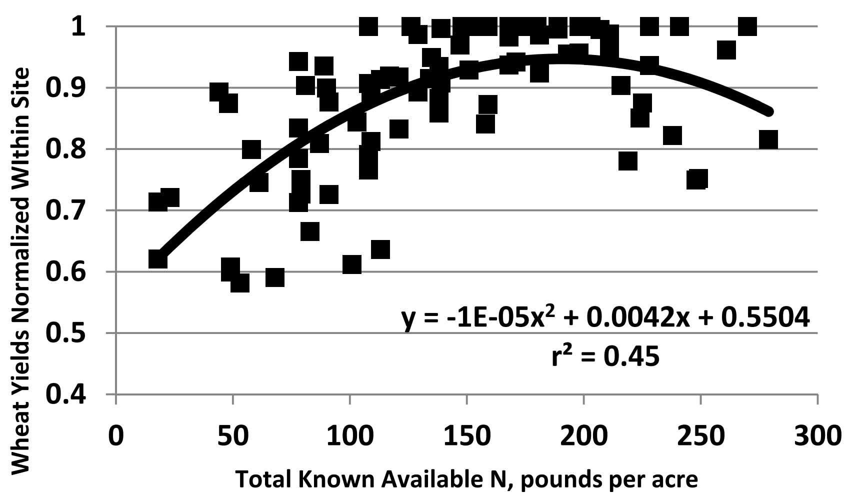

Figure 4b. Normalized spring wheat and durum wheat yields, compared with total known available N, east of the Missouri River, long-term no-till sites.

The maximum wheat yield described by original wheat yield data (Figure 4a) is similar to that described by the normalized wheat yields from long-term no-till sites in western North Dakota; however, the r^2 of the relationship from normalized wheat yield with total known available N is much greater than with the original wheat yield data.

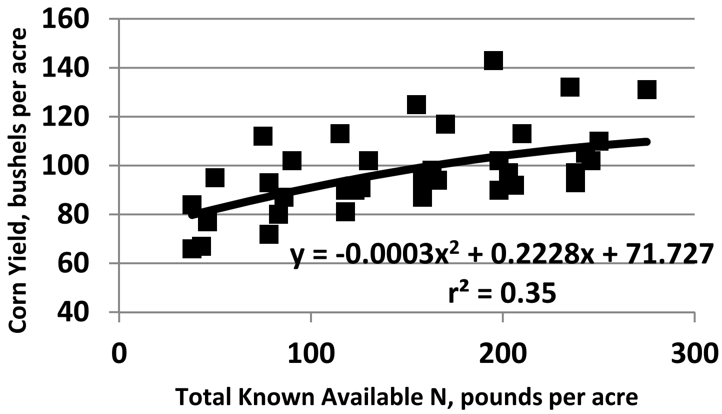

Figure 5a. Corn yield, west of the Missouri River, long-term no-till sites compared with total known available N.

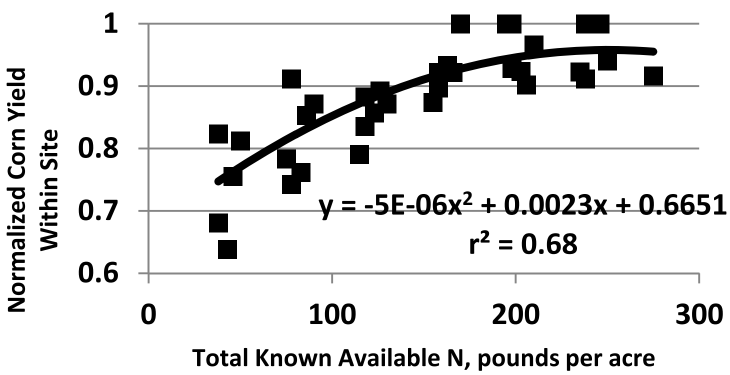

Figure 5b. Corn yield, normalized, west of the Missouri River, long-term no-till sites compared with total known available N.

Similar to the change of wheat yield response to N graph in Figures 3a/3b, Figure 5a depicts N rates increasing to nearly 300 lb N per acre to achieve maximum corn yield, whereas using normalized yield within sites (Figure 5b), maximum corn yield between sites is 230 lb N per acre using the equation in Figure 5b.

Figures 6a and 6b show that using the normalized corn yield for conventional till, high clay soils in eastern North Dakota, southern Manitoba, northwest Minnesota, and northern South Dakota increase the r^2 of the yield and available N relationship from about 0.21 to 0.47. Similarly, medium textured soils in this region had greater r2 using normalized yield than original yields (Figures 7a and 7b).

In the long-term no-till sites in eastern North Dakota (Figures 8a and 8b), not only was the r^2 superior when yield was normalized within site (0.68 compared with 0.20), but the maximum yield attained using the normalized regression was 173 lb N per acre compared with 632 lb N per acre using the original yield formula in Figure 8a.

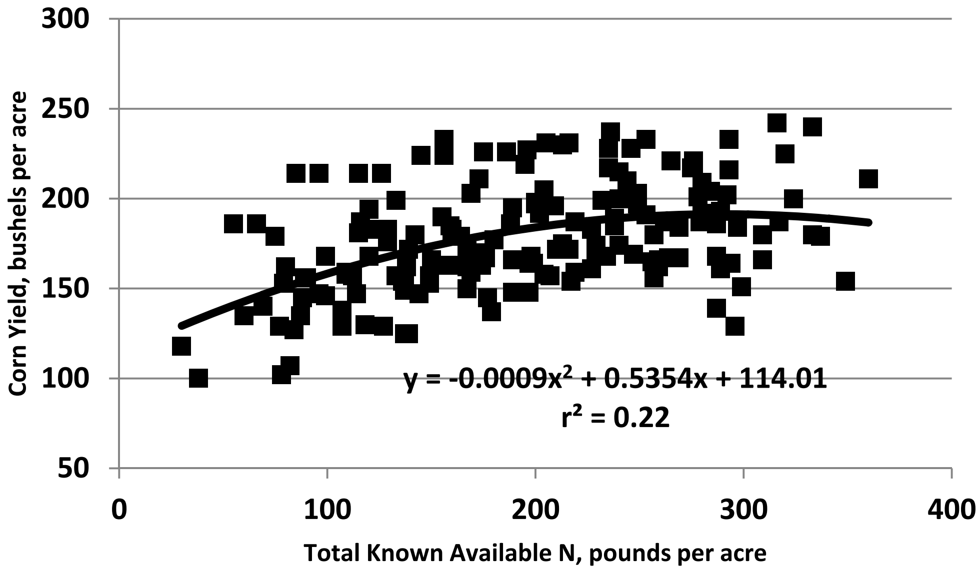

Figure 6a. Corn yield, eastern North Dakota, southern Manitoba, northwest Minnesota, and northern South Dakota, conventional till sites in high clay soils with maximum yield achieved greater than 160 bushels per acre.

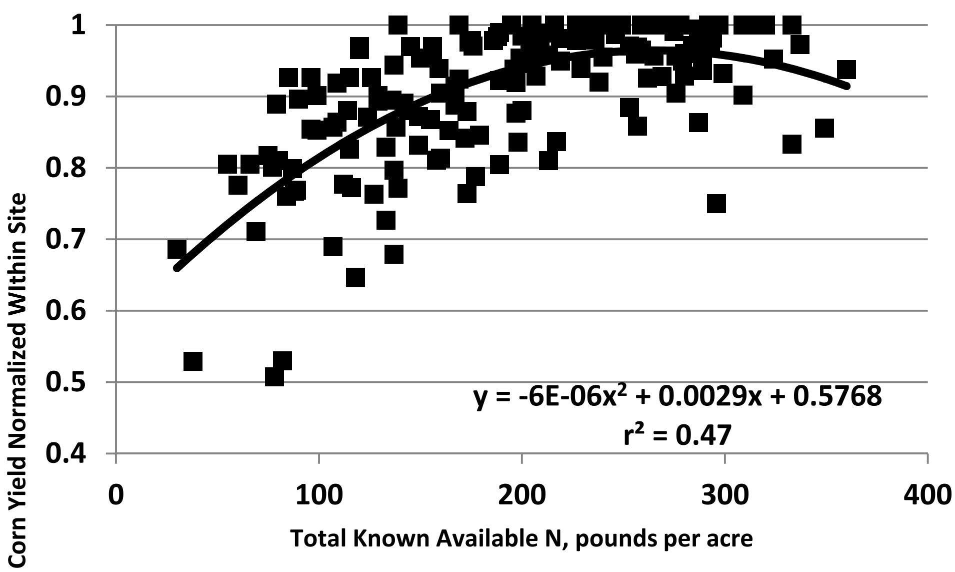

Figure 6b. Normalized corn yield, eastern North Dakota, southern Manitoba, northwest Minnesota and northern South Dakota, conventional till sites in high clay soils with maximum yield achieved greater than 160 bushels per acre.

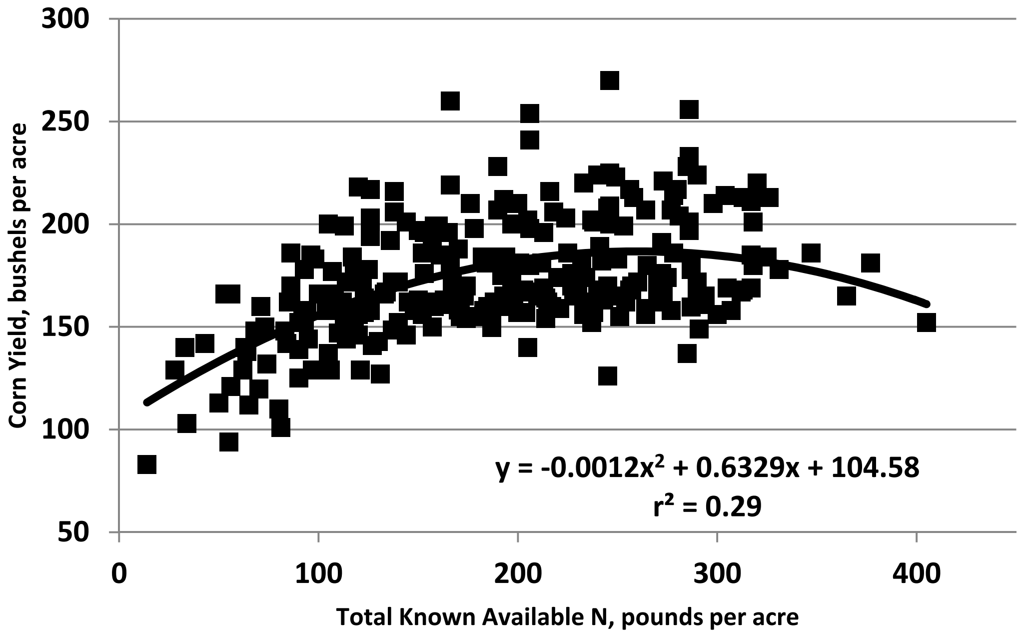

Figure 7a. Corn yield, eastern North Dakota, southern Manitoba, northwest Minnesota and northern South Dakota compared with total known available N, medium textured sites.

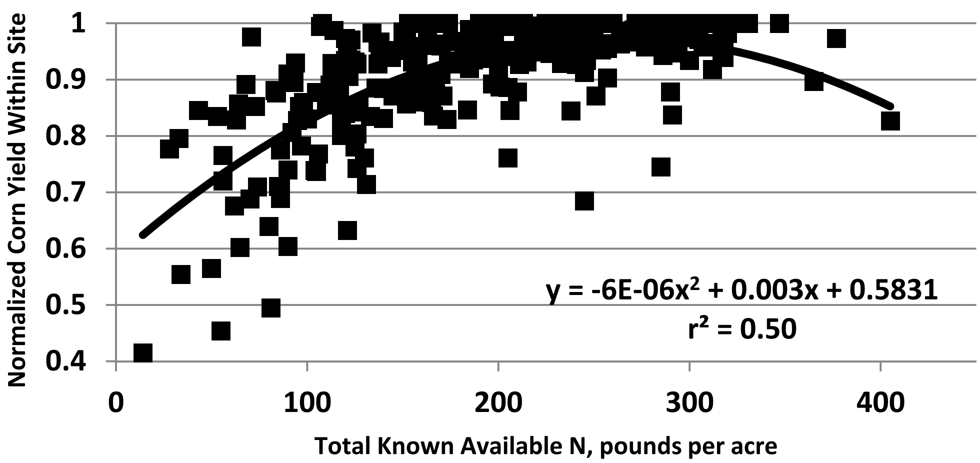

Figure 7b. Normalized corn yield, eastern North Dakota, southern Manitoba, northwest Minnesota and northern South Dakota compared with total known available N, medium textured sites.

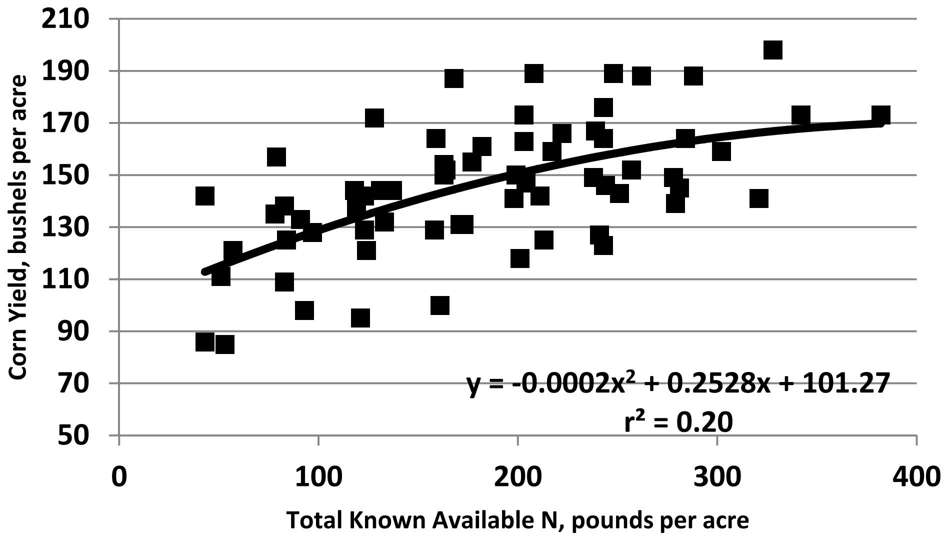

Figure 8a. Corn yield, eastern North Dakota, long-term no-till sites compared with total known available N.

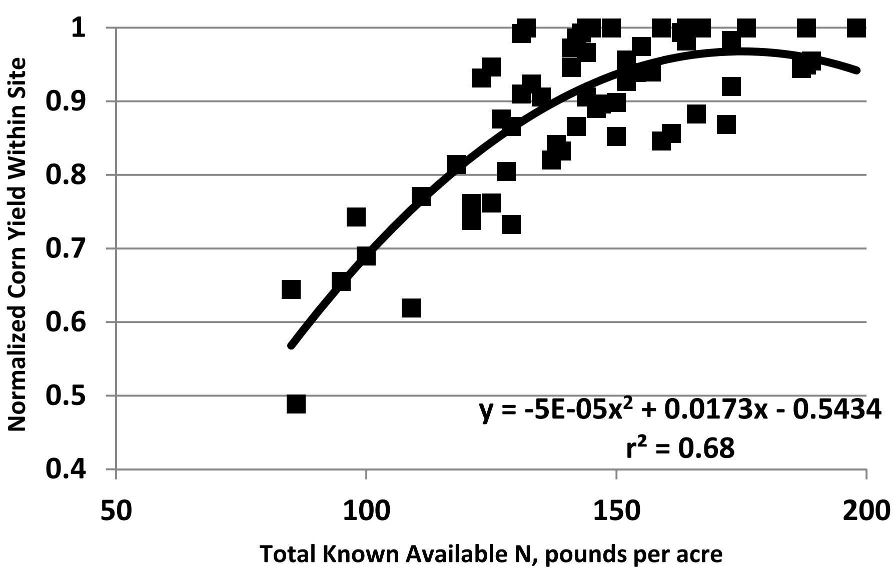

Figure 8b. Normalized corn yield, eastern North Dakota long-term no-till sites compared with total known available N.

Similar to the comparison between original yield data to normalized yield data for wheat and corn, the comparisons within sunflower category were higher in r^2 with normalized compared to original yield data, and in some categories, such as western sunflowers, the normalized regression equation with total known available N provides a reasonable N rate for achieving maximum yield, while that of the original data and total known available N does not (Figure 9a, 9b; 10a, 10b; 11a, 11b).

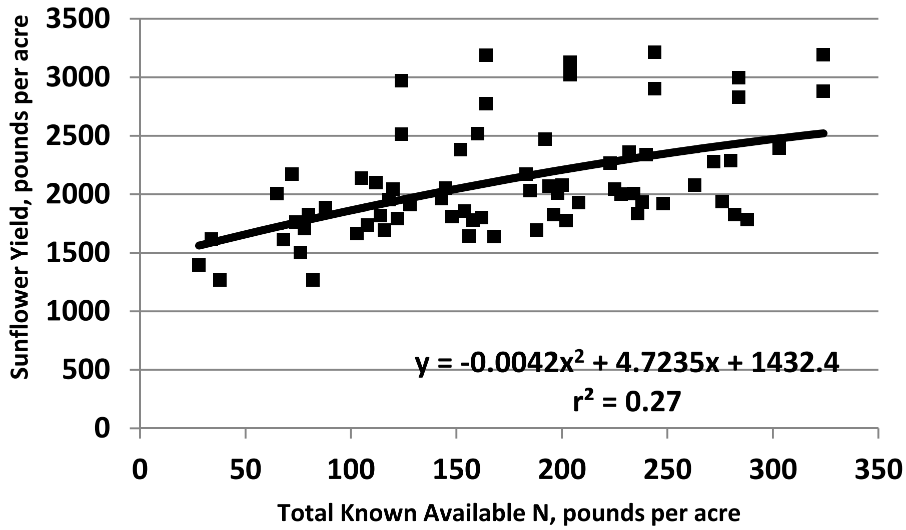

Figure 9a. Sunflower yield, western North Dakota, long-term no-till, compared with total known available N.

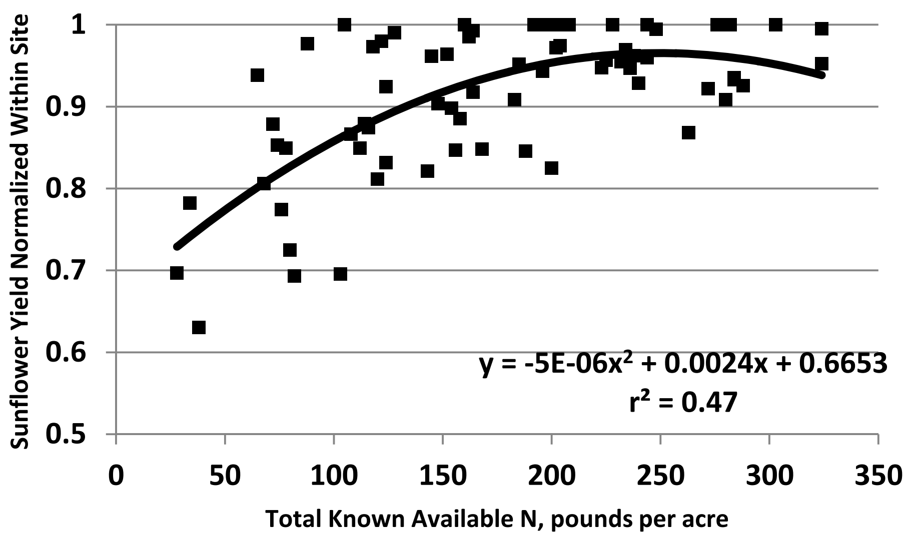

Figure 9b. Normalized sunflower yields within sites, western North Dakota, long-term no-till, compared with total known available N.

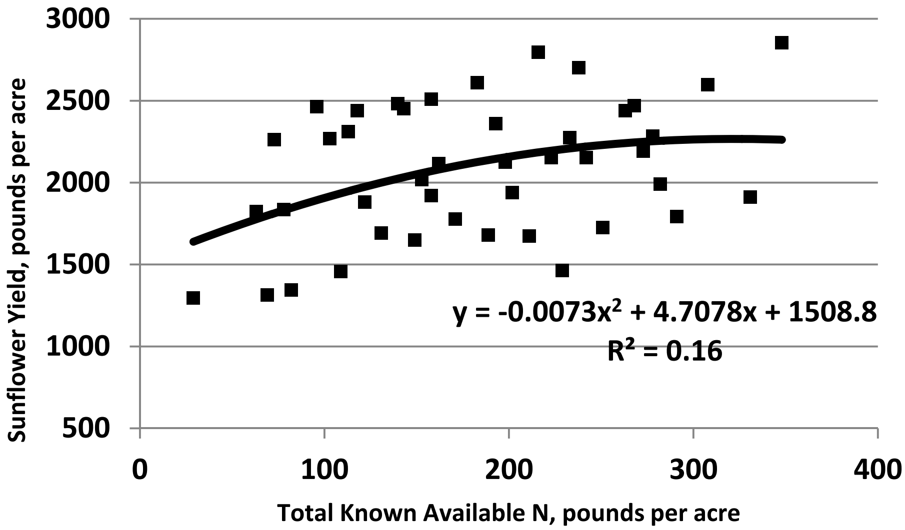

Figure 10a. Sunflower yield, eastern North Dakota, long-term no-till, compared with total known available N.

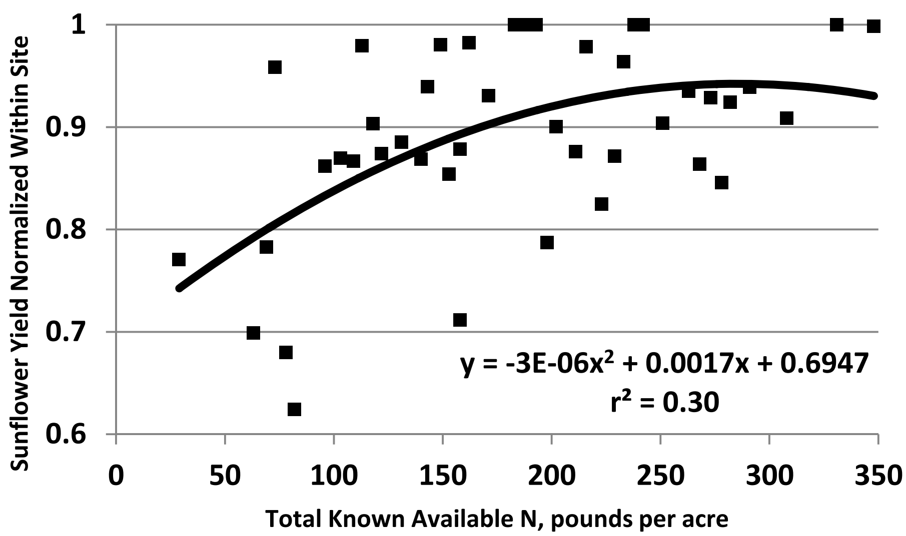

Figure 10b. Normalized sunflower yield, eastern North Dakota, long-term no-till, compared with total known available N.

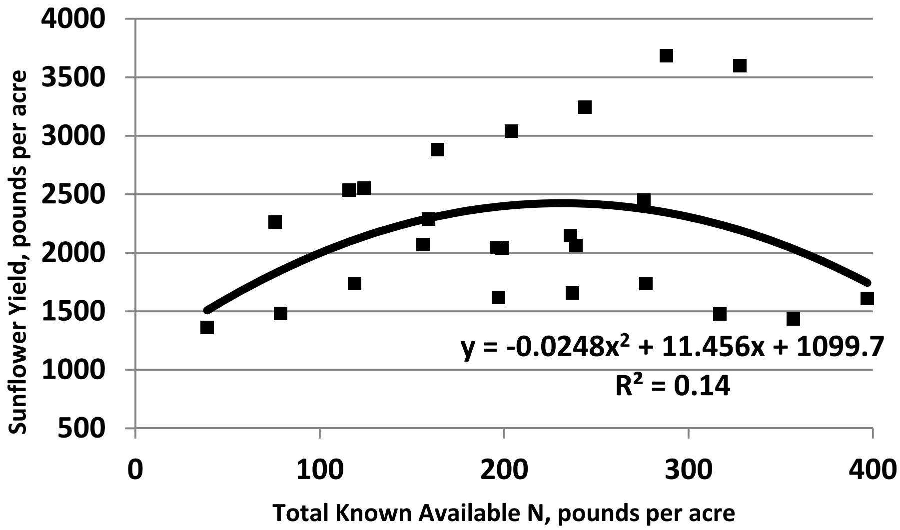

Figure 11a. Sunflower yield, eastern North Dakota, conventional till, compared with total known available N.

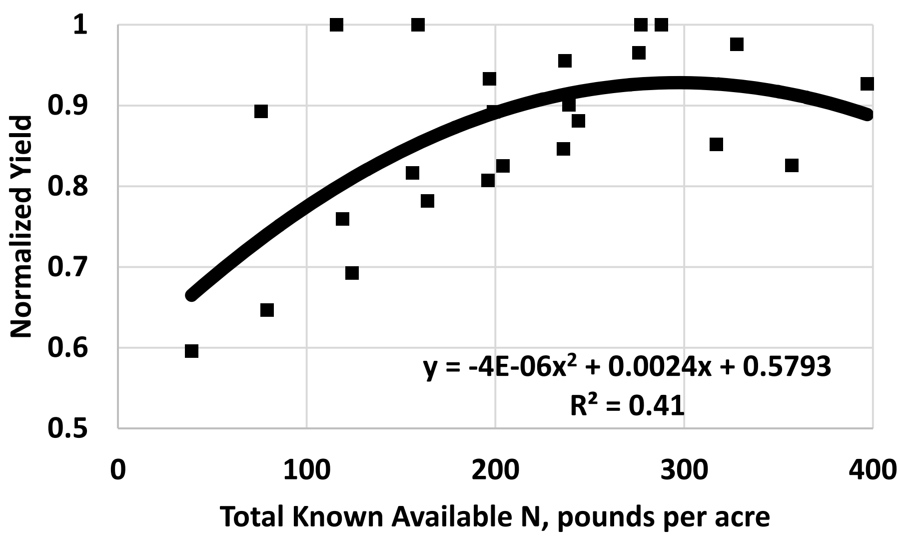

Figure 11b. Sunflower yield, eastern North Dakota, conventional till, compared with total known available N.

In wheat, corn and sunflowers, use of normalized data increased the relationship between yield and available N to the crops. This indicates that the 'cloud' of data around a raw yield vs available N relationship is a series of nearly parallel response curves. When normalized, the data around the normalized curve is much tighter as a result of the stacking of the individual site curves nearly on top of each other; and the r^2 and the real N vs yield relationship of the whole is better expressed.

These phenomena may surprise practitioners and farmers; however, the basis for similar recommended N rates regardless of realized yield might be explained by the sources of N availability to plants. Soil moisture acts to increase or decrease the availability of N to crops

(Martin et al., 1982). In dry soils, N does not move to the roots with mass flow, but is restricted in its path to the root and uptake may be limited to diffusion or root contact. Also, in dry soil, N mineralization rate is lower. The result of poor N efficiency in dry soil is that the rate of N per bushel achieved is higher than in a moist soil. In a moist soil, N mineralization rate is high and movement of N to roots is more efficient, so N efficiency is high and higher N rates are not required to achieve higher yield.

This investigation supports the use of the MRTN concept in wheat, corn and sunflower, and also indicates that use of normalized yield within site may be a better factor to model with available N or N rate compared to raw yield data.

REFERENCES

Arnall, D.B., A.P. Mallarino, M.D. Ruark, G.E. Varvel, J.B. Solie, M.L. Stone, J.L. Mullock, R.K. Taylor, and W.R. Raun. 2013. Relationship between grain crop yield potential and nitrogen response. Agronomy Journal 105:1335-1344.

Dahnke, W.C., C. Fanning, A. Cattanach, and L.J. Swenson. 1992. Fertilizing oat. North Dakota State University Extension Circular SF-716 (Revised). NDSU Extension Service, Fargo, ND.

Franzen, D., N. Kitchen, K. Holland, J. Schepers, and W. Raun. 2016. Algorithms for in-season nutrient management in cereals. Agronomy Journal 108:1-7.

Hoeft, R.G., and T.R. Peck. 2002. Soil testing and fertility, Chapter 11. pp. 91-131. *In* Illinois Agronomy Handbook, 23rd Edition. P. Picklesimer, ed. University of Illinois Cooperative Extension Service, Urbana, IL.

Martin, D.L., D.G. Watts, L.N. Mielke, K.D. Frank, and D.E. Eisenhauer. 1982. Evaluation of nitrogen and irrigation management for corn production using water high in nitrate. Soil Science Society of America Journal 46:1056-1062.

Raun, W.R., J.B. Solie, and M.L. Stone. 2011. Independence of yield potential and crop nitrogen response. Precision Agriculture 12:508-518.

Sawyer, J.S., and E.D. Nafziger. 2005. A regional approach to making nitrogen fertilizer rate decisions for corn. pp. 16-24. In Proceedings of the 21st North Central Extension-Industry Soil Fertility Conference, 2005, Nov. 16-17, Des Moines, IA. IPNI, Brookings, SD.

Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1995. Tri-State fertilizer recommendations for corn, soybeans, wheat and alfalfa. Purdue Extension Publication AY-9-32-W. Lafayette, IN.

Warncke, D., J. Dahl, L. Jacobs, and C. Laboski. 2004. Nutrient recommendations for field crops in Michigan. Extension Bulletin E2904, May, 2004, Michigan State University Extension, East Lansing, MI.

PROCEEDINGS OF THE

46th

NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 32

November 2-3, 2016
Holiday Inn Airport
Des Moines, IA

PROGRAM CHAIR:

Dorivar Ruiz Diaz
Kansas State University
Manhattan, KS 66506
(785) 532-7213
ruizdiaz@ksu.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/