NORTHWEST CROPS & SOILS PROGRAM

2023 Rye Planting Date x Planting Depth Trial

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2023 RYE PLANTING DATE X PLANTING DEPTH 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. Farmers are interested in understanding how planting date and seeding depth impact winter survival, grain yield, and quality. In 2022-2023, University of Vermont Extension Northwest Crops and Soils (NWCS) Program conducted a trial to evaluate the impact of planting date and seeding depth on the performance of an open-pollinated and hybrid rye varieties.

MATERIALS AND METHODS

The rye planting date x seeding depth trial was initiated at Borderview Research Farm in Alburgh, VT in the fall of 2022. Agronomic information is displayed in Table 1. The experimental design was a randomized complete block with split-split plots. The main plots were planting date starting on 24-Sep and occurring weekly until 22-Oct 2022. The split plot was planting depths of 0.5", 1.0", and 1.5". The split-split plot included a open pollinated (Hazlet) and hybrid (Tayo) rye variety. The field was prepared with a Pottinger TerraDisc®. First planting date plots were seeded in 5' x 20' plots with a Great Plains Cone Seeder on 24-Sep 2022 at a seeding rate of 350 live seeds m^{-2} with subsequent planting dates established approximately 1 week apart, varying slightly as a result of weather and field conditions.

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	Fall plow, disc, and spike tooth harrow	
Harvest area (ft.)	5 x 20	
Seeding rate (live seeds m^{-2})	350	
Replicates	4	
Variety	Hazlet (OP) & Tayo (Hybrid)	
Planting date – Germination date	24-Sep 2022	3-Oct 2022
	3-Oct 2022	12-Oct 2022
	10-Oct 2022	24-Oct 2022
	16-Oct 2022	28- Oct 2022
	22-Oct 2022	5-Nov 2022
Planting Depths	0.5"	
	1.0"	
	1.5"	
Harvest date	6-Aug 2023	

After fall establishment, and prior to sustained freezing temperatures (9-Nov), percent ground cover was measured by processing photographs using the Canopeo© smartphone application. Additionally, tiller and plant counts were taken from a one-foot section within each plot to evaluate stand establishment on 10-Nov. On 3-Aug 2023, prior to harvest, three plant heights per plot were measured, 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 6-Aug. 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. Samples for each planting date at the 1.0" planting depth were saved for quality analysis to further determine potential impacts of planting date on rye quality. 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 2. 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 2. 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 planting date x seed depth interactions

There were no significant interactions between variety, planting date, and planting depth, indicating that the varieties responded similarly to the various planting date and planting depth treatments. Similarly, there were no significant interactions between planting date and variety, and planting depth and variety.

A slight interaction was observed between planting depth and planting date ($p=0.086$) for percent ground cover in the fall of 2022. Planting depths responded slightly differently to planting dates when looking at fall ground cover, however these impacts were minimal.

Impacts of variety

Varieties Tayo (hybrid) and Hazlet (open pollenated) were chosen as two commonly grown cereal rye varieties that generally perform well across a number of growing regions and also as representatives of the hybrid and open pollenated rye groups. No significant differences across any of the establishment or harvest measurement were observed in these two varieties indicating they both performed similarly under the given growing conditions (Table 3).

Table 3. Rye variety establishment and harvest measurements. Alburgh, VT, 2023.

Variety	Fall population	Fall tiller	Fall canopy	Height	Lodging	Harvest moisture	Test weight	Yield @ 13.5% moisture
	plants ft-1	plant-1	%	cm	%	%	lbs bu-1	lbs ac-1
Hazlet	13.5	2.02	19.49	135	16.1	11.8	51.2	2759
Tayo	14.0	2.01	18.96	136	11.3	11.6	50.4	3479
LSD (0.10)‡	NS§	NS	NS	NS	NS	NS	NS	NS
Trial mean	13.8	2.02	19.22	135	13.7	11.7	50.8	3119

‡LSD; least significant difference at the p=0.10 level.
§NS; no significant differences between treatments.

Impacts of planting date

When looking solely at the impacts of planting date on the various metrics, there were a number of significant differences across the five planting date treatments (Tables 4 and 5). Highest observed plant populations were seen from the first planting date (24-Sep) at 16.8 plants ft^{-1} with no other planting dates showing a similar population. Similarly, fall tillers and fall canopy were highest in the first planting date as well at 4.34 tillers $plant^{-1}$, and 44.9% ground cover respectively. Each of these metrics showed a general decreasing trend from the first to the fifth planting dates.

Table 4: Rye planting date fall establishment measurements, Alburgh, VT, 2023.

Planting Date	Fall population		Fall tiller		Fall canopy	
	plants ft^{-1}		plant^{-1}		%	
24-Sep	**16.8**	**a**	**4.34**	**a**	**44.9**	**a**
3-Oct	12.4	cd †	2.41	b	21.3	b
10-Oct	11.5	d	1.32	c	12.5	c
16-Oct	14.5	b	1.00	d	10.9	c
22-Oct	13.7	bc	1.02	cd	6.45	d
LSD (0.10) ‡	1.73		0.316		4.04	
Trial mean	13.8		2.02		19.2	

†Treatments marked with the same letter do not differ significantly.
The top performing treatment is shown in **bold.**
‡LSD; least significant difference at the p=0.10 level.

Prior to harvest, heights and lodging were recorded (Table 5). Tallest plants were seen in the first planting date (24-Sep) at 169 cm and showed a decreasing trend with later planting dates until the fifth planting date (22-Oct) at 112 cm. Lodging followed a similar trend with highest lodging observed in the first planting date at 36.3% and lowest observed in the fifth planting date at 1.5%. Yield, test weight, and moisture did not appear to be impacted by planting date. Harvest moistures were all within desirable ranges for each treatment within the trial falling below 14% moisture and averaging 11.7%. The test weight averaged 50.8 lbs bu^{-1} falling below the desirable cereal rye test weight of 56 lbs bu^{-1}. Similarly, yields within the trial were quite low averaging only 3119 lbs ac^{-1}.

Table 5: Rye planting date harvest measurements, Alburgh, VT, 2023.

Planting Date	Height		Lodging		Harvest moisture	Test weight	Yield @ 13.5% moisture
	cm		%		%	lbs bu^{-1}	lbs ac^{-1}
24-Sep	**169**	**a**	36.3	c	12.1	51.2	3260
3-Oct	143	b†	13.5	bc	11.5	51.8	3032
10-Oct	131	bc	9.40	bc	10.9	50.9	2923
16-Oct	122	bc	7.70	b	12.2	49.7	3874
22-Oct	112	c	**1.50**	**a**	11.8	50.4	2506
LSD (0.10)‡	25.7		8.64		NS§	NS	NS
Trial mean	135		13.7		11.7	50.8	3119

†Treatments marked with the same letter do not differ significantly.
The top performing treatment is shown in **bold.**
‡LSD; least significant difference at the p=0.10 level.
§NS; no significant differences between treatments.

Across planting dates, there was also a strong correlation (r=0.972471) between plant heights and lodging; as plant heights decreased, so did lodging (Figure 1). It is likely that those treatments planted earlier in the fall in 2022 had stronger stand establishment that resulted in more vigorous plants in the following spring, thus allowing plants to put on more growth leading up to harvest. While this could generally be considered a positive effect, weather conditions this season also had impacts on plant growth, which would have influenced taller plants significantly more than those shorter ones seen in later planting dates. While yields were not impacted in this scenario, it is possible that more severe lodging could greatly reduce harvestability. As such, more vigorous spring growth may not always be desirable.

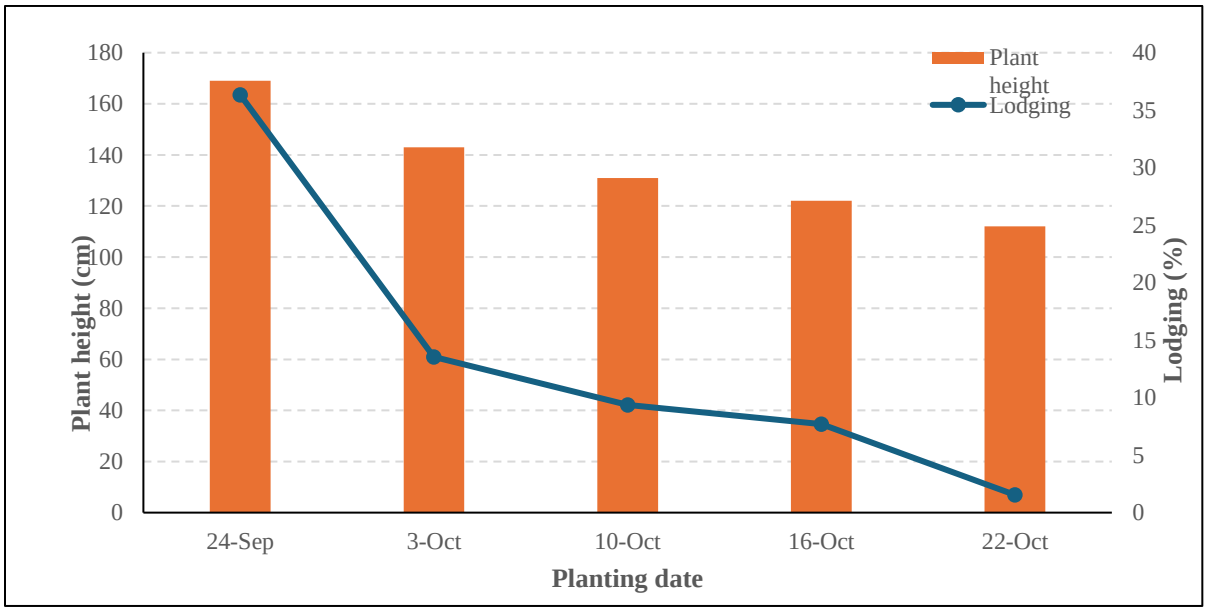

Figure 1. Rye plant height and lodging by planting date. Alburgh, VT 2023.

Impacts of planting depth

Planting depth did not appear to have any impact on any of the various measured metrics when planted at a depth of 0.5, 1.0, or 1.5" depths (Table 6).

Table 6. Rye planting depth establishment and harvest measurements. Alburgh, VT, 2023.

Planting Depth	Fall population	Fall tiller	Fall canopy	Height	Lodging	Harvest moisture	Test weight	Yield @ 13.5% moisture
	plants ft-1	plant-1	%	cm	%	%	lbs bu-1	lbs ac-1
0.5"	13.9	2.11	19.51	131	14.7	11.5	50.5	3560
1.0"	14.1	1.95	18.21	145	11.8	12.0	51.1	2835
1.5"	13.4	1.98	19.97	130	14.6	11.6	50.9	2931
LSD (0.10)‡	NS§	NS	NS	NS	NS	NS	NS	NS
Trial mean	13.8	2.02	19.22	135	13.7	11.7	50.8	3119

‡LSD; least significant difference at the p=0.10 level.

§NS; no significant differences between treatments.

DISCUSSION

For good germination, many seeds require good soil moisture and contact in order to induce imbibition. During the germination process, seeds also have a limited amount of energy to produce the radicle (first root) and the cotyledon (the first embryonic leaf) that will emerge from the soil. Seeds planted too deep may produce cotyledons that struggle to breach the soil surface resulting in delayed emergence or plant death. The three observed planting depths within this study did not appear to have any impact on plant establishment under these given conditions, however deeper or shallower plantings could have detrimental impacts on stand establishment depending on growing conditions.

Interestingly, there were no significant interactions between variety and planting date. Farmers have been concerned that hybrid rye might require earlier planting dates compared to open pollinated rye varieties. This study showed that OP and hybrids performed similar regardless of planting date. Planting date for both the Hazlet and Tayo varieties had the greatest impacts on plant growth observed in this study with lower plant populations, tiller counts, and ground coverage observed as rye was planted later and later into the fall of 2022. While not measured as part of this study, fall planting dates could potentially impact straw yields as the overall plant heights were significantly shorter from the first to the fifth planting dates. Plant heights followed a similar trend, decreasing from the first to the last planting date. No significant differences were observed in yield, test weight, or moisture across planting dates; however, heights and lodging could impact harvestability for farmers making timing for planting in the fall of further importance. 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 planting date and depth on cereal rye productivity in the Northeast.

ACKNOWLEDGEMENTS

The UVM Extension Northwest Crops and Soils Team would like to acknowledge the USDA SARE Grant Award No. LNE22-437 for their support. The NWSC Team would like to thank Roger Rainville and the staff at Borderview Research Farm. We would also like to acknowledge Anna Brown, Catherine Davidson, Hillary Emick, Ivy Krezinski, Andrea Rainville, Lindsey Ruhl, Laura Sullivan, Sophia Wilcox Warren, and Sara Ziegler for their assistance with data collection and entry. This information is presented with the understanding that no product discrimination is intended and neither endorsement of any product mentioned, nor criticism of unnamed products, is implied.

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