OPTIMIZING NITROGEN INPUTS IN BARLEY PRODUCTION IN NORTH DAKOTA

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ABSTRACT

Nitrogen (N) management plays a critical role in balancing yield and malting quality of two-row spring barley (*Hordeum vulgare* L.) grown in the Northern Plains. A field experiment was conducted at three locations in North Dakota to evaluate the effect of N fertilizer source on grain yield, protein, and kernel plump. Treatments included eight commercially available N sources including urea, enhanced efficiency urea, urea ammonium nitrate, calcium ammonium nitrate, sulfur enriched granular urea, and a non-fertilized check. Treatments were arranged in a randomized complete block design. All fertilized treatments received 150 lb N ac^{-1}, corresponding to 80% of the regional agronomic optimum N rate for malting barley production. Results showed N fertilization significantly increased grain yield and protein concentration compared with the unfertilized check, while kernel plump remained unaffected by N source. Despite small differences among sources, all fertilized treatments produced protein concentrations within the AMBA-recommended range (10-13%), indicating acceptable malting quality. The non-fertilized check exhibited the most desirable protein level (10%), demonstrating the typical trade-off between yield and quality. These findings highlight applying uniform N rates while varying fertilizer source can sustain yield gains without exceeding protein thresholds critical for malting quality in North Dakota barley production systems.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a major cereal crop cultivated across the Northern Great Plains of the United States, primarily for malting, food products, and animal feed (Akar, Avci, & Dusunceli, 2004). North Dakota consistently ranks among the leading barley-producing states, accounting for approximately 20% of total U.S. production in 2025 (USDA-NASS, 2025). According to the North Dakota Barley Council (2025), approximately 90% of the state's barley is marketed for malting and brewing, highlighting the strong connection between barley production and the regional malting industry.

Maintaining grain quality is essential for the malting sector, which requires kernels with plump greater than 90% and protein concentrations under 13% to ensure desirable malt extract potential and brewing performance (AMBA, 2025). Achieving this balance between yield and grain quality represents a major agronomic challenge for producers in the region. Nitrogen (N) is the most yield-limiting nutrient for barley and has a direct influence on both productivity and grain quality (McFarland et al., 2015). While adequate N supply is required to maximize yield and maintain sufficient protein content, excessive N can increase grain protein above acceptable malting thresholds and reduce kernel plumpness (Franzen, 2023). Previous studies report as N rates increase, grain protein concentration rises (Goettl et al., 2024) while kernel plumpness tends to decline (Sainju et al., 2024).

To improve N use efficiency and minimize environmental losses, enhanced efficiency fertilizers (EEFs), including urease and nitrification inhibitors and controlled release formulations, have been developed to synchronize N availability with crop uptake (Franzen, 2022). However, their agronomic performance under the cool and variable climatic conditions of the Northern Plains remains uncertain, as environmental factors such as soil temperature and rainfall patterns can strongly influence N release and uptake (Olson-Rutz et al., 2011).

Given the economic importance of malting barley in North Dakota and the sensitivity of quality parameters to N management, this study was conducted to evaluate the effect of N fertilizer source on grain yield, protein concentration, and kernel plump of two-row spring barley across multiple sites in eastern North Dakota. The findings aim to identify the most effective N sources for optimizing N use efficiency while maintaining malting quality standards.

MATERIALS AND METHODS

Field experiments were conducted during the 2025 growing season at three sites in North Dakota, near Hillsboro, Lakota, and Valley City; These sites represent distinct soil types common to barley production in the state—Fargo-Hegne (silty clay), Hamerly-Wyard (loam), and Barnes-Buse (loam), respectively (Soil Survey Staff, 2025).

The experiment was arranged in a randomized complete block design (RCBD) with nine N treatments and four replicated blocks per site. Treatments consisted of eight commercial N fertilizer sources, each applied at 80% (150 lb N ac^{-1}) of the recommended regional agronomic optimum N rate (Goettl et al., 2024) and one unfertilized check. Each fertilizer source had distinct chemical characteristics and release mechanisms (Table 1).

Prior to planting, composite soil samples (0-24 in) were collected from each site to determine baseline fertility, including nitrate-N, phosphorus (P), potassium (K), pH, and organic matter. The total known available N (TKAN) was calculated as the sum of soil nitrate (N_s), previous crop credit (N_{pc}), tillage contribution (N_t), and fertilizer N applied (N_{fert}), following the NDSU recommendation framework (Franzen, 2023). For this experiment, TKAN levels corresponded to 87±16 lb N ac^{-1} for the unfertilized check and 150 lb N ac^{-1} for all fertilized treatments.

Barley cultivars Explorer (Hillsboro) and AAC Synergy (Lakota and Valley City) were used, both two-row recognized by the American Malting Barley Association (AMBA, 2025) for malting quality potential. All fertilizers were surface applied within one week of seeding. Seeding occurred between May 7 and May 9, 2025, with in-season crop management carried out by the cooperating farmers, in accordance with regional best management practices, to control pest and disease pressure. Harvest occurred between August 13 and August 14, 2025, at physiological maturity. Grain moisture and test weight were 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. Percent plump kernels were considered the weight of kernels which do not pass through a 6/64-inch sieve. Grain protein content was determined using near infrared spectroscopy (NIR).

Table 1. Description of nitrogen fertilizer sources used in the study.

Treatment	Analysis	Description
Urea	46% N	Granular fertilizer and the most widely used N source due to high N concentration and low cost.
CAN 27 (Calcium Ammonium Nitrate)	27% N, 4% Ca	Provides both nitrate and ammonium forms of N with added calcium, improving soil structure and reducing volatility.
Amidas (Urea + Ammonium Sulfate)	35% urea-N, 5% ammonium-N, 5.5% S	Combines rapid and stable N forms, adding sulfur to enhance protein synthesis and improve grain quality.
UAN (Urea Ammonium Nitrate)	28% N	Liquid fertilizer containing both urea and ammonium nitrate; liquid formulation allows uniform application and better soil contact, enhancing N availability.
ESN (Environmentally Smart Nitrogen)	44% N	Polymer-coated urea that provides slow N release, minimizing leaching and volatilization losses.
SuperU	46% N	Stabilized urea with both a urease inhibitor (NBPT) and a nitrification inhibitor (DCD) to reduce volatilization and nitrate losses.
Urea + NBPT	46%N	Urea treated with urease inhibitor NBPT only, slowing surface hydrolysis and reducing ammonia volatilization.
Tropicote (Calcium Nitrate)	15.5% N, 19% Ca	Provides nitrate-N and calcium to support grain filling and mitigate soil acidity.

Data analysis was performed using JMP (SAS Institute, Cary, NC). Analysis of variance (ANOVA) was carried out as randomized complete block design. Data in this study was considered statistically significant at $p \leq .05$.

RESULTS AND DISCUSSION

Grain Yield

Barley grain yield responded significantly to N source ($p < 0.0001$; Table 2). All fertilized treatments produced markedly higher yields compared to the non-fertilized check, which averaged only 47.2 bu ac^{-1}. The highest yields (59-60 bu ac^{-1}) were obtained with Can27 and SuperU, although differences among enhanced-efficiency sources were not statistically significant. These results indicate that most N sources supplied adequate plant-available N to maximize yield under the conditions of this study.

Table 2. Mean values for barley yield, grain protein content, and kernel plump averaged across three North Dakota locations.

Treatment	Yield	Protein	Plump
	bu ac^{-1}	%	%
Check	47.2 b	10.0 c	96.2 a
ESN	53.5 ab	11.1 a	95.4 a
Urea	58.3 a	11.0 a	95.1 a
Can 27	59.7 a	10.9 ab	94.9 a
Amidas	58.5 a	11.2 a	94.4 a
UAN 28	58.8 a	10.6 b	94.8 a
SuperU	59.7 a	11.0 a	94.6 a
Tropicote*	57.8 a	11.0 a	94.7 a
Urea + NBPT	58.5 a	11.0 a	94.4 a
p-value	<.0001	<.0001	NS

Note: Means with the same letter within each column are not significantly different at the .05 probability level.
Abbreviation: NS, nonsignificant; ESN Environmentally Smart Nitrogen; UAN Urea Ammonium Nitrate
*10% Tropicote + 90% Urea

Grain Protein

Grain protein concentration increased significantly with N fertilization, reflecting greater N uptake and assimilation in the fertilized plots. Protein values among N sources ranged from 10.9% to 11.2%, while the non-fertilized check produced the lowest value (10%). Although this unfertilized treatment had the lowest yield, it exhibited the most desirable protein level for malting quality, falling near the lower end of the AMBA recommended range (10-13%). Fertilized treatments remained within the acceptable threshold but trended toward the upper limit, indicating that N additions enhanced yield but also elevated grain protein concentration.

Among N sources, Amidas produced the highest mean protein value (11.2%; Table 2), which may be attributed to its ammonium-sulfate-based composition providing both N and sulfur. Sulfur can stimulate protein synthesis, potentially improving N assimilation efficiency (Adeyemi, 2023). Despite small numerical differences among N sources, all fertilized treatments delivered sufficient available N for protein accumulation while maintaining acceptable malting quality standards.

Kernel Plump

Unlike yield and protein, kernel plumpness was not significantly affected by N source (p = 0.36; Table 2). Plumpness values remained uniformly high (94-96%), indicating that kernel filling was more strongly influenced by environmental conditions-such as temperature and moisture than by fertilizer source. Similar patterns were observed in Idaho, where kernel plumpness exceeded 97% across most sites but declined under moisture stress during the grain-filling period (Adeyemi, 2023). Even the non-fertilized check showed plumpness above 96%, meeting AMBA's quality requirement (>90%). The absence of a treatment effect implies none of the N sources reduced grain size or malting potential. Thus, while N management strongly affected yield and protein, plumpness remained stable across all treatments, underscoring that N source selection can optimize yield and protein without compromising kernel quality.

CONCLUSION

N fertilization significantly improved barley yield and protein concentration relative to the unfertilized check, confirming the essential role of N in achieving optimal productivity. However, no significant differences were detected among N sources for any measured variable, indicating that all fertilizers supplied adequate available N to support yield and maintain acceptable malting quality.

Although statistical differences were minimal, Amidas tended to produce slightly higher protein values, likely due to its sulfur component enhancing amino acid synthesis and N assimilation. Conversely, the unfertilized check exhibited the most desirable protein concentration (10%), within the lower end of the AMBA-recommended (13%), representing the best malting quality among treatments.

Overall, these results suggest all N sources performed similarly under the tested conditions, but the choice of fertilizer should also account for economic return, environmental impact, and N use efficiency technologies. Balancing yield, malting quality, and sustainability remains essential for optimizing N management in North Dakota barley production systems.

REFERENCES

Adeyemi, O. E. 2023. *Barley yield and protein response to nitrogen and sulfur fertilizer rates and application timing* (Master's thesis, University of Idaho, Moscow, ID). University of Idaho College of Graduate Studies.

American Malting Barley Association (AMBA). 2025. *Quality Evaluation Program*.

Franzen, D. W. 2022. *Nitrogen Extenders and Additives for Field Crops (SF1581).* North Dakota State University Extension, Fargo, ND.

Franzen, D. W. 2023. *Fertilizing Malting and Feed Barley (SF714).* North Dakota State University Extension, Fargo, ND.

Franzen, D. W. 2023. *North Dakota fertilizer recommendation tables and equations (SF882).* Fargo, ND: North Dakota State University Extension.

Goettl, B., T DeSutter, H. Bu, A. Wick, and D. Franzen. 2024. *Managing nitrogen to promote quality and profitability of North Dakota two-row malting barley.* Agronomy Journal 116: 719-726.

McFarland, A., C. Kapp, R. Freed, J. Isleib, and S. Graham. 2015*. Malting Barley Production in Michigan (GMI035).* Michigan State University Extension, East Lansing, MI.

North Dakota Barley Council (NDBC). 2025. *North Dakota Barley Industry Overview 2025*. Fargo, ND.

Olson-Rutz, K., C. Jones, and C. P. Dinkins. 2011. *Enhanced Efficiency Fertilizers: Potential to Improve Nutrient Use and Reduce Losses*. Montana State Univ. Extension Publ. EB0188. Bozeman, MT

Sainju, U., A. Lenssen, and B. Allen. 2024. *Reduced nitrogen rate sustains malt barley yield and quality in dryland cropping systems*. Agronomy Journal, 116(3), 719–728.

Soil Survey Staff. 2025. *Web Soil Survey.* USDA-Natural Resources Conservation Service

USDA–NASS. 2025. *Small Grains 2025 Summary*. United States Department of Agriculture, Washington, DC.