



2024 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 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 2023-2024, 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 2023. 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 22-Sep and occurring weekly until 30-Oct 2023. The split plot was planting depths of 0.5”, 1.0”, and 1.5”. The split-split plot included an 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 22-Sep 2023 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, 2023-2024.

	Borderview Research Farm, Alburgh, VT		
Soil type	Benson rocky silt loam		
Previous crop	Corn		
Tillage operations	Pottinger TerraDisc™		
Harvest area (ft.)	5 x 20		
Seeding rate (live seeds m ⁻²)	350		
Replicates	4		
Variety	Hazlet (OP) & Tayo (Hybrid)		
Planting date – Emergence date	PD1	22-Sep 2023	29-Sep 2023
	PD2	29-Sep 2023	4-Oct 2023
	PD3	4-Oct 2023	17-Oct 2023
	PD4	11-Oct 2023	20- Oct 2023
	PD5	20-Oct 2023	3-Nov 2023
	PD6	30-Oct 2023	Did not emerge
Planting Depths	0.5”		
	1.0”		
	1.5”		
Harvest date	29-Jul 2024		

After fall establishment, and prior to sustained freezing temperatures (16-Nov), percent ground cover was measured by processing photographs using the Canopeo© smartphone application. Additionally, plant and tiller counts were taken from a one-foot section within each plot to evaluate stand establishment on 16-Nov. During spring green-up, 17-Apr 2024, ground cover was once again recorded and a winter survival rating was given to each plot; 0% equating to no rye present, and 100% equating to survival of the entire plot of rye. In addition to ground cover and winter survival, population and tiller counts were obtained from a one-foot section. On 26-Jul 2024, 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 29-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. 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 ($p < 0.10$).

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 2. 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 5,506, 235 above average.

Table 2. Seasonal weather data collected in Alburgh, VT, 2023-2024.

Alburgh, VT	Sep 2023	Oct 2023	Nov 2023	Apr 2024	May 2024	Jun 2024	Jul 2024
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)	2.40	5.38	2.03	4.47	2.27	6.65	6.67
Departure from normal	-1.27	1.55	-0.67	1.40	-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.

Within this trial, data for planting date three (PD3, 4-Oct), and planting date six (PD6, 30-Oct) are largely absent. While PD3 was planted with what is typically adequate time for establishment within the growing season, a major rain event occurred 7-Oct through 8-Oct in which over three inches of rain was accumulated during that period. This resulted in soil saturation and washing out many of the plots resulting in overall poor stand establishment. Conversely, PD6 did not have adequate conditions for germination and as such, no data is represented for this planting date and associated treatments.

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 variety and depth. This provides some evidence that open-pollinated and hybrid rye varieties respond similarly to planting date and planting depth.

Planting date x seed depth interactions

A number of significant interactions were observed within the trial between planting date and seed depth indicating that seed depth treatments had different responses to planting date for winter survival, grain moisture, test weight, and yield (Table 3, Figure 1, Table 4).

Table 3. Rye planting date x planting depth establishment and spring green-up measurements. Alburgh, VT, 2024.

Planting date	Planting depth	Fall ground cover	Fall populations	Fall tillers	Spring ground cover	Winter survival	Spring populations	Spring tillers
		%	plants m ²	tillers plant ⁻¹	%	%	plants m ²	tillers plant ⁻¹
22-Sep	0.5"	38.2	287	2.86	36.9	89.4	390	5.33
22-Sep	1.0"	34.6	315	2.90	36.5	92.5	272	5.41
22-Sep	1.5"	35.0	297	2.77	33.0	85.0	325	6.14
29-Sep	0.5"	11.5	236	2.07	14.3	57.5	205	5.38
29-Sep	1.0"	14.3	276	2.45	20.6	65.0	215	4.81
29-Sep	1.5"	9.85	262	2.23	18.3	53.8	228	5.32
4-Oct	0.5"	2.20	138	0.890	0.499	3.50	46.8	2.15
4-Oct	1.0"	2.50	123	1.00	0.916	3.00	12.4	1.25
4-Oct	1.5"	2.86	133	1.00	0.656	4.13	22.2	1.56
11-Oct	0.5"	4.52	313	1.00	11.3	70.0	126	4.35
11-Oct	1.0"	3.68	281	1.04	5.91	25.8	68.9	1.89
11-Oct	1.5"	4.25	301	0.980	9.39	59.4	170	3.98
20-Oct	0.5"	0.668	226	1.00	6.05	46.3	140	2.70
20-Oct	1.0"	0.528	215	1.00	5.20	42.5	93.5	3.04
20-Oct	1.5"	0.718	199	1.00	5.64	52.5	155	3.02
LSD (0.10)‡		NS§	NS	NS	NS	0.0007	NS	NS
Trial mean		11.0	240	1.61	13.7	50.0	164	3.76

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

§NS; no significant differences between treatments.

When looking at winter survival, the 1.0" planting depth treatments appeared to surpass those 0.5" and 1.5" treatments in both PD1 and PD2, whereas the last two planting dates the winter survival for the 1.0" depth dropped significantly when compared to the other two. Winter survival for PD3 was also severely impacted by heavy rain events in the fall across all planting depth treatments.

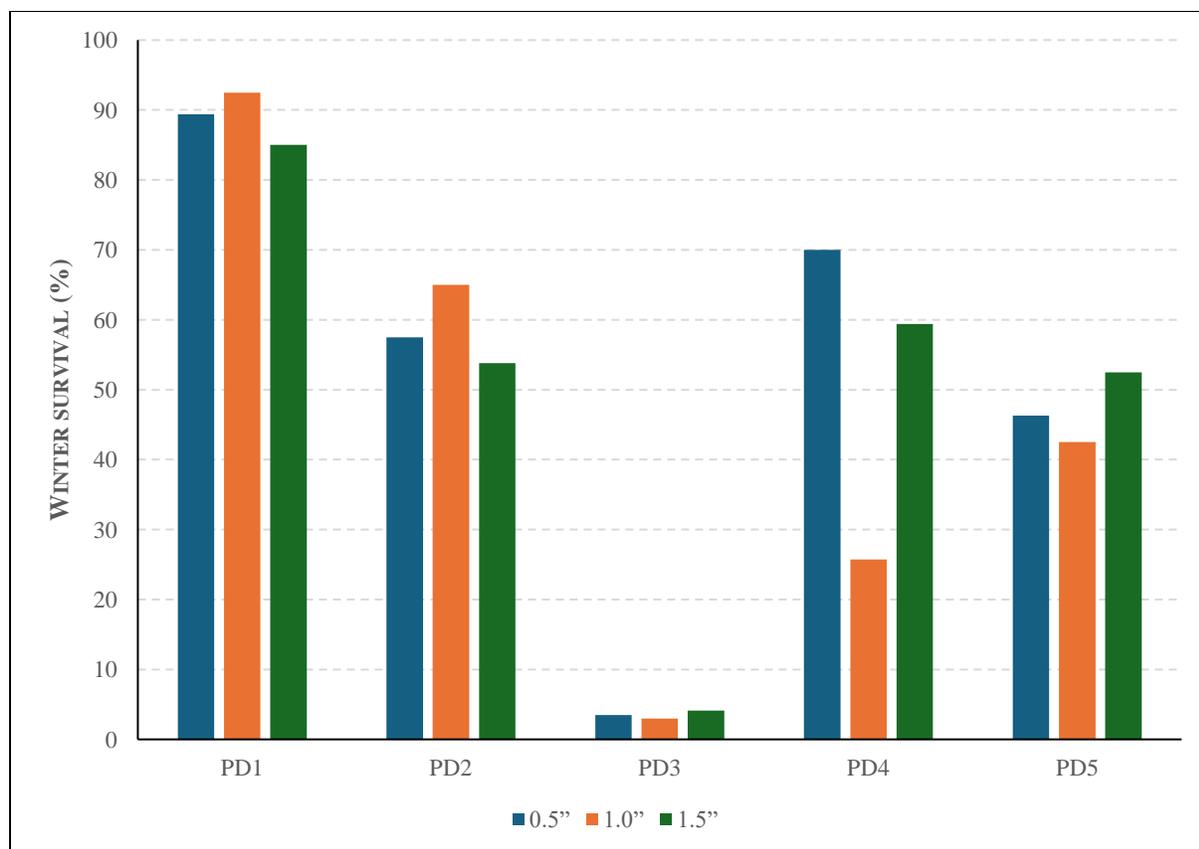


Figure 1. Winter survival by planting date and depth. Alburgh, VT, 2024.

There were no interactions between planting date and planting depth for height, lodging, grain moisture, or test weight. Some differences were observed across grain yields with highest yields seen in the first planting date at the shallowest depth.

Table 4. Rye planting date x planting depth harvest measurements. Alburgh, VT, 2024.

Planting date	Planting depth	Height	Lodging	Grain moisture	Test weight	Yield @ 13.5% moisture
		cm	%	%	lbs bu ⁻¹	lbs ac ⁻¹
22-Sep	0.5"	120	5.00	15.8	53.9	3708
22-Sep	1.0"	125	1.25	15.8	53.3	3467
22-Sep	1.5"	126	7.50	16.1	52.3	3056
29-Sep	0.5"	109	2.50	16.3	52.4	2004
29-Sep	1.0"	113	5.00	16.0	54.0	2783
29-Sep	1.5"	113	5.00	16.2	52.6	2286
11-Oct	0.5"	115	4.38	15.5	52.3	3515
11-Oct	1.0"	106	1.25	17.1	50.9	2777
11-Oct	1.5"	112	2.50	15.8	52.3	3032

20-Oct	0.5”	111	7.50	15.3	51.7	3141
20-Oct	1.0”	118	1.25	17.0	52.1	3278
20-Oct	1.5”	114	7.50	16.3	51.5	2782
LSD (0.10)‡	-	NS§	NS	NS	NS	0.016
Trial mean	-	115	4.22	16.1	52.4	2986

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

§NS; no significant differences between treatments.

Impacts of variety

Varieties Tayo (hybrid) and Hazlet (open pollinated) were chosen as two commonly grown cereal rye varieties that perform well across a number of growing regions. A number of significant differences were observed between these varieties (Tables 5 & 6). Fall development was similar between the two varieties. However, differences became more apparent during spring green-up. Hazlet appeared to be the hardier variety between the two with an average winter survival of 56.9%, and populations of 183 plants m².

Table 5. Rye variety establishment and spring green-up measurements. Alburgh, VT, 2024.

Variety	Fall ground cover	Fall populations	Fall tillers	Spring ground cover	Winter survival	Spring populations	Spring tillers
	%	plants m ²	tillers plant ⁻¹	%	%	plants m ²	tillers plant ⁻¹
Hazlet	11.8	246	1.62	14.2	56.9	183	3.55
Tayo	10.3	234	1.60	13.1	43.1	146	3.96
LSD (0.10)‡	NS§	NS	NS	NS	5.08	22.6	0.405
Trial mean	11.0	240	1.61	13.7	50.0	164	3.76

‡LSD; least significant difference at the p=0.10 level. The top performing treatment is shown in **bold**.

§NS; no significant differences between treatments.

Several differences were observed between the two varieties at harvest and in grain quality. Hazlet had the greatest average heights (126 cm), however, it was also more susceptible to lodging when compared to Tayo. Tayo treatments also had the highest yields at 3,119 lbs ac⁻¹. Higher protein levels were observed in Hazlet at 8.23%, whereas Tayo had the higher average falling number at 295 seconds.

Table 6. Rye variety harvest and grain quality measurements. Alburgh, VT, 2024.

Variety	Height	Lodging	Grain moisture	Test weight	Yield @ 13.5% moisture	Crude protein @ 12% moisture	Starch @ 12% moisture	Falling number
	Cm	%	%	lbs bu ⁻¹	lbs ac ⁻¹	%	%	seconds
Hazlet	126	6.77	15.9	52.6	2655	8.23	61.4	157
Tayo	105	1.67	16.1	52.3	3119	7.53	61.8	295
LSD (0.10)‡	4.72	2.38	NS§	NS	364	0.220	0.2	14.6
Trial mean	115	4.22	16.1	52.4	2887	7.88	61.6	226

‡LSD; least significant difference at the p=0.10 level. The top performing treatment is shown in **bold**.

§NS; no significant differences between treatments.

Impacts of planting date

There were a number of significant differences across the five planting date treatments (Tables 7 and 8). Plant establishment in the fall was greatly impacted by weather events as seen in PD3 (4-Oct) in which some of the lowest populations and tiller counts were recorded, comparable to, or lower than, the latter two planting dates. Tillering and ground cover followed a declining trend from the first to the last planting date initially showing 35.9% cover at PD1, decreasing to 0.638% by PD5. Those plants in the first planting date also had the greatest number of tillers at 2.84 tillers plant⁻¹, with the last three planting dates showing significantly diminished tillering. These trends continued throughout the spring green-up period with greatest spring ground cover, winter survival, spring populations, and spring tillers observed in PD1. Spring populations were significantly higher in PD1 at 328 plants m², closest to the target population of 350 plants m², whereas latter planting dates were significantly lower with lowest observed values seen in PD3 (27.2 plants m²). Spring tillers were statistically similar between PD1 and PD2 at 5.62 and 5.17 tillers plant⁻¹. Values for each spring metric were lowest in PD3 across the board highlighting the importance not only of planting date, but also timing of plantings which can be exacerbated by major weather events. When compared to the 2023 growing season of this trial, similar trends were observed with a decreasing trend from the first to the fifth planting dates for ground cover and populations.

Table 7. Rye variety establishment and spring green-up measurements. Alburgh, VT, 2024.

Planting date	Fall ground cover	Fall populations	Fall tillers	Spring ground cover	Winter survival	Spring populations	Spring tillers
	%	plants m ²	tillers plant ⁻¹	%	%	plants m ²	tillers plant ⁻¹
22-Sep	35.9 a†	301 a	2.84 a	35.5 a	89.0 a	328 a	5.62 a
29-Sep	11.9 b	257 b	2.25 b	17.7 b	58.8 b	217 b	5.17 a
4-Oct	2.52 c	131 d	0.960 c	0.690 d	3.54 d	27.2 d	1.66 c
11-Oct	4.15 cd	297 ab	1.01 c	8.87 c	51.7 bc	121 c	3.41 b
20-Oct	0.638 d	212 c	1.00 c	5.63 c	47.1 c	130 c	2.92 b
LSD (0.10)‡	2.48	42.3	0.140	3.36	8.03	1.82	0.641
Trial mean	11.0	240	1.61	13.7	50.0	8.35	3.76

†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 8). PD3 was not harvested as a result of the poor stand establishment and plants were outcompeted by weeds throughout the growing season after spring measurements were taken. Tallest plants were seen in the first planting date at 124 cm with PD2, PD4, and PD5 all having statistically similar heights at 112, 111, and 115 cm respectively. Grain moisture was consistent across planting dates though was higher than desired for storage, requiring additional drying (down to 13.5% moisture) to reduce potential for spoilage.

Yield and test weight were highest in PD1 at 3,411 lbs ac⁻¹ and 53.2 lbs bu⁻¹ respectively. Test weights were comparable in PD2 (53.0 lbs bu⁻¹). 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 with the highest falling number seen in PD1 at 242 seconds and was statistically similar to PD2 (222 seconds and PD5 (224 seconds).

Table 8. Rye planting date harvest and grain quality measurements, Alburgh, VT, 2024.

Planting date	Height cm	Lodging %	Grain moisture %	Test weight lbs bu ⁻¹	Yield @ 13.5% moisture lbs ac ⁻¹	Crude protein @12% moisture %	Starch @12% moisture %	Falling number seconds
22-Sep	124 a †	4.58	15.9	53.2 a	3411 a	6.89 c	62.2 a	242 a
29-Sep	112 b	4.17	16.1	53.0 a	2358 c	7.33 b	62.0 a	222 ab
11-Oct	111 b	2.71	16.1	51.8 b	2711 bc	8.49 a	61.2 b	216 b
20-Oct	115 b	5.42	16.2	51.8 b	3067 b	8.79 a	61.0 b	224 ab
LSD (0.10) ‡	6.68	NS§	NS	0.659	515	0.311	0.291	20.6
Trial mean	115	4.22	16.1	52.4	2887	7.88	61.6	226

†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.

A strong negative correlation between crude protein and starch ($r=-0.97443$) was observed across planting dates: an increase in crude protein across planting dates resulted in a decrease in starch concentrations (Figure 2). Additionally, positive correlations were observed between lodging and crude protein ($r=0.7248$) and between lodging and starch ($r=0.9892$).

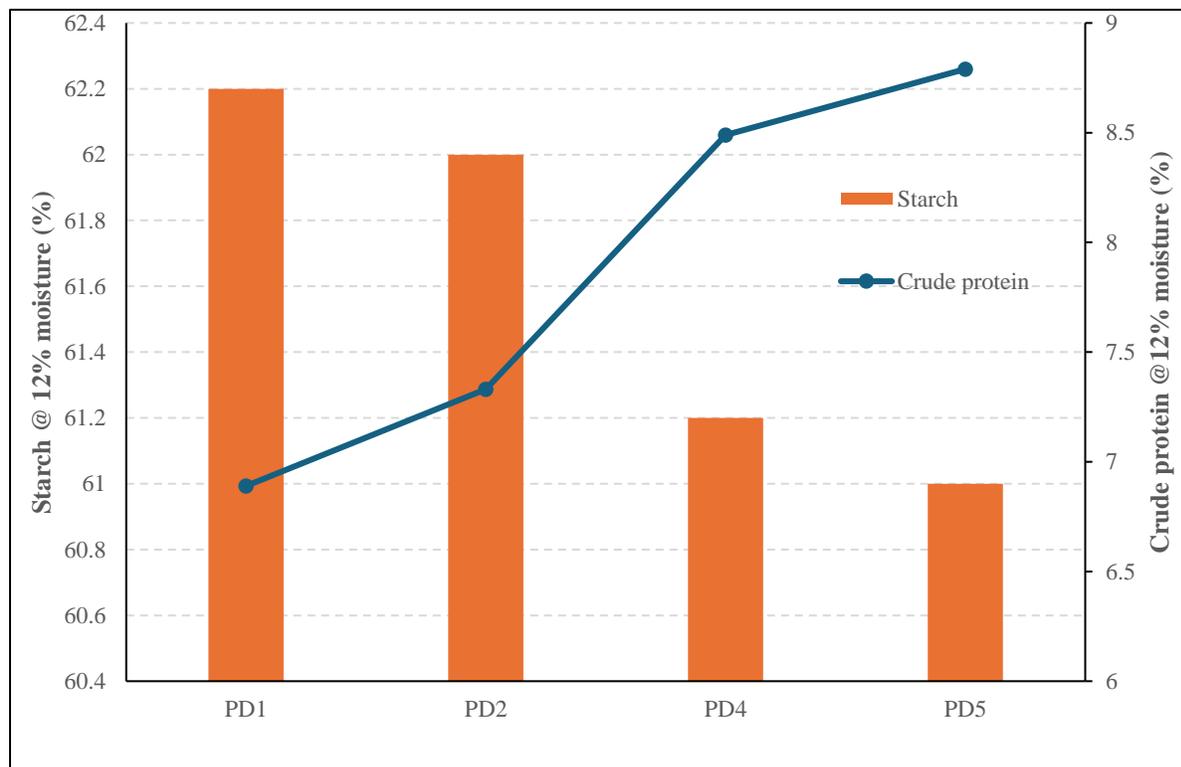


Figure 2. Rye starch and crude protein concentrations by planting date. Alburgh, VT, 2024.

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 similarly 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 2023. Plant populations at establishment were fairly consistent, though often did not meet the target rate of 350 plants m², especially in PD2-PD5. These values were for the latter planting dates were similar, excluding PD3 which experienced heavy rainfall, though were subsequently highly variable largely as a result of plant maturity and tillering ability, thus impacting winter survival as a whole. This further highlights the importance of establishing a fall planted rye crop earlier on to reduce the potential for loss or diminished yields.

In addition to impacts seen through establishment, grain yield and quality (most noticeably for protein and starch) was also impacted. These two qualities are closely linked as synthesis is dictated by resource availability. 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. Furthermore, grains will typically allocate nutrient resources towards increasing seed yields before producing proteins. As a result, these higher yields can result in lower protein content as observed in results from PD1, in turn influencing starch concentrations.

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