2023 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 2022-2023, 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 2022. Plots were managed with practices similar to those used by producers in the surrounding area. 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 17-Sep 2022 at a seeding rate of 350 live seeds m^{-2}. Main plots were treatments consisted of varying application rates and periods and subplots were variety (Table 2). Fall applications were made on 6-Oct 2022 and spring applications were made on 26-Apr 2023 in the form of calcium ammonium nitrate (CAN) 27-0-0.

Table 1. Agronomic and trial information for the rye cover crop variety trial, 2022-2023.

	Borderview Research Farm, Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Winter Wheat
Tillage operations	Pottinger TerraDisc®
Harvest area (ft.)	5 x 20
Seeding rate (live seeds m^{-2})	350
Replicates	4
Varieties	Hazlet, Tayo
Planting date	17-Sep 2022
Harvest date	31-Jul 2023

Table 2. Nitrogen fertility treatment application rates and times, 2022-2023.

Treatment	Application date
Control (no additional N)	No application
90 lbs N/ac fall applied	6-Oct 2022
90 lbs N/ac spring applied	26-Apr 2023
45/45 lbs N/ac split application (fall/spring)	6-Oct 2022 / 26-Apr 2023

On 8-Nov 2022, 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 (12-Apr 2023) percent ground cover was once again recorded to further evaluate application rates and winter kill for each plot. Biomass samples were collected on 11-May alongside soil nitrate samples. On 26-Jul 2023, three plant heights per plot were measured for each plot, excluding awns. Lodging was assessed visually as percent lodged, with 0% indicating no lodging and 100% indicating the entire plot was lodged. Grain plots were harvested at the Alburgh site with an Almaco SPC50 plot combine on 31-Jul. 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 ($p<0.10$).

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

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.

RESULTS

Seasonal precipitation and temperature recorded at Borderview Research Farm in Alburgh, VT are displayed in Table 3. The average fall temperature (Sep 2022 to Nov 2022) was 51.8° F, which was 2.23°F warmer than the 30-year normal. The average temperature from Mar 2023 to Jul 2023 was 1.30° F cooler than the 30-year normal. This growing season was wetter than past years with a total precipitation of 24.1 inches from Mar 2023 to Jul 2023. The catastrophic flash flooding that occurred mid-month in Jul 2023 resulted in 10.8 inches of precipitation, a departure of 6.69 inches more than the 30-year average. From Sep 2022 to Jul 2023, there were 5260 Growing Degree Days (GDDs), which is less than the mean historical GDD trends over the last 30 years.

Table 3. Weather data for rye variety trial in Alburgh, VT.

Alburgh, VT	Sep-22	Oct-22	Nov-22	Mar-23	Apr-23	May-23	Jun-23	Jul-23
Average temperature (°F)	60.2	51.3	41.5	32.2	48.3	57.1	65.7	72.2
Departure from normal	-2.52	0.96	2.24	-0.07	2.7	-1.28	-1.76	-0.24
Precipitation (inches)	4.4	2.56	3.01	2.00	4.94	1.98	4.4	10.8
Departure from normal	0.73	-1.27	0.31	-0.24	1.87	-1.78	0.14	6.69
Growing Degree Days (base 32°F)	861	607	346	103	280	766	1023	1274
Departure from normal	-61	39	111	-35	-132	-53	-40	22

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1991-2020) 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 slight differences were observed in fall and spring ground cover and establishment. Overall, each fertility treatment appeared to have good fall stand establishment and winter survival as reflected in the percent ground cover during the two observation periods. The 45-45 lbs N ac^{-1} split application treatment had the highest overall ground cover at 92.8% coverage and was statistically similar to the spring and fall applied fertilizer treatments. Heights and lodging data were collected within the trial prior to harvest. There appeared to be no treatment impact from fertilizer applications on plant heights, however there was an observed impact on lodging. The control, receiving no supplemental fertilizer, had the lowest overall lodging at 49.4% and was statistically similar to the 45-45 split application and the 90 lbs N ac^{-1} spring applied treatment, whereas the greatest observed lodging was seen in the 90 lbs N ac^{-1} fall applied treatment at 74.4%.

Table 4. Rye nitrogen fertility establishment and harvest measurements, Alburgh, VT, 2023.

Treatment	Fall ground cover	Spring ground cover	Height	Lodging
	%	%	cm	%
45-45 lbs N ac^{-1} split application (fall/spring)	**92.8a**	86.3ab	139	68.1ab
90 lbs lbs N ac^{-1} fall applied	89.2ab	**89.4a**	140	74.4b
90 lbs lbs N ac^{-1} spring applied	88.7ab	83.6b	143	63.1ab
Control	87.2b	87.6ab	148	**49.4a**
LSD (p=0.10)	4.52	4.50	NS§	23.9
Trial mean	89.5	86.7	142	63.8

†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.

Test weight, harvest moisture and yields are shown in Table 5. There were no significant differences between treatments for test weight with a trial average of 44.8 lbs bu^{-1}, well below the ideal test weight of 56.0 lbs bu^{-1} for rye. Control plots had the lowest average harvest moisture at 19.3% and were statistically similar to the 45-45 split spring-fall application and the 90 lbs N ac^{-1} spring applied nitrogen treatments. Ideal grain storage moisture is around 13.5% and all treatments would need to be further dried down to reduce potential crop loss. Yields were affected similarly by treatments with the control exhibiting highest yields at 4566 lbs ac^{-1}, again statistically similar to the 45-45 split spring-fall application and the 90 lbs N ac^{-1} spring applied nitrogen treatments.

Table 5. Rye nitrogen fertility harvest and quality measurements, Alburgh, VT, 2023.

Treatment	Test weight	Harvest moisture	Yield @ 13.5%	Crude protein @ 12% moisture	Starch at 12% moisture	Falling Number	DON
	lbs bu-1	%	lbs ac-1	%	%	seconds	ppm
45-45 lbs N/ac split application (fall/spring)	44.0	20.7ab†	3884ab	8.31	61.3	113	3.50
90 lbs N/ac fall applied	43.9	21.5b	3402b	8.11	61.5	107	3.40
90 lbs N/ac spring applied	45.0	20.4ab	4222ab	8.21	57.8	123	3.40
Control	46.4	**19.3a**	**4566a**	7.70	62.0	130	3.80
LSD (p=0.10) ‡	NS§	1.91	1144	NS	NS	NS	NS
Trial Mean	44.8	20.5	4019	8.08	60.7	118	3.50

†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 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 DON did not appear to be significantly influenced by fertility applications within this trial. Falling number had no significant differences across treatments with a trial average of 118 seconds. An ideal falling number falls 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. Overall, DON levels were high this year and all treatments had levels of DON exceeding the 1 ppm threshold for safe human consumption.

DISCUSSION

Greatest observed differences in nitrogen application treatments appeared to be seen in yields and lodging within the trial with no impacts observed on grain quality across the various fertility treatments. The control treatment this year had the highest overall yields, likely as a result of the lower rates of lodging observed within the trial. Plants may have been especially susceptible to lodging this year given the excessive amounts of precipitation received prior to harvest during grain dry down periods. Fall nitrogen applications to cereal rye may improve stand establishment and spur growth before winter dormancy periods. However, from this experiment, it appeared as if fall timing of nitrogen applications had minimal impact on the yield and quality of rye produced. The University of Vermont Extension Northwest Crops and Soils (NWCS) Program intends to repeat this trial in the 2023-2024 growing season as additional research is required to determine impacts of N application timing and rate on cereal rye productivity in the Northeast.

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