RECENT 2-ROW MALTING BARLEY REVISION FOR NORTH DAKOTA

Dave Franzen and Brady Goettl
North Dakota State University, School of Natural Resource Sciences-Soils

ABSTRACT

As the demand of two-row malting barley (*Hordeum vulgare* L.) increases, having sound nitrogen (N) recommendations is increasingly necessary. Not only does N play a role in grain yield, but it may also significantly impact grain malting characteristics including protein, plump, and test weight. To determine the impacts N rate and N availability have on two-row malting barley, two experimental sites were established in both spring 2020 and 2021. The experiments were organized as a randomized complete block design with a split-plot arrangement; each site consisted of 100 experimental units in 2020 and 50 experimental units in 2021. Treatments consisted of five fertilizer rates (0, 40, 80, 120, and 160 pounds N per acre) and two barley cultivars (ND Genesis and AAC Synergy), with cultivar as the main plot treatment and N rate as sub-plot treatment. Soil nitrate-N samples were taken prior to planting and N credits from the previous crop were considered to determine the total known available soil N (TKAN). It was determined there was a strong relationship between N rate and relative grain yield. There was also a strong positive correlation between N rate and grain protein. When the relationship between relative grain yield and TKAN was modeled using a best-fit regression, it was determined maximum yield can be reached at 187 TKAN per acre. Additionally, grain protein content at 187 pounds TKAN per acre was 12.8 %, which meets malting quality requirements. No significant interactions between N rate and kernel plump or test weight were noted at the N rates applied in these experiments. When factoring in economic information, the TKAN range needed to produce the barley crop at the highest profitability is lower than TKAN of maximum yield; ranging from 106 up to 189 pounds TKAN per acre.

INTRODUCTION

The Northern Great Plains region states and provinces are large producers of barley. Historically, the barley cultivars in this region destined for the malting industry were six-row types; however, very recently, malting companies began to contract only two-row barley cultivars, leading to a shift in production. One of the reasons behind this change in preference from six-row to two-row barley for malting is the generally lower grain protein content (McKenzie et al., 2005; Franzen and Goos, 2019). Barley with lower protein content results in more rapid water uptake during malting, which allows the grain to progress through the process more quickly (Hertsgaard et al., 2008), decreasing malting costs. Additionally, high protein in the malt produces problems during beer fermentation, generating cloudiness in the final product. McKenzie et al. (2005) asserted N fertilization is the most important factor in malting barley production since N in excess of what is required for yield increases grain protein (Lauer and Partridge, 1990).

There is an established correlation between N fertilization and percentage of plump kernels, protein content, and test weight, malting quality factors established by maltsters (Lauer and Partridge, 1990; McKenzie et al., 2005; O’Donovan et al., 2015). The American Malting Barley Association sets the ideal criteria for two-row barley as follows: protein content ≤130 g kg^{-1} and >90% plump kernels retained on a 2.38 mm sieve (American Malting Barley Association, 2023b). Two of the most common reasons for malting barley rejection are high protein content and a low percentage of plump kernels. The consequence of grain rejection by maltsters is very severe; feed-barley price is about half that of malting grade.

Baethgen et al. (1995) stated a balance must be found between obtaining profitable yield for malting barley and meeting quality requirements. This balance between yield and quality should also consider N use efficiency. As a result, grain could be produced at a yield which will maximize economic returns for the farmer, meet malting quality requirements, and minimize residual soil nitrate-N following harvest. The purpose of this study was to determine the rate of available N which will maximize profitable yield and optimize grain quality characteristics for two-row malting barley in the Northern Great Plains.

METHODS

These on-farm experiments took place during the 2020 and 2021 growing seasons, with two experimental sites each year. In total, four site-years of data were generated on non-irrigated, no-till locations in Grand Forks and Barnes Counties in North Dakota, near Logan Center (LC) and Valley City (VC), respectively.

Both VC sites had been under no-till management for over 40 years, producing several rotational crops including corn (*Zea mays* L.), soybean (*Glycine max* L.), oil-seed sunflower (*Helianthus annuus* L.), six-row malting barley, and hard red spring wheat (*Triticum aestivum* L.). The previous crop at the 2020 VC site (46.88403N, 97.915529W) was oil-seed sunflowers, with corn being previously grown in another VC site in 2021 (46.880486N, 97.913760W).

The LC sites in 2020 (47.795544N, 97.773766W) and 2021 (47.791001N, 74 97.775661W) were transitioned to no-till management less than 5 years before the establishment of the experiment. Crops in rotation consisted of pinto bean (*Phaseolus vulgaris* L.), soybean, six-row malting barley, and hard red spring wheat. The previous crop on the LC sites was pinto bean in 2020 and 2021.

Table 1. Soil properties and chemical analyses for each experimental location, measured prior to barley seeding. Nitrate-N was sampled to a depth of 2-feet while P, K, pH, and organic matter were sampled to a depth of 6 inches.

Environment	Series	Texture	NO_3-N	P, Olsen	K	pH	OM
			ppm	ppm	ppm		%
VC2020	Swenoda†	sandy loam	43	27	201	5.2	2.6
LC2020	Barnes‡	loam	47	15	282	6.7	3.9
VC2021	Barnes	loam	49	23	67	5.1	2.2
LC2021	Barnes	loam	60	25	207	5.6	5.2

†Coarse-loamy, mixed, superactive, frigid Pachic Hapludolls (Soil Survey Staff, 2023)
‡Fine-loamy, mixed, superactive, frigid Calcic Hapludolls (Soil Survey Staff, 2023)

The independent variables consisted of 5 N fertilizer treatments within two cultivars of two-row barley. The N treatments ranged from 0 to 160 pounds N per acre in 40 pound per acre increments (0, 40, 80, 120, 160 pounds N per acre) spanning the range above and below current N recommendations for two-row barley. The two cultivars used in this experiment were ND Genesis and AAC Synergy, which are two-row malting barley cultivars recommended by the American Malting Barley Association (American Malting Barley Association, 2023a). ND Genesis was released in 2015 by North Dakota State University and AAC Synergy in 2015 by Syngenta Seeds (Basil, Switzerland). Each experimental unit was 8 feet wide by 40 feet long and they were organized in a randomized complete block design with a split-plot arrangement, with cultivar as the main plot and N-rate as sub-plots. In 2020, the treatments were replicated 10 times producing 100 experimental units at each site. The number of experimental units were reduced by 50% in 2021, consisting of five replications for a total of 50 experimental units at each site.

To determine the optimum N rate for a crop, fertilizer N is only one factor considered in North Dakota State University Extension recommendations; the total known plant available N

(TKAN) from all known sources should be considered for profitable and environmentally responsible N management. To determine TKAN, preplant soil nitrate-N (N_S) was added to crop N credits (N_{PC}), no-tillage N credits (N_{TC}), and amount of fertilizer N applied (N_{Fert}) (Equation 1) (Clark et al. 2020; Franzen, 2018; Hergert, 1987; Schultz et al., 2018).

$$TKAN = N_{PC} + N_{TC} + N_S + N_{Fert} \quad [1]$$

Previous crop N credits, reported in Franzen (2018), include a 40 pound N per acre credit after soybean, edible bean, and other annual legumes. A 40 pound N per acre credit is assessed in systems under continuous no-till for >6 years, systems in transitional or intermittent no-till are penalized 20 pounds N per acre, conventional systems receive no N credit or reduction (Franzen, 2023).

In 2020, the sum of soil nitrate-N (N_S), N credits from previous crops (N_{PC}), and tillage (N_{TC}) ranged from 52 pounds N per acre to 84 pounds N per acre across research sites and transects, in 2021 the range was from 64 pounds N per acre to 83 pounds N per acre (Table 3). In 2020 and 2021, the LC site received a 44.8 kg N ha^{-1} credit from the previous crop of pinto beans, but was penalized 20 pounds N per acre for being in the transitional no-till stage (Franzen, 2023). No previous crop credits were assessed at the VC site, but a 40 pound per acre long term no-till N credit was added each year (Franzen, 2023).

At planting, N fertilizer was hand-broadcast applied to the specific treatments, using pre-weighed SUPERU (46% N) as the fertilizer N source. SUPERU is a urea-based fertilizer treated with *dicyandiamide* (DCD) and *N-(n-butyl) thiophosphoric triamide* (NBPTP), which are a nitrification inhibitor and urease inhibitor, respectively (Koch Agronomic Services LLC, 2019). Additionally, 100 pounds per acre of pelletized gypsum (calcium sulfate, 20% S) was broadcast applied at the time of N application to ensure S deficiency did not confound N response.

Barley was no-till drilled on 6 May 2020 at both the LC and VC site, 5 April 2021 at VC, and 6 April 2021 at LC. At all sites, the barley was sown in 7.5 inch rows at the seeding rate of 1.2 million seeds per acre using a John Deere 1890 No-Till Air Drill (Deere and Co., Moline, IL). In-furrow fertilizer (12% N, 40% P_2O_5, 4% Zn) was applied at both of the 2021 sites at the rate of 75 pounds per acre at VC and 100 pounds per acre at LC (Franzen and Goos, 2019). In-season crop and pest management was uniformly completed by the cooperating farmers.

Grain was direct harvested on 10 August 2020 at the VC site and on 18 August 2020 at LC, 5 August 2021 at VC, and 11 August 2021 at LC using a plot combine (ALMACO, Nevada, IA). To limit edge interaction from N movement among the treatments, only the center 5 feet of each experimental unit was harvested. Grain was collected in breathable cloth bags and transported to the laboratory for all post-harvest measurements and quality analyses.

2.5 Data collection and lab analysis

The harvested, field moist, grain samples were placed into convection driers at 60℃ for 12 h prior to processing. Samples were weighed and then cleaned using a Clipper Model-2B cleaner (A.T. Ferrell Co., Bluffton, IN) to separate chaff and debris not eliminated by the combine.

Grain moisture was measured using a Dickey-John model GAC500 XT grain analyzer (Dickey-John, Auburn, Illinois). Grain harvest weights were adjusted to the standard moisture content of 13.5% for yield calculations. Quality measurements were conducted by the NDSU Barley Quality Laboratory. Quality relating to kernel size was determined by sieving. Percent plump kernels were considered as the percent of kernels, by weight, which do not pass through a 2.38 mm sieve (American Malting Barley Association, 2023b). Grain protein content was determined using FOSS Infratec 1241 Grain Analyzer (FOSS, Hilleroed, Denmark).

Data analysis was performed using SAS 9.4 and JMP (SAS Institute, Cary, NC). Analysis of variance (ANOVA) was conducted as randomized complete block design with a split plot arrangement using SAS PROC MIXED. Year and location were combined into one source of variation, environment, and considered a random effect. Replication was analyzed as a random effect and barley cultivar and N-rate as fixed effects. Data was tested for homogeneity of variance using Bartlett's chi-square test. Regression analysis was performed using JMP Nonlinear Modeling. Data in this study was considered statistically significant at $p \leq 0.05$.

Recognizing the independence of actual crop yield and N rate (Vanotti and Bundy, 1994; Raun et al., 2011), this approach used in this study relies on the strong relationship between relative (also referred to as standardized or normalized) yield and TKAN (Franzen et al., 2021). Relative yield was calculated by dividing the maximum yielding experimental unit at each site by yield of each experimental unit. For the development of the N recommendation, mean TKAN and yield within each N-rate treatment for each environment was calculated. Relative yield was then determined within each environment and regressed against TKAN. For economic analysis, the relative yield was then multiplied by the average yield to convert the proportion back to bushels per acre The economic optimum N rate (EONR) for two-row malting barley was calculated based on the relationship between barley price (P_b) and cost of N fertilizer (P_n) (Nafziger et al., 2004; Sawyer et al., 2006). The relative grain yield regression coefficients (a, b, and c) from the yield to TKAN comparison were used in Equation 2 to calculate EONR at various barley and N fertilizer costs (Fausti et al., 2018).

$$EONR = \frac{P_n}{P_b} \times \frac{1}{2a} - \frac{b}{2a} \quad [2]$$

$$TC = (N)P_n \quad [3]$$

$$TR = [aN^2 + bN + c]P_b \quad [4]$$

Total cost (TC) related to N input (N) and P_n was calculated using Equation 3. Total return (TR) was calculated as yield as a function of N multiplied by P_b (Equation 4). Net return (NR) was then calculated as the difference between TR and TC.

RESULTS AND DISCUSSION

The yields between the two barley cultivars was similar, and yield and protein increased with N rate (Table 3). When relative grain yield was plotted against TKAN and fitted with polynomial trendline (r^2=0.66), maximum potential yield is realized at 182 pounds TKAN per acre (Figure 1). As a comparison, when actual (non-normalized) yield was plotted against TKAN, the relationship was very poor (r^2=0.04), further supporting the independence of yield and N rate (Franzen et al., 2021). The relationship between grain protein content and TKAN was modeled using a linear regression (r^2=0.29) (Figure 2); using the linear equation, grain protein content at 182 pounds TKAN per acre is 12.8%. Since the data shows the grain protein content is, on average, below the maximum malting content of 13 % at the TKAN of maximum yield, EONR was calculated without any limitations put in place based on grain protein content.

Table 3. Mean barley yield, grain protein and, kernel plump, over four North Dakota environments.

Effects	Variables	Yield	Relative Yield‡	Protein	Plump
		bu/acre		ppm	%
Cultivar	Synergy	64.8	.66	11.6	94
	Genesis	59.2	.61	12.0	94
	P-value	NS	NS	NS	NS
N Rate lb/a	0	43.5 a	.46 a	10.7 a	93
	40	58.5 ab	.61 ab	11.3 b	94
	80	68.6 b	.70 b	11.9 c	94
	120	69.8 b	.71 b	12.4 d	94
	160	70 b	.71 b	12.7 d	93
	P-value	*	*	***	NS

†Means with the same letter within column are not significantly different at the 0.05 probability level.
‡Relative yield is calculated as the maximum yield divided by each experimental unit within individual environments.
*, *** Significant at the 0.05, and 0.001 probability levels
NS Nonsignificant.

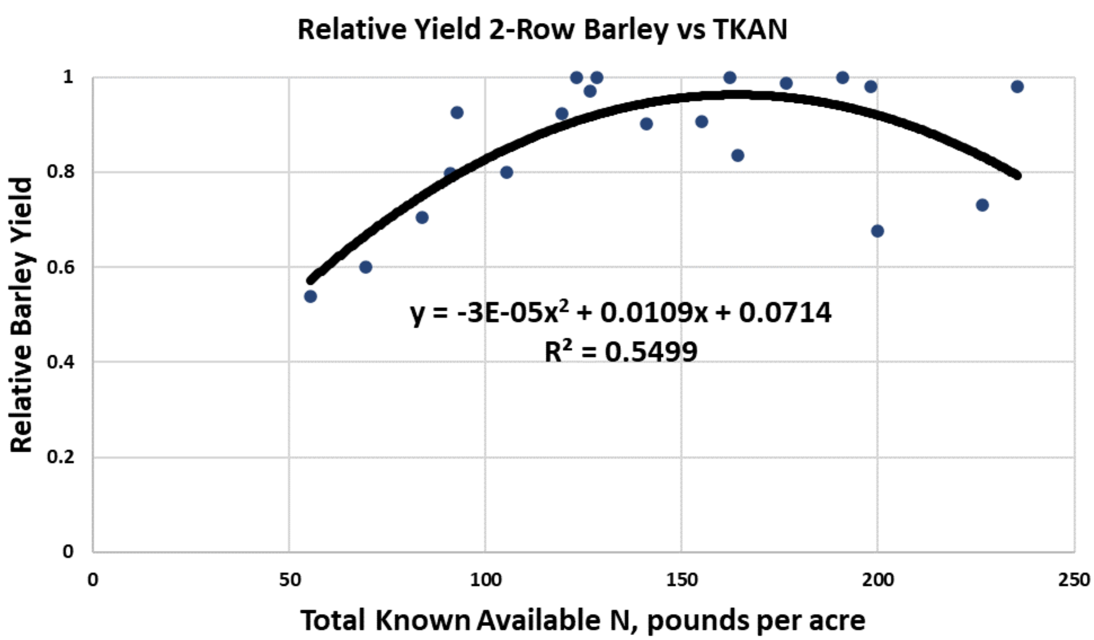

Figure 1. Relative two-row barley yield data averaged across replications and cultivars at four eastern North Dakota sites compared to total known available N, fitted with a quadratic trendline.

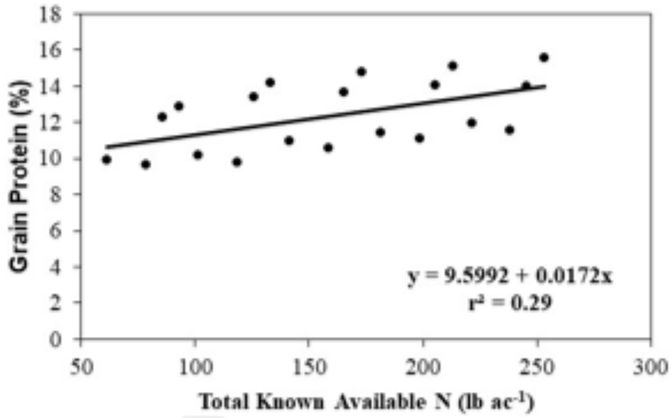

Figure 2. Two-row barley grain protein content averaged across replications and varieties at four eastern North Dakota sites compared to total known available N, fitted with a linear trendline.

Barley prices to the farmer range from $3.50 per bushel to $6.50 per bushel, with N costs the past decade ranging from 40 cents per pound N to $2 per pound N. The maximum Economic N rate from these experiments is 174 pounds N per acre (at $6.50 per bushel barley and $1.30 per pound N). As barley price decreases, N cost increases, or both, the ratio between N cost and barley price (N:barley) becomes larger, indicating tighter potential margins and thus promoting lower N rates. The benefit of calculating N rate based on the EONR method is to attain maximum economic return at higher N:barley price ratios, without the necessity of fertilizing to maximum yield (Figure 3).

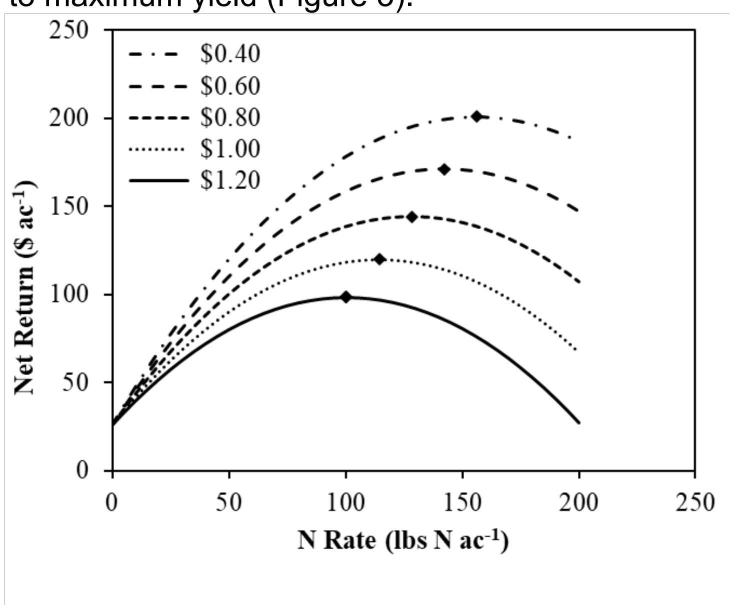

Figure 3. Comparison of economic optimum N rates for two-row malting barley in eastern North Dakota and net return with barley price at $4.40 per bushel and N costs at $0.40, $0.60, $0.80, $1.00, and $1.20 per pound of N.

CONCLUSIONS

The results from four site-years of data support previous findings that N rate is a driver of grain yield and protein concentration in 2-row malting barley. There was no relationship between N rate and kernel plump. Regression analysis of grain yield and TKAN determined maximum grain yield was attainable at 235 pounds N per acre. Additionally, when fertilized at the rate of maximum yield, grain protein content averaged 12.8 %, which is below the 13.0 % standard maximum protein for malting (American Malting Barley Association, 2023b). When factoring in economics, the TKAN range needed to produce the barley crop at the highest profitability is less than the TKAN for maximum yield.

REFERENCES

American Malting Barley Association. 2023a. Recommended Varieties. https://ambainc.org/recommended-varieties.php (accessed 15 February 2023).

American Malting Barley Association. 2023b. Malting Barley Breeding Guidelines Ideal Commercial Malt Criteria. https://drive.google.com/file/d/1HkCcyiaIWfIT_6wTRyMSdfcD8YOCt0rs/view (accessed 15 February 2023).

Baethgen, W.E., C.B. Christianson, and A.G. Lamothe. 1995. Nitrogen fertilizer effects on growth, grain yield, and yield components of malting barley. Field Crops Res 43(2–3): 87–99. doi: 10.1016/0378-4290(95)00034-N.

Clark, J. D., Fernández, F. G., Veum, K. S., Camberato, J. J., Carter, P. R., Ferguson, R. B., Franzen, D. W., Kaiser, D. E., Kitchen, N. R., Laboski, C. A. M., Nafziger, E. D., Rosen, C. J., Sawyer, J. E., & Shanahan, J. F. 2020. Soil-nitrogen, potentially mineralizable-nitrogen, and field condition information marginally improves corn nitrogen management. Agron J 112(5): 4332–4343. https://doi.org/10.1002/AGJ2.20335.

Fausti, S., B.J. Erickson, D.E. Clay, and C.G. Carlson. 2018. Deriving and using an equation to calculate economic optimum fertilizer and seeding rates. Practical Mathematics for Precision Farming: 181–189. doi: 10.2134/PRACTICALMATH2016.0027.

Franzen, D. 2023. North Dakota fertilizer recommendation tables and equations. North Dakota State University Extension Service SF882. https://www.ag.ndsu.edu/publications/crops/north-dakota-fertilizer-recommendation-tables /sf882.pdf.

Franzen, D., H. Bu, B. Goettl, A. Wick, M. Berti, et al. 2021. Independence of Yield and N Rate and Use of EONR in N Fertilizer Recommendations in North Dakota. North Central Extension-Industry Soil Fertility Conference. p. 11–15

Franzen, D., and R.J. Goos. 2019. Fertilizing malting and feed barley. North Dakota State University Extension Service SF723.

Hergert, G. W. 1987. Status of Residual Nitrate-Nitrogen Soil Tests in the United States of America. Soil Testing: Sampling, Correlation, Calibration, and Interpretation, 73–88. https://doi.org/10.2136/SSSASPECPUB21.C8.

Hertsgaard, K., P. Schwarz, and R. Mattern. 2008. Importance of Barley Plumpness and Protein for Malt Quality. North Dakota State University Extension and Ag Research News. https://www.ag.ndsu.edu/news/newsreleases/2008/sept-4-2008/importance-of-barley-plumpness-and-protein-for-malt-quality (accessed 15 February 2023).

Koch Agronomic Services LLC. 2019. SUPERU. https://kochagronomicservices.com/Documents/SUPERU-Product-Label.pdf?action=view (accessed 28 September 2020).

Lauer, J.G., and J.R. Partridge. 1990. Planting Date and Nitrogen Rate Effects on Spring Malting Barley. Agron J 82(6): 1083–1088. doi: 10.2134/agronj1990.00021962008200060011x.

McKenzie, R.H., A.B. Middleton, and E. Bremer. 2005. Fertilization, seeding date, and seeding rate for malting barley yield and quality in southern Alberta. Canadian Journal of Plant Science 85(3): 603–614. doi: 10.4141/P04-152.

Nafziger, E.D., John.E. Sawyer, and R.G. Hoeft. 2004. Formulating N recommendations for corn in the Corn Belt using recent data. North Central Extension-Industry Soil Fertility Conference. Potash and Phosphate Inst., Brookings, SD, Des Moines, IA

O'Donovan, J.T., Y. Anbessa, C.A. Grant, A.L. Macleod, M.J. Edney, et al. 2015. Relative responses of new malting barley cultivars to increasing nitrogen rates in western Canada. Canadian Journal of Plant Science 95(5): 831–839. doi: 10.4141/CJPS-2014-415.

Raun, W.R., J.B. Solie, and M.L. Stone. 2011. Independence of yield potential and crop nitrogen response. Precis Agric 12(4): 508–518. doi: 10.1007/s11119-010-9196-z.

Sawyer, J., E. Nafziger, G. Randall, L. Bundy, B. Joern, et al. 2006. Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn. (PM 2015). https://nue.okstate.edu/Index_Publications/IowaStatePM2015.pdf (accessed 15 February 2023).

Schultz, E., DeSutter, T., Sharma, L., Endres, G., Ashley, R., Bu, H., Markell, S., Kraklau, A., & Franzen, D. (2018). Response of Sunflower to Nitrogen and Phosphorus in North Dakota. Agron J 110(2), 685–695. https://doi.org/10.2134/AGRONJ2017.04.0222.Soil Survey Staff. 2023. Web Soil Survey. United States Department of Agriculture-Natural Resources Conservation Service. http://websoilsurvey.sc.egov.usda.gov/ (accessed 27 September 2021).

Vanotti, M.B., and L.G. Bundy. 1994. An Alternative Rationale for Corn Nitrogen Fertilizer Recommendations. Journal of Production Agriculture 7(2): 243–249. doi: 10.2134/JPA1994.0243.