2024 Rye Nitrogen Fertility Trial

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The interest in growing cereal rye for grain to be sold as cover crop seed, or to other value-added markets (distillers and bakers), has increased considerably across the Northeast region in recent years. This winter-hardy grain has the ability to survive cold winters and can be more tolerant of marginal land not suitable for other crops. As a result, farmers and end-users are requesting yield and quality information on cereal rye varieties. In 2023-2024, University of Vermont Extension Northwest Crops and Soils (NWCS) Program conducted a nitrogen (N) fertility trial to evaluate yield and quality of cereal rye under variable nitrogen application scenarios.

MATERIALS AND METHODS

The rye fertility trial was initiated at Borderview Research Farm in Alburgh, VT in the fall of 2023. Agronomic information is displayed in Table 1. The experimental design was a randomized complete block with split plots and four replicates. The field was prepared with a Pottinger TerraDisc® and plots were seeded with a Great Plains Cone Seeder on 21-Sep 2023 at a seeding rate of 350 live seeds m^{-2}. Main plots were treatments nitrogen application rate and timing (Table 2). The subplots were variety including an open-pollinated (Hazlet) and hybrid (Tayo) type. Fall nitrogen applications were made on 4-Oct 2023 and spring applications were made on 17-Apr 2024 in the form of calcium ammonium nitrate (CAN) 27-0-0.

Table 1. Agronomic and trial information for the rye cover crop variety trial, 2023-2024.

	Borderview Research Farm, Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Cool season forages
Tillage operations	Pottinger TerraDisc®
Harvest area (ft.)	5 x 20
Seeding rate (live seeds m^{-2})	350
Replicates	4
Varieties	Hazlet, Tayo
Planting date	21-Sep 2023
Harvest date	22-Jul 2024

Table 2. Nitrogen (N) fertility treatment application rates and times, 2023-2024.

Treatment	Application date
Control (no additional N)	No application
90 lbs N/ac fall applied	4-Oct 2023
90 lbs N/ac spring applied	17-Apr 2024
45/45 lbs N/ac split application (fall/spring)	4-Oct 2023 / 17-Apr 2024

On 26-Oct 2023, percent ground cover of rye plots was recorded for each treatment using the Canopeo© smartphone application to determine potential impacts of fertility applications on rye establishment. In the following spring (17-Apr 2024) percent ground cover was once again recorded to further evaluate application rates and winter kill for each plot. At harvest, lodging was assessed visually as percent lodged, with 0% indicating no lodging and 100% indicating the entire plot was lodged. Grain plots were harvested with an Almaco SPC50 plot combine on 22-Jul 2024. Seed was cleaned with a small Clipper M2B cleaner (A.T. Ferrell, Bluffton, IN) and a one-pound subsample was collected to analyze quality characteristics. Grain quality was determined at the E. E. Cummings Crop Testing Laboratory at the University of Vermont (Burlington, VT). Grains were analyzed for crude protein and starch content using the Perten Inframatic 9500 NIR Grain Analyzer (Perkin Elmer, Waltham, MA). The samples were then ground into flour using the Perten LM3100 Laboratory Mill (Perkin Elmer). Falling number for all rye varieties were determined using the AACC Method 56-81B, AACC Intl., 2000 on a Perten FN 1500 Falling Number Machine Mill (Perkin Elmer). The falling number indirectly measures enzymatic activity in the grain, which is typically used as an indicator of pre-harvest sprouting. It is determined by the time it takes, in seconds, for a stirrer to fall through a slurry of flour and water to the bottom of a test-tube. Deoxynivalenol (DON) analysis was done using Veratox DON 2/3 Quantitative test from the NEOGEN Corp (Lansing, MI). This test has a detection range of 0.5 to 5 ppm. Samples with DON values greater than 1 ppm are considered unsuitable for human consumption. Samples from one replicate were evaluated for DON and all samples tested below the FDA threshold for human consumption (1 ppm) (data not shown).

Standard characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within the trial were treated as random effects, and treatments were treated as fixed. Treatment mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

Variations in project results can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table, a LSD value is presented for each variable (e.g. yield). Least Significant Differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two values. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In the previous example, treatment A is significantly different from treatment C but not from treatment B. The difference between A and B is equal to 200, which is less than the LSD value of 300. This means that these treatments did not differ in yield. The difference between A and C is equal to 400, which is greater than the LSD value of 300. This means that the yields of these treatments were significantly different from one another.

Treatment	Yield
A	**2100***
B	1900*
C	1700
LSD	300

RESULTS

Seasonal precipitation and temperature recorded at Borderview Research Farm in Alburgh, VT are displayed in Table 3. Fall temperatures at establishment through October were 6.60° F warmer than average leading to strong winter survival for nearly all treatments. Similar to the 2023 growing season, we saw a significantly wetter season with 29.9 total inches, 4.52 inches above the average. The average temperature during the primary growing season was 5.88° F above average with cumulative Growing Degree Days (GDDs) reaching 5506, which is 235 above average.

Table 3. Seasonal weather data collected in Alburgh, VT, 2023-2024.

Alburgh, VT	23-Sep	23-Oct	23-Nov	24-Apr	24-May	24-Jun	24-Jul
Average temperature (°F)	64.7	54.9	35.9	45.7	61.9	68.5	73.7
Departure from normal	1.97	4.63	-3.39	0.13	3.47	0.95	1.33
Precipitation (inches)	2.4	5.38	2.03	4.47	2.27	6.65	6.67
Departure from normal	-1.27	1.55	-0.67	1.4	-1.49	2.39	2.61
Growing Degree Days (base 32°F)	980	711	175	327	926	1093	1294
Departure from normal	58	143	-60	-84	108	29	41

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2020) for Burlington, VT.

Variety x fertility application interactions

There were no significant interactions between variety and fertility applications, indicating that the varieties responded similarly to the various fertility treatments.

Impacts of fertility applications

Table 4 displays field and harvest measurements. Some differences were observed in spring ground cover with the highest coverage seen in the 45-45 lbs N ac^{-1} split application treatment at 79.07% and was statistically similar to both the spring and fall applications of 90 lbs N ac^{-1}. Heights and lodging measurements were collected within the trial prior to harvest. All treatments receiving additional nitrogen applications had higher levels of lodging, with the highest seen in the split application and the spring application at 78.1% lodging each. Conversely, the control receiving no supplemental nitrogen had the lowest overall lodging at 33.6%, despite having the tallest plants within the trial at 140cm.

Table 4. Rye nitrogen fertility establishment and harvest measurements, Alburgh, VT, 2024.

Treatment	Fall ground cover	Spring ground cover	Height	Lodging
	%	%	cm	%
45-45 lbs N ac^{-1} split application (fall/spring)	62.79	**79.1a**†	129 b	78.1 c
90 lbs N ac^{-1} fall applied	64.60	78.3 a	138 a	56.9 b
90 lbs N ac^{-1} spring applied	65.41	68.7 ab	137 a	78.1 c
Control	60.08	66.3 b	**140 a**	**33.6 a**
LSD (p=0.10)‡	NS§	10.9	6.50	20.8
Trial mean	63.22	73.1	136	61.7

†Treatments marked with the same letter do not differ significantly.
‡LSD; least significant difference at the p=0.10 level.
§NS; no significant differences between treatments.

Significant differences in nitrogen treatments were observed in moisture, test weight, crude protein, starch, and falling number (Table 5). Ideal grain storage moisture is around 13.5% and all treatments would need to be further dried down to reduce potential crop loss. All grain tested below 14% with lowest observed moisture seen in the 90 lbs N ac^{-1} spring applied treatment at 13.0%, which was statistically similar to the split nitrogen application at 13.4%, both below the ideal moisture for storage. The ideal test weight for rye is 56 lbs bu^{-1}; the only treatment meeting this standard was the 45-45 lbs N ac^{-1} split application treatment at 56.5 lbs bu^{-1} but was statistically similar to the 90 lbs N ac^{-1} fall applied treatment at 55.3 lbs bu^{-1}. Yields did not appear to be impacted by nitrogen treatments with a trial average of 5201 lbs ac^{-1}, and highest yields seen in the split nitrogen application treatment at 5543 lbs ac^{-1}.

Table 5. Rye nitrogen fertility harvest and quality measurements, Alburgh, VT, 2024.

Treatment	**Harvest moisture**	**Test weight**	**Yield @ 13.5% moisture**	**Crude protein @ 12% moisture**	**Starch @ 12% moisture**	**Falling number**
	%	**lbs bu^{-1}**	**lbs ac^{-1}**	**%**	**%**	**seconds**
45-45 lbs N ac-1 split application (fall/spring)	13.4 ab†	**56.5 a**	5543	7.86 a	61.4c	196 b
90 lbs N ac-1 fall applied	13.9 b	55.3 a	5244	7.34 b	61.8 b	214 ab
90 lbs N ac-1 spring applied	**13.0 a**	52.0 b	5057	**7.89 a**	61.4 c	200 ab
Control	13.7 b	52.8 b	4961	6.86 c	**62.2 a**	**216 a**
LSD (p=0.10) ‡	0.492	2.34	NS§	0.283	0.252	19.5
Trial mean	13.5	54.2	5201	7.49	61.7	206

†Treatments marked with the same letter do not differ significantly.
‡LSD; least significant difference at the p=0.10 level.
§NS; no significant differences between treatments.

The four nitrogen treatments were also analyzed for crude protein and starch concentrations, adjusted for 12% moisture, falling number, and DON concentrations (Table 5). Quality of cereal rye for crude protein, starch and falling number all appeared to be significantly influenced by fertility applications within this trial. All treatments receiving supplemental nitrogen had significantly higher levels of crude protein when compared to the control, with the highest observed value seen in the 90 lbs N ac^{-1} spring applied treatment. Conversely, the control treatment had the highest values for both starch and falling number at 62.2% and 216 seconds respectively. An ideal falling number for wheat is between 250 and 300 seconds, however, lower falling numbers around 100-200 seconds have been acceptable to bakers using rye flour. Falling number for all treatments appeared to be within an acceptable range for baking. One replication of the study was evaluated for DON levels, with no treatments exceeding the 1 ppm threshold considered safe for human consumption.

DISCUSSION

While no differences were apparent between the two varieties in how they reacted to supplemental nitrogen treatments, there were a number of observed impacts as a result of nitrogen application timing. Compared to previous years, more differences were seen in grain quality. In general, protein can be impacted by plant genetics as well as environmental conditions such as temperature, precipitation, and plant available nitrogen in the soil. Grains will typically allocate nutrients and other resources towards increasing seed yields before producing protein. In this instance, it appeared as if nitrogen requirements were met for yields, with supplemental nitrogen increasing the overall protein content by up to 1% or more. Yields in 2024 were not impacted by nitrogen treatment, however trial averages were approximately 800 lbs ac^{-1} higher than in 2023. This is likely to be more impacted by weather conditions in which greater lodging was observed in 2023, alongside lower test weights within the trial. Given the growing conditions for the season, there also appeared to be little influence on fall establishment as a result of nitrogen application timing, however previous years showed some benefit to fall applications, helping to spur some growth before winter.

Because rye relies on different grain components to create high-quality bread, and ferments more readily than wheat, it is expected that lower falling numbers are preferred for rye than for wheat, possibly closer to 100-200 seconds. Those falling number values averaged between 196-216 across nitrogen treatments, however Tayo had a higher average than Hazlet. Qualities such as falling number are more highly impacted by variety as opposed to nitrogen timing, and as such varietal selection would likely be the main driver in falling number values over nitrogen inputs in this instance. Furthermore, other compounds such as pentosans, polysaccharides that impact the water holding capacity of the flour, could prove to be more impactful in rye flour and baking quality, highlighting the importance of additional studies with rye.

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