2022 Rye Harvest Date

Dr. Heather Darby, UVM Extension Agronomist
Hillary Emick and Anna Brown
UVM Extension Crops and Soils Technicians
802-524-6501

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Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

The interest in growing cereal rye for grain has increased considerably across the Northeast region. Rye can be grown to be sold as cover crop seed, or to value-added markets such as bakers and distillers. As a result, farmers and end-users are requesting yield and quality information on cereal rye varieties. In 2022, University of Vermont Extension Northwest Crops and Soils (NWCS) Program conducted a trial to evaluate the effects of harvest date on yield and quality of cereal rye. Falling number is a laboratory test that measures the viscosity of flour. Falling number can indicate sound quality grain that was properly ripened, harvested and stored. There are well established ranges for falling number as an indicator of baking and malting quality in wheat and barley. There is less information on the ideal range for falling number in cereal rye. The goal of this project was to evaluate the impact of harvest date on yields and quality parameters, specifically falling number. Four varieties of rye were evaluated: Bono, Danko, Hazlet, and Serafino. Rye plots were harvested at one week intervals through the last two weeks of July and first two weeks of August.

MATERIALS AND METHODS

The field was plowed, disked, and prepared with a spike tooth harrow to prepare the seedbed for planting. The experimental design was a randomized complete block with split plots and 4 replicates. The main plots were harvest date and the split plots were variety. The plots were planted with a Great Plains cone seeder on 22-Sep 2021 and plots were 5' x 20' (Table 1).

Table 1. Agronomic and trial information for the rye cover crop variety trial, 2021-2022.

	Borderview Research Farm, Alburgh, VT
Soil Type	Benson rocky silt loam
Previous Crop	Annual forages
Tillage Operations	Fall plow, disc, and spike tooth harrow
Harvest Area (ft.)	5 x 20
Seeding Rate (live seeds m^{-2})	350
Replicates	4
Planting Date	22-Sep 2021
Harvest Dates (HD)	HD 1: 20-Jul 2022
	HD 2: 29-Jul 2022
	HD 3: 4-Aug 2022
	HD 4: 12-Aug 2022

Grain plots were harvested with an Almaco SPC50 plot combine at one week intervals from 20-Jul through 12-Aug. Following harvest, seed was cleaned with a small Clipper M2B cleaner (A.T. Ferrell, Bluffton, IN). Grain moisture, test weight, and yield were measured. A subsample (approximately one-pound) was collected to determine quality. Quality measurements included standard testing parameters used by commercial mills. Grains were analyzed for protein and starch content using the Perten Inframatic 9500 Grain Analyzer. Rye flour for baking should have starch content between 56–70% and protein content

between 8–13%. Samples were ground into flour using the Perten LM3100 Laboratory Mill. Falling number was measured on the Perten FN 1500 Falling Number Machine (AACC Method 56-81B, AACC Intl., 2000). The falling number is related to the level of enzymatic activity and sprouting damage that may have occurred in the grain. It is measured 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.

Variations in yield and quality can occur because of variations in genetics, soil, weather and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties 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 (i.e. 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 varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In this example, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety.

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. The fall of 2021 was slightly warmer and wetter than normal from September through November. The temperature was 3.03 degrees warmer than normal and there was 2.78 inches of precipitation more than average. This allowed for good germination and establishment of the winter rye. The spring and summer of 2022 continued to be wetter, although slightly cooler than average. In total during the rye growing season, there was over 40 inches of precipitation – 9.43 inches more than average. A total of 6739 growing degree days (GDD's) accumulated – 131 more than average.

Table 2. Temperature and precipitation summary for Alburgh, VT, 2021-2022 growing season.

	2021			2022					
	Sep	**Oct**	**Nov**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Average temperature (°F)	63.1	54.6	37.6	32.3	44.8	60.5	65.3	71.9	70.5
Departure from normal	0.40	4.31	-1.68	-0.03	-0.81	2.09	-2.18	-0.54	-0.20
Precipitation (inches)	4.49	6.23	2.26	2.52	5.57	3.36	8.19	3.00	4.94
Departure from normal	0.82	2.40	-0.44	0.28	2.50	-0.40	3.93	-1.06	1.40
Growing Degree Days (32°-95°F)	933	701	232	170	391	883	1000	1236	1193
Departure from normal	11	133	-3	32	-20	65	-64	-17	-6

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT. (http://www.nrcc.cornell.edu/page_nowdata.html).

Impact of Harvest Date

Yield, harvest moisture, and test weight were measured at the time of harvest (Table 3). Yields were high across the trial, with the highest yield on HD1 (20-Jul) at 6639 lbs ac^{-1}. Yield declined steadily through the harvest season and yield from the first harvest date was significantly different from all other dates. Harvest moisture varied across the study period with highest harvest moisture occurring at the first harvest date and lowest occurring at the second harvest date. The moisture content at the second date was statistically dissimilar from the other dates and was the only harvest date when the moisture was below 14% and did not require additional drying down for storage. Test weight was highest in HD2 (29-Jul) at 53.7 lbs bu^{-1} with no other harvest dates statistically similar.

Table 3. Harvest data and grain quality for winter rye harvest dates, Alburgh, VT, 2022.

Harvest date	Yield @ 13.5% moisture lbs ac^{-1}	Harvest moisture %	Test weight lbs bu^{-1}	Starch %	Crude protein %	Falling number seconds
20-Jul	**6639**[a†]	22.3[c]	52.1[b]	**62.9**	6.44[c]	263[b]
29-Jul	6012[b]	**13.3**[a]	**53.7**[a]	62.8	6.54b[c]	262[b]
4-Aug	5869[b]	16.9[b]	52.2[ab]	60.9	6.66a[b]	277[b]
12-Aug	5826[b]	18.3[c]	48.8[c]	62.7	**6.71**[a]	**109**[a]
LSD (p=0.10)‡	575	1.23	1.27	NS[¥]	0.18	20.9
Trial mean	6087	17.7	51.7	62.3	6.59	228

†Within a column, harvest dates with the same letter were not different from the top performer (in **bold**).

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

¥NS – No significant differences.

Crude protein varied very little across harvest dates, although the later harvest dates were statistically different from the earlier ones. Protein for all harvest dates was below the desired range for ideal rye baking quality (<8%). There was no statistical difference in starch content and all harvest dates had starch within the acceptable range for rye flour. Falling number was highest at the 3rd harvest date and lowest at the 4th harvest date, disrupting a trend observed in previous years of the study when falling number declined as the study proceeded. While more research is underway to confirm ideal falling numbers for rye, preliminary research seems to put this value between 150-200 seconds. The first three harvest dates all had falling number above this range and the final harvest date had falling number below.

Impact of Variety

The varieties varied significantly in terms of all parameters measured. The highest yielding variety across the four harvest dates was Serafino at 7042 lbs bu^{-1} (Table 4). This was statistically similar to Bono at 6926 lbs bu^{-1}. Rye yields were very high across all the rye trials at Borderview Research farm in 2022. Harvest moisture varied significantly between varieties but on average all were above moisture content required for long term storage. Serafino had the highest test weight at 52.2 lbs bu^{-1}, and was statistically similar to all other varieties.

Table 4. Harvest data and grain quality for winter rye varieties, Alburgh, VT, 2022.

Variety	Yield @ 13.5% moisture	Harvest moisture	Test weight	Starch	Crude protein	Falling number
	lbs ac^{-1}	%	lbs bu^{-1}	%	%	Seconds
Bono	6926[a]†	17.9[b]	52.1	62.9[a]	6.26[b]	266[c]
Danko	5619[b]	**16.9[a]**	51.6	60.6[b]	6.91[a]	202[b]
Hazlet	4760[c]	17.7[b]	50.9	62.7[ab]	**6.92[a]**	**162[a]**
Serafino	**7042[a]***	18.2[b]	**52.2**	**63.1[a]**	6.27[b]	280[c]
LSD(p=0.10) ‡	575	1.23	NS¥	2.22	0.18	20.9
Trial mean	6087	17.7	51.7	62.3	6.59	228

†Within a column, harvest dates with the same letter were not different from the top performer (in **bold**).

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

¥NS – No significant differences.

Serafino also had the highest starch at 63.1%, statistically similar to Bono at 62.9%. All varieties had acceptable starch content. Hazlet had the highest protein concentrations at 6.92%, statistically similar to Danko at 6.91%. Averaged across the four harvest dates, Hazlet had a significantly lower falling number compared to all other varieties.

Harvest date x variety interactions

There were no statistically significant harvest date x variety interactions for yield, test weight, starch, protein, and falling number; in other words, both varieties performed similarly at each harvest date in terms of these characteristics. The only statistically significant effect of harvest date by variety was in terms of harvest moisture and variety. For each harvest date, a different variety had the lowest moisture content.

Falling number

Falling number measures viscosity by recording the time in seconds it takes for a plunger to fall through a slurry to the bottom of a test tube. The viscosity is an indicator of enzymatic (alpha-amylase) activity in the kernel, which most often results from the early stages of germination occurring pre-harvest in the grain. Low falling number means high enzymatic activity, or more pre-harvest sprouting. This is most common if there are rain events as the grain is ripening prior to harvest. Falling number is a widely understood indicator of wheat flour quality, though its use as an indicator of rye flour quality is still being explored. Low falling number in wheat, below 250, has a negative impact on bread quality and can lead to lower prices paid for the wheat or possible rejection at the mill. The ideal range for wheat is 250-350. High falling numbers, over 400 seconds, can potentially lead to slower fermentation, poorer loaf volume and drier bread texture, depending on the end product. Because rye bread relies on different grain components to create high-quality bread, and ferments more quickly than wheat, it is expected that lower falling numbers are preferred for rye than for wheat, likely between 150-200 seconds and potentially as low as 100 seconds. For rye in particular, waiting longer to harvest may result in grains that are more suited for baking as currently, as lower falling numbers are more desirable than those needed for wheat.

DISCUSSION

This is the fifth year that a rye harvest date study has been conducted by the NWCS team in Alburgh, Vermont. Over the first four years of the study, falling number consistently decreased by harvest date over the course of the trial (Figure 1). Multiyear data displayed is for the first three harvest dates only because in some years the rye could not be harvested by the fourth harvest date due to lodging.
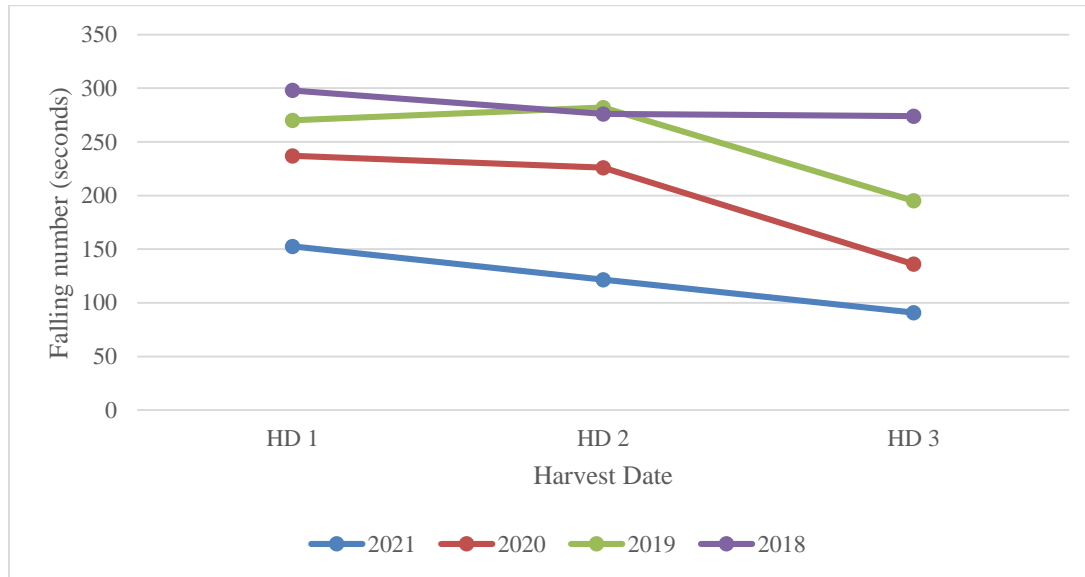

Figure 1. Falling number by harvest date for 4 years of study in Alburgh, VT.

This trend of falling number decreasing from the first harvest date until the last harvest date was consistent over the first four years of the harvest date study but was not as consistent in 2022. All varieties trialed in 2022 showed a similar trend of falling number remaining relatively constant across the first three harvest dates, actually increasing slightly between the first two or second two harvest dates for some varieties, and dropping drastically by the fourth harvest date (Figure 2).
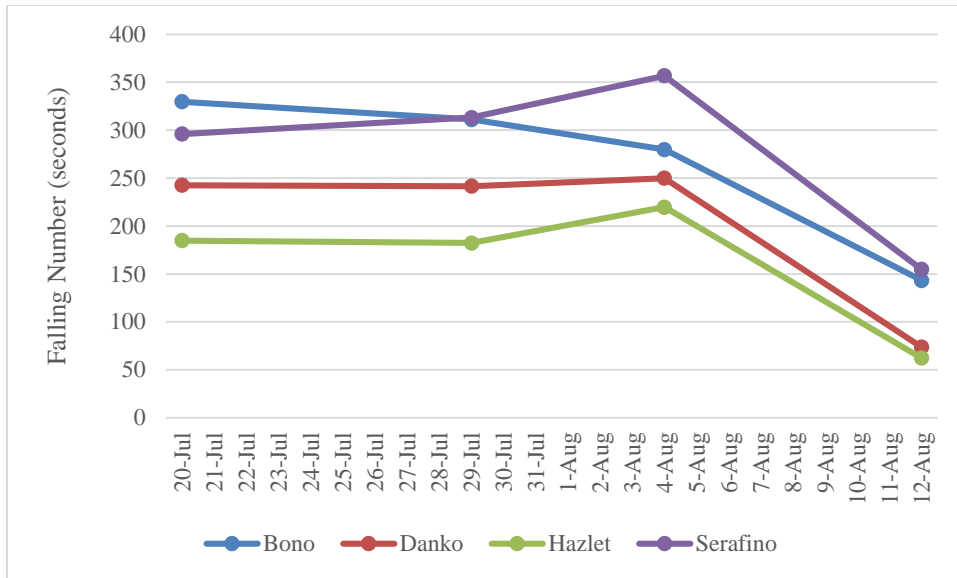
Figure 2. Interaction between harvest date and variety for falling number, 2022.

During a harvest period with greater amounts of rainfall from week to week, there is greater potential for harvest timing to affect grain quality. This can be an important consideration when attempting to determine ideal harvest windows as farmers may be forced to harvest at an earlier or later date to salvage a crop and maintain grain quality. There was only 0.32 inches of precipitation between the first and second harvest dates, and only 0.25 inches of precipitation between the second and third harvest date. The lack of precipitation accounts for the lack of any significant change in falling number between the first three harvest dates. However, over an inch of rain fell (1.08 inches) between the third and fourth harvest dates likely resulting in the rapid decline in falling number (Figure 3). This highlights the importance of the impact on falling number not merely of the passage of time between harvest date but the weather conditions occurring in the interim.
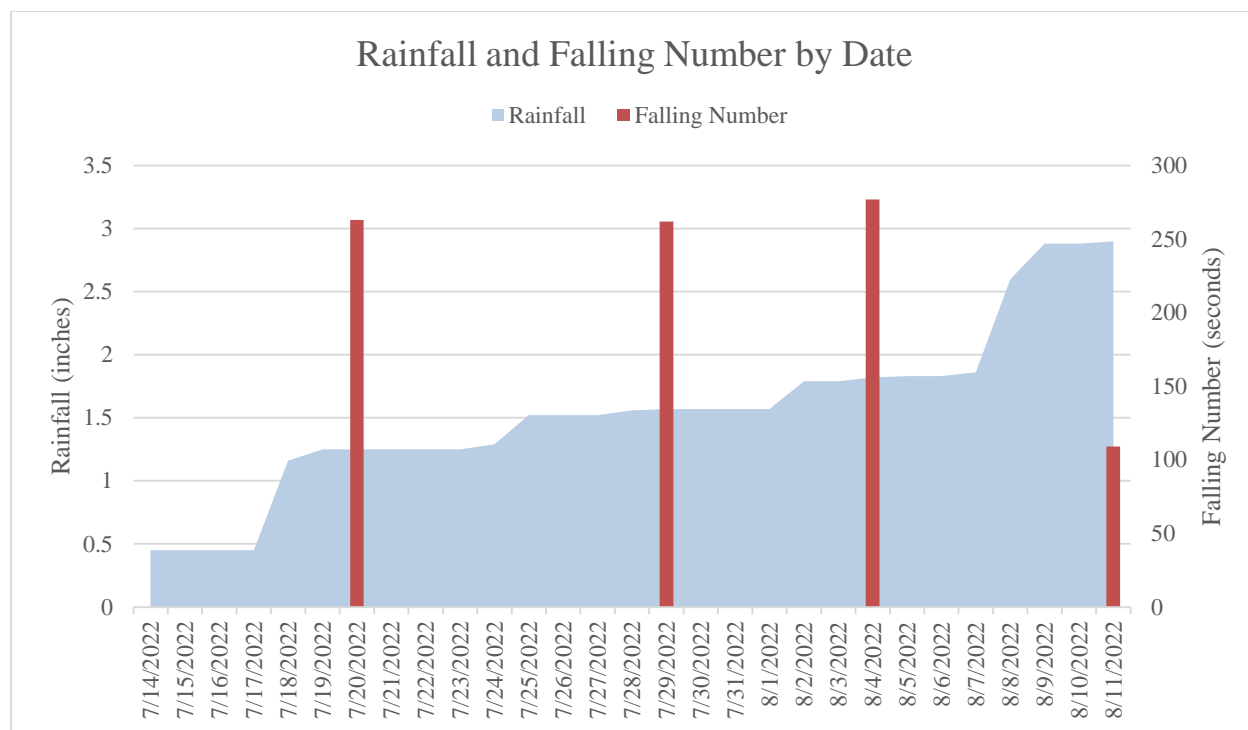
Figure 3. Rainfall through harvest period and falling number by harvest date

In the 2018-2021 trials, only two varieties of rye were evaluated in the harvest date trial. Significant differences between varieties across years and across many different parameters indicated varieties may react differently to a delayed harvest. The 2022 trial had been expanded to include four varieties to generate a greater range of more broadly applicable data on rye harvest date. The 2023 rye harvest date planted in September 2023 also includes four varieties.

Although not considered statistically significant, the interactions between harvest date and variety on falling number did vary considerably. Bono and Serafino both had falling numbers around 300 (280-357) across the first three harvest dates, and by the fourth harvest date these varieties fell to 143 and 155 respectively. These varieties benefitted by staying in the field through the additional precipitation received in mid-August from a baking quality standpoint. However, Danko and Hazlet had lower falling numbers (between 242-250 for Danko and between 185-220 for Hazlet) in the earlier harvest dates, and by the final harvest date the falling numbers for these varieties had dropped to 74 and 62 respectively, which may be too low to indicate sound baking quality even in rye. These varieties may have been harvested a bit past the ideal window for harvest timing.

End use should be considered, among other factors, when determining harvest date. Where a low falling number may be appropriate for bakers, because it may also indicate pre-harvest sprouting, it is less desired for malting, a process in which grain is sprouted in a controlled method for beer and spirit production. If the rye is destined for a malt house, brewery or distillery, lower falling number may have a bigger impact on end quality. This research seeks to more clearly identify common and appropriate falling number ranges for cereal rye in the Northeast to assist growers and end-users understand the quality of rye crops.

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