HOW SHOULD WE MANAGE NITROGEN FOR HYBRID WINTER RYE IN SOUTH DAKOTA?

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ABSTRACT

Hybrid winter rye (*Secale cereale* L.) has gained interest as a grain crop across the U.S. Midwest in recent years. However, regional recommendations for spring nitrogen (N) management remain limited in the Upper Midwest. Therefore, the objectives of this project were to 1) evaluate the effects of N rate, source, and application timing on grain yield and 2) determine the agronomic and economic optimum N rates (AONR and EONR). During the 2025 and 2026 growing seasons, a field trial was conducted in southeastern South Dakota, where all treatments received a uniform 30 lb. N ac^{-1} fall application followed by spring N rates ranging from 0 to 210 lb N ac^{-1}. At 60 and 90 lb N ac^{-1}, source treatments included Urea and SuperU®, while timing treatments included single and split applications, with the second application occurring in April or May. Using the quadratic-plateau model, spring EONR was 19 and 27 lb N ac^{-1} in 2025 and 2026, respectively, with predicted grain yields of 61 and 88 bu ac^{-1}. Corresponding AONR values were 26 and 121 lb N ac^{-1}, with yields of 61 and 98 bu ac^{-1}. Thus, in 2026, an additional 94 lb N ac^{-1} above EONR increased predicted yield by only 10 bu ac^{-1}. Neither N source nor application timing affected grain yield at 60 or 90 lb N ac^{-1} in either growing season. Overall, modest spring N rates maximized economic return, while SuperU® and split applications provided no yield advantage over urea and a single application.

INTRODUCTION

Nitrogen (N) management is important for maximizing cereal grain yield and economic returns while minimizing potential environmental losses. Insufficient N can limit crop productivity, whereas excessive N application increases fertilizer costs and the risk of N losses (Cassman et al., 2002; Snyder et al., 2009). The benefits of split N applications and optimum N rates can vary with growing conditions in winter cereals (Graham and Stockton, 2019; Lindsey et al., 2026). Hybrid breeding has increased the grain yield potential of winter rye (*Secale cereale* L.) compared with open-pollinated cultivars (Nye et al., 2025). Increasing spring N rates from 35 to 70 lb N ac^{-1} did not significantly increase winter rye grain yield (Szuleta et al., 2023). However, information on spring N management for hybrid winter rye remains limited in the Upper Midwest.

Therefore, the objectives of this study were to 1) evaluate the effects of spring N rate, source, and application timing on hybrid winter rye grain yield and 2) determine the agronomic and economic optimum N rates (AONR and EONR) in southeastern South Dakota (SD).

MATERIALS AND METHODS

This study was conducted during the 2024-2025 and 2025-2026 growing seasons at the South Dakota State University Southeast Research Farm (SERF) near Beresford, SD (43.0° N, 96.8° W), on a well-drained Egan silty clay loam soil, with soybean (*Glycine max* (L.) Merr.) as the preceding crop. Hybrid winter rye cultivars 'Receptor' (2024-2025) and 'Serafino' (2025-2026) were planted in the fall using a no-till drill at a seeding rate of 800,000 seeds ac^{-1}, seeding depths of 1 and 1.75 inches, respectively, and a row spacing of 7.5 inches. The experiment was arranged in a randomized complete block design (RCBD) with four replications in each growing season. Individual plots measured 15 ft × 50 ft (0.017 ac), totaling approximately 0.96 ac of experimental plot area per year. All plots received a uniform application of 30 lb N ac^{-1} at planting.

Before spring N applications, 20 soil cores per replication were collected in a zigzag pattern at 0–6 inches and 6–24 inches depths. Samples were transported to South Dakota State University (Brookings, SD), refrigerated, air-dried, ground, and sieved (2 mm) before analysis at Ward Laboratories Inc. (Kearney, NE). Analyses at both depths included nitrate-N (NO_3^--N), ammonium-N (NH_4^+-N), and routine soil fertility properties.

Fourteen spring N treatments were evaluated, including eight N rates (0, 30, 60, 90, 120, 150, 180, and 210 lb N ac^{-1}), two additional N source treatments, and four split-application treatments. All N rates and N source treatments were fertilized once in March. SuperU®, a stabilized urea containing dicyandiamide (DCD) and N-(n-butyl) thiophosphoric triamide (NBPT) (Koch Agronomic Services, Wichita, KS), was used in all fertilized treatments except the two N source treatments, which received conventional urea (46-0-0) at 60 and 90 lb N ac^{-1}. At these same rates, single March applications of SuperU® were compared with split applications of 30 lb N ac^{-1} in March followed by an additional 30 or 60 lb N ac^{-1} in April or May.

Nitrogen source and application timing effects on grain yield were evaluated using analysis of variance (ANOVA), and treatment means were compared using Tukey's HSD test at $P \leq 0.05$. AONR and EONR were determined by averaging from linear-plateau and quadratic-plateau regression models fitted to grain yield responses to spring N rates (Cerrato and Blackmer, 1990; Scharf et al., 2005). Economic calculations used N fertilizer prices of US$0.75 and US$0.79 lb^{-1} N and rye grain prices of US$3.00 and US$3.68 bu^{-1} in 2025 and 2026, respectively. Statistical analyses were performed using JMP® Student Edition (Version 18.2.2; SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

Initial Soil Properties

Soil inorganic N, measured as ammonium (NH_4^+–N) and nitrate (NO_3^-–N), differed between growing seasons before spring fertilization (Table 1). In 2025, NH_4^+–N accounted for approximately 71% of soil inorganic N in the 0-24 inches soil profile, with most of the NH_4^+–N stock found in the 6-24 inches layer. In contrast, NO_3^-–N represented approximately 81% of soil inorganic N in 2026.

Table 1. Soil test information from samples collected before spring fertilizer N application. Sampling depth of 0-6 inches for pH, organic matter (OM), and organic N release; and 0-24 inches for NH_4^+–N and NO_3^-–N.

Year	pH	OM	Organic N Release	NH_4^+–N (0-6 in)	NH_4^+–N (6-24 in)	NO_3^-–N (0-6 in)	NO_3^-–N (6-24 in)
		%	lb N ac^{-1}				
2025	7.2	5.60	42.5	31.35	133.2	36.55	30.15
2026	6.0	4.05	16.9	5.25	14.85	44.95	43.50

Grain Yield Response to N Rate

Hybrid winter rye grain yield response to spring N rates varied between growing seasons (Figures 1 and 2). In 2025, AONR and EONR were 25 and 22 lb N ac^{-1}, respectively, both resulting in an estimated grain yield of 61 bu ac^{-1}. In 2026, higher grain yields and optimum N rates were observed, with an AONR of 90 lb N ac^{-1} (86 bu ac^{-1}) and an EONR of 43 lb ac^{-1} (81 bu ac^{-1}), achieving 94% of the yield at AONR with 52% less N. In both years, EONR remained below 45 lb N ac^{-1}, indicating that relatively low spring N rates were sufficient to maximize economic returns.

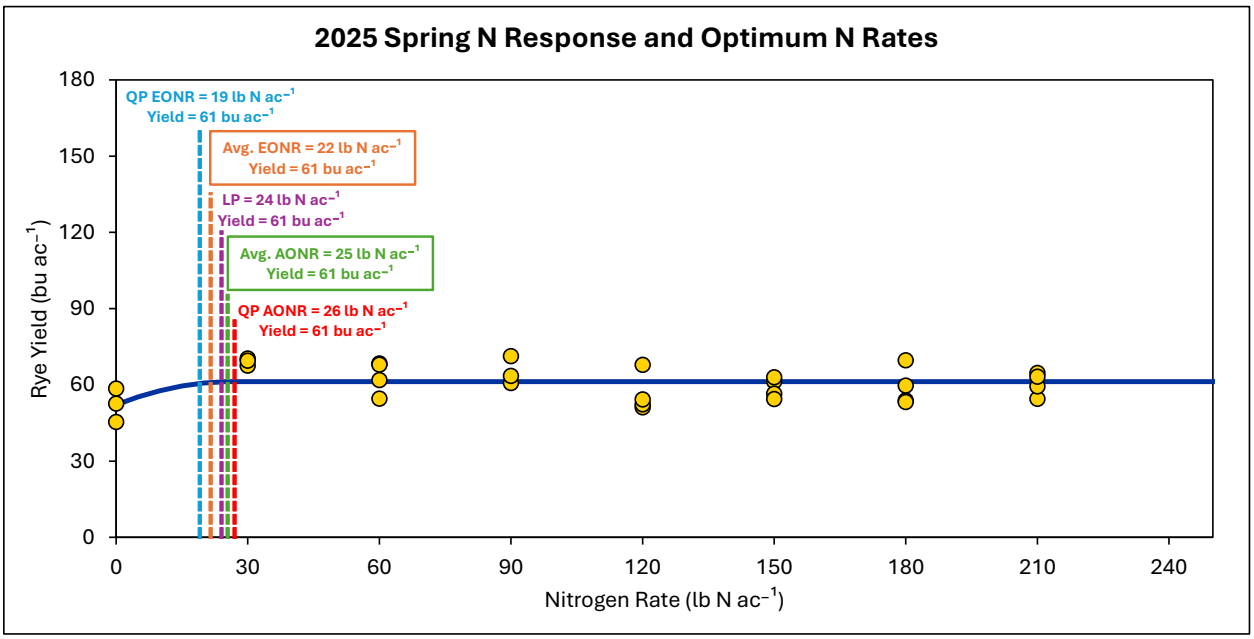


Figure 1. Hybrid winter rye grain yield response to spring N rate at Beresford, SD, in 2025. Average AONR and EONR were calculated as the arithmetic mean of the linear-plateau (LP) and quadratic-plateau (QP) model estimates. Both models had $R^2 = 0.16$.

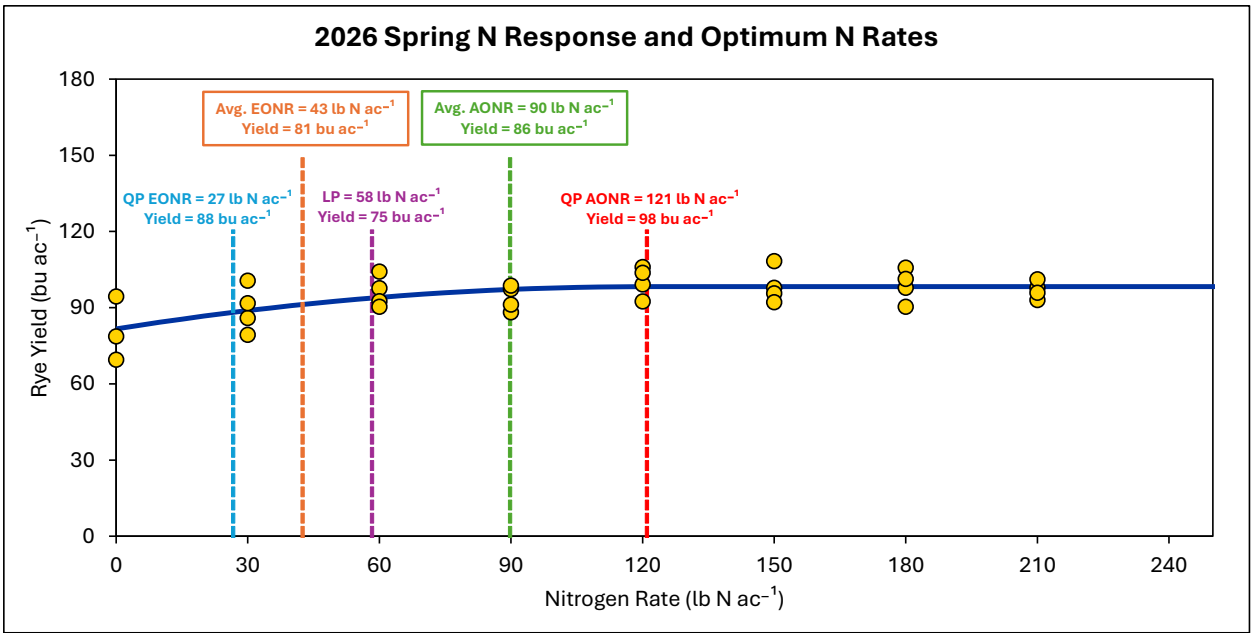


Figure 2. Hybrid winter rye grain yield response to spring N rate at Beresford, SD, in 2026. Average AONR and EONR were calculated as the arithmetic mean of the linear-plateau (LP) and quadratic-plateau (QP) model estimates. The QP model had $R^2 = 0.41$, while the LP model had $R^2 = 0.40$.

Optimum N rates and grain yields were greater in 2026 than in 2025, coinciding with more favorable moisture conditions. Estimated organic N release was greater in 2025 than in 2026 (Table 1), suggesting greater potential soil N supply. However, in-season N mineralization is influenced by environmental conditions (Sherbine et al., 2023), and drier conditions in 2025 may have limited the realization of this potential. Lower yield potential under drier conditions may also have reduced crop N demand, contributing to the lower spring N requirement observed in 2025.

N Source and Timing Effects

Grain yield was not consistently improved by using SuperU® instead of conventional urea or by splitting spring N applications (Figures 3 and 4). In 2025, split applications did not improve yield at 60 lb N ac^{-1}, whereas the March + April split produced the highest numerical yield at 90 lb N ac^{-1}. In 2026, treatment responses varied, but no significant differences were observed among N management strategies within either N rate.

The lack of consistent yield benefits suggests that neither stabilized urea nor split applications provided a clear agronomic advantage under the conditions evaluated. Similar findings were reported in winter wheat, where split N applications did not consistently improve grain yield (Abiola et al., 2025), and SuperU® provided no consistent advantage over conventional urea (Derrick et al, 2026). Thus, a single early-spring N application may be sufficient to meet the N demand of rapidly growing hybrid winter rye, potentially avoiding additional fertilizer and application costs.

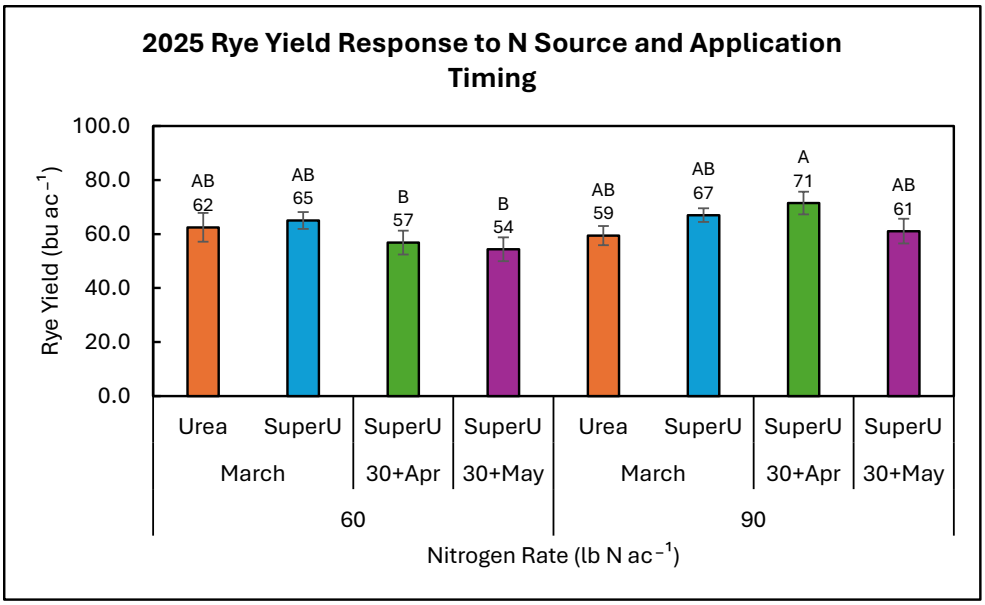


Figure 3. Hybrid winter rye grain yield response to spring N source and application timing in 2025. Different letters indicate significant differences among treatments (Tukey's HSD, $P \leq 0.05$).

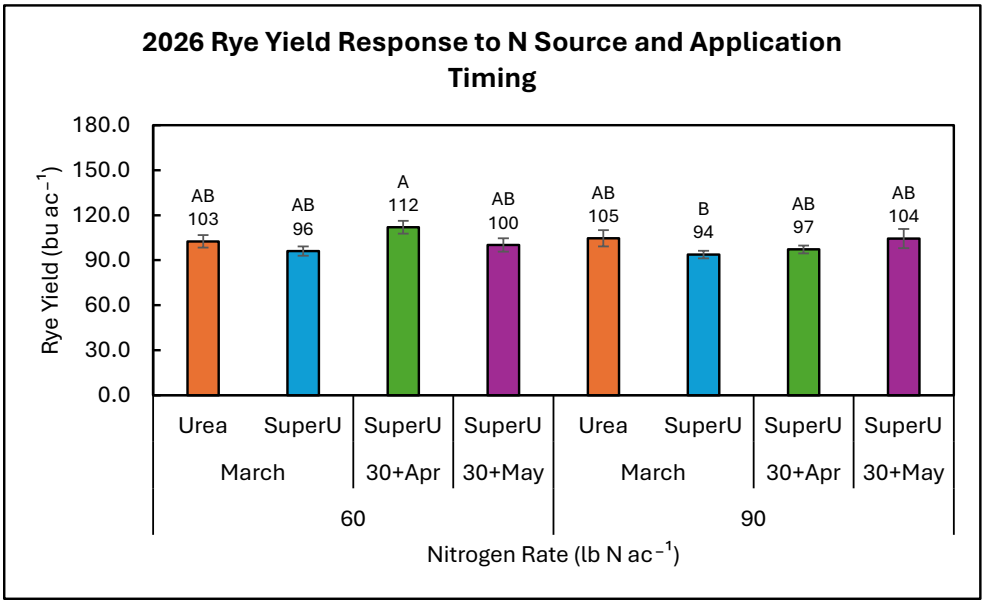


Figure 4. Hybrid winter rye grain yield response to spring N source and application timing in 2025. Different letters indicate significant differences among treatments (Tukey's HSD, $P \leq 0.05$).

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