OPTIMIZING NITROGEN INPUTS IN BARLEY PRODUCTION IN IDAHO, MONTANA, AND NORTH DAKOTA

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ABSTRACT

Nitrogen (N) management plays a critical role in balancing grain yield and malting quality of two-row spring barley (*Hordeum vulgare* L.) grown in the Northern Plains and Intermountain West. Field experiments were conducted at six locations across North Dakota, Montana, and Idaho to evaluate the effect of N fertilizer source on grain yield, protein, and kernel plump. Treatments included commercially available N sources, including enhanced-efficiency urea, urea ammonium nitrate, calcium ammonium nitrate, sulfur enriched granular urea, a non-fertilized check, and others sources, with all fertilized treatments applied at 80% of the regional recommended N rate for malting barley production. Treatments were arranged in a randomized complete block design. Nitrogen fertilization significantly increased grain yield compared with the unfertilized treatment in all states, whereas kernel plumpness was not affected by N sources in any state. Grain protein was influenced by N source in North Dakota, Montana, and Idaho, with small differences between sources. All treatments produced grain quality within the industry-required parameters.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important cereal crop cultivated in the United States, used primarily for malting, food products, and animal feed. According to USDA Crop Explorer, in the 2025/26 crop year, global barley production is projected to reach roughly 147,35 million tons, with the United States contributing about 3.38 million tons.

Idaho, Montana, and North Dakota are the three highest barley-producing states in the country (USDA-NASS, 2025). Despite regional differences, barley plays a major economic role across these states. In 2024, 66.2% of the barley planted in Montana was malt varieties (USDA-NASS, 2024), while approximately 90% of North Dakota production is contracted specifically for malting markets (North Dakota Barley Council, 2025), while Idaho is about 70% (Idaho Farm Bureau, 2025). Barley destined for malt receives a price premium and is accepted only when strict quality specifications are met (North Dakota Barley Council, 2025; MacLeod, 2014). According to the American Malting Barley Association (AMBA), acceptable malting barley requires protein concentrations below 13% and kernel plumpness above 90%, because lower protein concentrations allow kernels to reach the desired moisture content faster, accelerating the malting process (Hertsgaard et al., 2008; AMBA, 2025).

In barley, N is the most yield-limiting nutrient for barley (McFarland et al., 2015) and also has a strong influence on and grain quality. Adequate N is essential for maximizing yield; however, excessive N supply can increase grain protein concentration above malting thresholds and lower kernel plumpness (Franzen, 2023; Goettl et al., 2024; Sainju et al., 2024). To improve N use efficiency and minimize environmental losses, enhanced-efficiency fertilizers (EEFs), including urease and nitrification inhibitor-treated urea and controlled-release formulations, have been developed to synchronize N availability with crop uptake (Franzen, 2022).

With so many available commercial N fertilizers and the agronomic and environmental challenges associated with N management, this research highlights the need for region-specific N strategies for malting barley across the major producing areas of the Northern Great Plains and Intermountain West. Given the importance of maintaining malting quality while sustaining yield and reducing environmental losses, this study addresses these needs by evaluating how N fertilizer source affects grain yield, protein, and kernel plumpness in two-row spring barley grown across Idaho, Montana and North Dakota.

MATERIALS AND METHODS

Six field experiments were conducted during the 2025 growing season across Idaho, Montana and North Dakota. These sites represent distinct soil types; Idaho: Bahem (silty loam) and Declo (loam); Montana: Swims (silty clay); North Dakota: Fargo-Hegne (silty clay), Hamerly-Wyard (loam), and Barnes-Buse (loam) (Soil Survey Staff, 2025). Idaho trials were located near Aberdeen and Kimberly. Montana, one field trial was established near Kalispell. In North Dakota, trials were located near Hillsboro, Lakota, and Valley City.

The experiments were arranged in a randomized complete block design (RCBD) with five N treatments with four replicated blocks in Idaho, nine N treatments with three replicated blocks in Montana, and nine N treatments with four replicated blocks in North Dakota Treatments consisted commercial N fertilizer sources, each applied at 80% of the respective state's recommended rate, and one unfertilized check. N application rates were determined based on state-specific recommendations. For Idaho sites, the amount of N was calculated following University of Idaho recommendations at 178 lb N ac^{-1} (Mahler & Guy, 2007). For Montana, the crop demand was calculated according to Montana State University recommendations at 96 lb N ac^{-1} (Dinkins & Jones, 2019). In North Dakota, the total known available N was calculated according to North Dakota State University recommendations at 150 lb N ac (Goettl et al., 2024). Each fertilizer source had distinct chemical characteristics and release mechanisms (Table 1). Prior to planting, composite soil samples were collected from each site to determine baseline fertility, including nitrate-N (0-24 in), phosphorus (P), potassium (K), pH, and organic matter (0-6 in). Barley cultivars AAC Synergy (planted at two sites in North Dakota and one in Montana), Explorer (planted at one site in North Dakota), and BC Lexy, Copeland, LCS Odyssey, and Moravian 179 (planted in Idaho) were used—all two-row cultivars recognized by AMBA for malting quality potential (AMBA, 2025).

Table 1. Descriptions of various nitrogen fertilizer sources.

Source	N	Description
Amidas	40%	Urea with ammonium, and sulfur (Yara)
Ammonium Nitrate	33%	Fertilizer supplying nitrogen in both ammonium and nitrate forms
Ammonium Sulfate	21%	Nitrogen in the ammonium form with sulfur as sulfate
CAN27	27%	Nitrate and ammonium forms of N with added calcium (Yara)
ESN	44%	Polymer-coated urea (Nutrien)
Pivot Bio RETURN + Urea	46%	Nitrogen-fixing microbes (Pivot Bio)
SSN Urea Nutrisphere-N	46%	Urea coated with Maleic Itaconic Copolymer (Simplot)
SuperU	46%	Urea with both a urease inhibitor (NBPT) and a nitrification inhibitor (DCD) (Koch Industries)
Tropicote*	15.50%	Calcium nitrate (Yara)
UAN	28%	Liquid urea and ammonium nitrate
Urea	46%	Granular fertilizer
Urea + NBPT	46%	Urea with urease inhibitor

To determine N rate for Idaho site, University of Idaho's recommendation was followed. Fertilized N needed was calculated as the sum of N needed based on potential yield, N needed for residue breakdown, less mineralizable N and N soil test (Mahler & Guy, 2007). Total N corresponded to 94±22 lb N ac^{-1} for the unfertilized check treatment and 178±32 lb N ac^{-1} for all fertilized treatments. For Montana site, Montana State University's recommendation was followed, and total crop N requirement was calculated using a fixed rate of 1.2 lb N ac^{-1} for each bushel per acre of expected barley yield, less the amount of soil nitrate-N measured before planting (Dinkins & Jones, 2019). Total N corresponded to 17±2.7 lb N ac^{-1} for the unfertilized and 96 lb/N/ac for all fertilized treatments. For North Dakota sites, 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.

All fertilizers were surface applied within one week of seeding. Seeding occurred between April 15 and May 9, 2025. In-season crop management carried out by the cooperating farmers (North Dakota) or by university research staff at experimental stations (Montanta and Idaho), in accordance with regional best management practices, to control pest and disease pressure. Harvest occurred between August 13 and September 4, 2025. Grain moisture and test weight were measured using a Dickey-John model GAC500 XT grain analyzer (Dickey-John, Auburn, Illinois) or a Tango II near-infrared analyzer (Bruker, Billerica, Massachusetts). 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).

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 and Quality

Barley grain yield responded significantly to N source in Idaho, Montana, and North Dakota ($p<.05$; Table 2). In all three states, fertilized treatments produced significantly greater yields than the non-fertilized check. In Idaho, the highest yields were obtained with Urea+NBPT, SSN Urea Nutrisphere-N, and Ammonium sulfate, while the check treatment resulted in the lowest yield. In Montana, the highest yields were observed with Amidas, SuperU, Urea + NBPT, and Pivot Bio + Urea, while UAN produced lower yields among fertilized treatments. In North Dakota, yield differences were primarily associated with fertilization compared with the check treatment, and yields did not differ significantly among fertilized N sources. These results indicate that multiple N sources supplied sufficient plant-available N to maximize barley yield across locations.

Grain protein responded significantly to N source in Idaho, Montana and North Dakota ($p<.05$; Table 2). In Idaho, protein concentration ranged from 9.5 to 11.0% and in Montana from 9.3 to 10.9%, with mean separation showing small differences among N sources (Table 2). In North Dakota, the non-fertilized check had the lowest protein content (10%), whereas fertilized treatments generally resulted in higher protein concentrations (10.6-11.2%). 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.

Kernel plump was not affected by N source in Idaho, Montana, or North Dakota (Table 2). Plumpness values remained uniformly above 94% for all sites, indicating that kernel filling was more strongly influenced by environmental conditions-such as temperature and moisture than by fertilizer source. Thus, while N management affected yield and protein, plumpness remained stable, underscoring that N source selection can optimize yield and protein without compromising kernel quality.

CONCLUSION

Nitrogen fertilization increased barley grain yield across Idaho, Montana, and North Dakota, while differences among fertilizer sources were minimal when applied at 80% of the recommended N rate. Grain protein increased with N fertilization but remained within acceptable limits for malting, and kernel plumpness was unaffected by N source. These results indicate multiple N fertilizer sources can be used to achieve high yield and maintain malting quality across diverse production environments. Without impacting malting quality, the cost and sustainability benefits of each fertilizer can be weighed independently to meet farm economic and sustainability goals.

Table 2. Mean values for barley yield, grain protein content, and kernel plump averaged across research sites in Idaho, North Dakota, and Montana.

State	**Treatment**	**Yield**	**Protein**	**Plump**
		bu ac^{-1}	%	%
Idaho	Urea + NBPT	163 a	10.9 a	97.5
	SSN Urea Nutrisphere-N	152 a	10.5 a	98.8
	Ammonium Sulfate	152 a	10.4 ab	98.5
	SuperU	151 ab	10.3 ab	98.1
	ESN	150 ab	11.0 ab	98.6
	Can27	145 ab	10.8 ab	98.5
	Urea	144 ab	10.9 ab	98.5
	Ammonium Nitrate	141 ab	9.9 ab	98.3
	SuperU + ESN*	139 ab	10.9 ab	98.6
	Amidas	138 ab	9.5 ab	98
	Check	123 b	10.0 b	98.4
	p-value	<.05	<.05	NS
North Dakota	Urea	58.3 a	11.0 a	95.1
	Can 27	59.7 a	10.9 ab	94.9
	Amidas	58.5 a	11.2 a	94.4
	UAN 28	58.8 a	10.6 b	94.8
	SuperU	59.7 a	11.0 a	94.6
	Tropicote†	57.8 a	11.0 a	94.7
	Urea + NBPT	58.5 a	11.0 a	94.4
	ESN	53.5 ab	11.1 a	95.4
	Check	47.2 b	10.0 c	96.2
	p-value	<.0001	<.0001	NS
Montana	Can 27	130 a	10.1 ab	98.5
	Amidas	140.07 a	10.9 a	98.5
	SuperU	139.64 a	10.8 a	98.1
	Urea + NBPT	135.19 a	10.6 a	98.7
	Pivot Bio + Urea	135.15 a	10.3 ab	98.6
	Urea	122.22 ab	10.0 ab	98.3
	ESN	121.26 abc	10.9 a	97.8
	UAN	102.54 bc	9.3 a	98.7
	Check	95.28 c	9.4 b	98.4
	p-value	<.05	<.05	NS

Note: Means with the same letter within the same column for each state are not significantly different at the .05 probability level.

Abbreviations: NS, nonsignificant; ESN, Environmentally Smart Nitrogen; UAN Urea Ammonium Nitrate

*50% SuperU + 50% ESN

†10% Tropicote + 90% Urea

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