NORTHWEST CROPS & SOILS PROGRAM

2014-2015 Organic Heirloom Spring Wheat Seeding Rate Trial

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University of Vermont Extension began its heirloom spring wheat project in 2007 to determine whether heirloom varieties developed before 1950 could thrive in Vermont's climate. Many consumers are interested in heirloom wheat as they feel it has better flavor, while many farmers are also interested in heirloom wheat varieties as they may have superior genetics that are better adapted to the challenging growing conditions in the Northeast. Several producers have asked questions about the best agronomic practices for cultivating heirloom wheat. It is unclear if heirloom wheat will require lower seeding rates as compared to modern day varieties. Seeding rates can influence weed populations and fertility needs, as well as overall yield and quality. This report compiles research results from 2014 and 2015 trials in order to identify heirloom spring wheat seeding rate trends over multiple years. These projects were funded through the UNFI Foundation that has set a priority to **protect the biodiversity** of our seed supply and the stewardship of genetic resources of organic seed.

MATERIALS AND METHODS

In 2014 and 2015 heirloom spring wheat seeding rate trials were established at Borderview Research Farm in Alburgh, Vermont. The experimental plot design was a randomized complete block split design with four replications. Seeding rate was the main plot and variety the split plot. The seedbeds in 2014 and 2015 in Alburgh were prepared by conventional tillage methods. All plots were managed with practices similar to those used by producers in the surrounding areas (Table 1). The previous crop planted in 2014 site was sod, and in 2015 the previous crop was summer annuals. Prior to planting, both trial sites were disked and spike tooth harrowed to prepare for seeding. The plots were seeded with a Great Plains NT60 Cone Seeder at seeding rates of 50, 75, 100, 125, or 150 lbs ac^{-1} with two different heirloom varieties: Ladoga and Red Fife. Plot size was 5' x 20'. Trial was planted on 25-Apr in 2014 and on 19-Apr in 2015.

Table 1. General plot management of the heirloom spring wheat seeding rate trial, 2014-2015.

Trial Information	Borderview Research Farm, Alburgh, VT	
	2014	2015
Soil type	Benson rocky silt loam	Benson rocky silt loam
Previous crop	Sod	Summer annuals
Tillage operations	Fall plow, spring disk & spike tooth harrow	Fall plow, spring disk & spike tooth harrow
Row spacing (inches)	6	6
Seeding rate (lbs ac^{-1})	50, 75, 100, 125, & 150	50, 75, 100, 125, & 150
Replicates	4	4
Heirloom spring wheat varieties	Ladoga & Red Fife	Ladoga & Red Fife
Planting date	25-Apr	19-Apr
Harvest date	8-Aug	5-Aug
Harvest area (feet)	5 x 20	5 x 20

In 2014, plant populations were measured on 5-Jun by taking two, 1/3-meter plant counts per plot. In 2015, plant populations were measured by taking three, 12-inch plant counts on 14-May. Prior to harvest, in both years, plant heights were measured, excluding the awns, and a visual estimate of the percentage of lodged plants were taken. Grain plots were harvested with an Almaco SPC50 plot combine on 8-Aug in 2014 and on 5-Aug in 2015, the harvest area was 5' x 20'. At the time of harvest, grain moisture, test weight, and yield were calculated.

Following harvest, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). An approximate one-pound subsample was collected to determine quality. Quality measurements included standard testing parameters used by commercial mills. Test weight was measured by the weighing of a known volume of grain. Generally, the heavier the wheat is per bushel, the higher baking quality. The acceptable test weight for bread wheat is 56-60 lbs per bushel. Once test weight was determined, the samples were then ground into flour using the Perten LM3100 Laboratory Mill. At this time, flour was evaluated for its protein content and falling number. Grains were analyzed for protein content using the Perten Inframatic 8600 Flour Analyzer. Grain protein affects gluten strength and loaf volume. Most commercial mills target 12-14% protein. Crude protein was calculated on a 12% moisture basis. The determination of falling number (AACC Method 56-81B, AACC Intl., 2000) was measured on the Perten FN 1500 Falling Number Machine. The falling number is related to the level of sprout damage that has 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 the tube. Falling numbers greater than 350 indicate low enzymatic activity and sound quality wheat. A falling number lower than 200 indicates high enzymatic activity and poor quality wheat. Deoxynivalenol (DON) analysis was analyzed using Veratox DON 5/5 Quantitative test from the NEOGEN Corp. 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.

All data was analyzed using a mixed model analysis where replicates were considered random effects. The LSD procedure was used to separate seeding rate means when the F-test was significant ($P < 0.10$).

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 (e.g. yield). Least Significant Differences at the 10% level of probability are shown. Where the difference between two varieties 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. In the example below, variety A is significantly different from variety C, but not from variety B. The difference between A and B is equal to 725, which is less than the LSD value of 889. This means that these varieties did not differ in yield. The difference between A and C is equal to 1454, which is greater than the LSD value of 889. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that variety B was not significantly lower than the top yielding variety

Variety	Yield
A	3161
B	3886*
C	**4615***
LSD	**889**

RESULTS

Seasonal precipitation and temperatures were recorded with a Davis Instruments Vantage Pro2 with Weatherlink data logger on site in Alburgh, VT (Table 2, Table 3). The 2014 growing season experienced lower than normal temperatures in April, July, and August with above average temperatures in May and June. There was above average rainfall throughout the growing season which equaled 6.44 inches above normal perception levels. From April to August, there was an accumulation of 4440 Growing Degree Days (GDDs) in Alburgh, VT, which is 52 GDDs lower than the 30-year average.

Table 2. Temperature and precipitation summary for Alburgh, VT, 2014.

Alburgh, VT	Apr	May	Jun	Jul	Aug
Average Temperature (F)	43.0	57.4	66.9	69.7	67.6
Departure from Normal	-1.80	1.00	1.10	-0.90	-1.20
Precipitation (inches) *	4.34	4.90	6.09	5.15	3.98
Departure from Normal	1.52	1.45	2.40	1.00	0.07
Growing Degree Days (base 32)	330	789	1041	1171	1108
Departure from Normal	-53.9	32.8	27.3	-26.9	-31.0

Based on weather data from Davis Instruments Vantage Pro2 with Weatherlink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

In 2015, the growing season was marked by lower than normal temperatures in April, June, and July and higher than normal rainfall in June. From April to August, there was an accumulation of 4613 Growing Degree Days (GDDs) which is 50 GDDs above the 30-year average. Overall rainfall was 8.12 inches below seasonal norm of 18.02 inches (Apr-Aug).

Table 3. Temperature and precipitation summary for Alburgh, VT, 2015.

Alburgh, VT	Apr	May	Jun	Jul	Aug
Average temperature (°F)	43.4	61.9	63.1	70.0	69.7
Departure from normal	-1.4	5.5	-2.7	-0.6	0.9
Precipitation (inches)	0.09	1.94	6.42	1.45	0.00
Departure from normal	-2.73	-1.51	2.73	-2.70	-3.91
Growing Degree Days (base 32°F)	373	930	938	1188	1184
Departure from normal	-11	174	-76	-10	45

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.

Seeding Rate x Year Interaction

There was a significant interaction between seeding rate and year for DON concentration (Figure 1). This interaction indicates that seeding rate responded differently between years in terms of DON concentrations. This was likely due to differences in weather between years. The 2015 growing season was more conducive for Fusarium head blight infection as compared to 2014. In 2014, there was little variation of DON concentration between seeding rates and all were less than 1 ppm. In 2015, the lowest seeding rate (50 lbs ac^{-1}) had the highest DON concentration, above 4 ppm. In general, as the seeding rates increased the DON concentrations decreased. Additional years of research should be conducted to further determine if the concentration of DON is reduced by higher seeding rates.

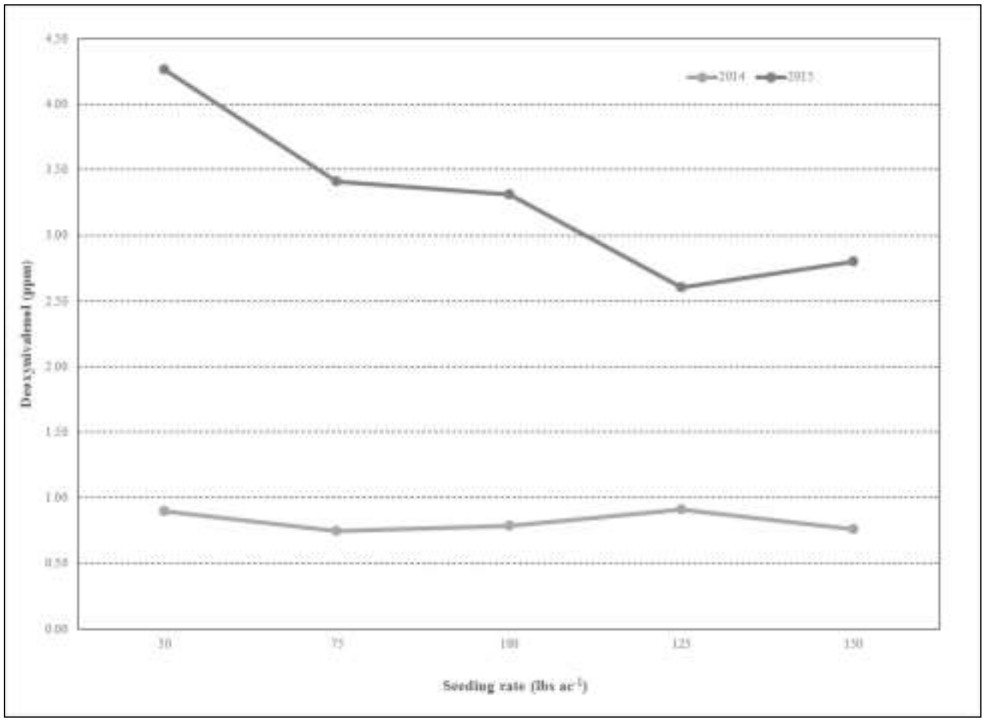

Figure 1. Seeding rate by year interaction of Deoxynivalenol (DON) concentration, Alburgh, VT, 2014-2015.

Impact of Year

There were significant differences in plant population and the amount of lodging between years (Table 4). 2015 had the highest plant populations (1,224,036 plants ac^{-1}), the tallest overall plant heights (44.9 inches) and the least amount of lodging (2.00%) compared to the 2014 trial year.

Table 4. The impact of the year on plant populations, heights, and lodging, Alburgh, VT 2014-2015.

Year	Plant population	Plant height	Lodging
	plants ac^{-1}	inches	%
2014	941,622	43.2	10.8
2015	**1,224,036**	**44.9**	**2.00**
LSD (0.10)	116,974	NS	4.99
Trial mean	1,082,829	44.1	6.38

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

Spring heirloom wheat yield, harvest moisture, test weight, crude protein and DON concentration were significantly different between years (Table 5, Figure 2). The 2015 trial year yielded highest with 1584 lbs ac^{-1} compared to the 2014 yield of 1133 lbs ac^{-1}. The lowest harvest moisture between years was 2015 (15.6%). Both trial years had harvest moistures above 14%, the moisture necessary for grain storage, so therefore had to be dried down. 2015 also had the highest overall test weight of 55 lbs bu^{-1}. Neither trial year met industry standards of 60 lbs bu^{-1} for test weight. The 2014 trial year had the highest overall crude protein level of 13.5%, meeting commercial baking standards of 12 -14% protein, the 2015 protein content did not meet industry standards. The lowest DON concentration was in 2014 (0.82 ppm) compared to 3.28 ppm in 2015.

Table 5. The impact of the year on wheat harvest and quality, Alburgh, VT, 2014-2015.

Year	Yield @ 13.5% moisture	Harvest moisture	Test weight	Crude protein @ 12% moisture	Falling number	DON
	lbs ac^{-1}	%	lbs bu^{-1}	%	seconds	ppm
2014	1133	20.1	51.9	**13.5**	293	**0.82**
2015	**1584**	**15.6**	**55.0**	11.1	**301**	3.28
LSD (0.10)	191	0.30	0.50	0.25	NS	0.26
Trial mean	1358	17.8	53.5	12.3	297	2.05

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

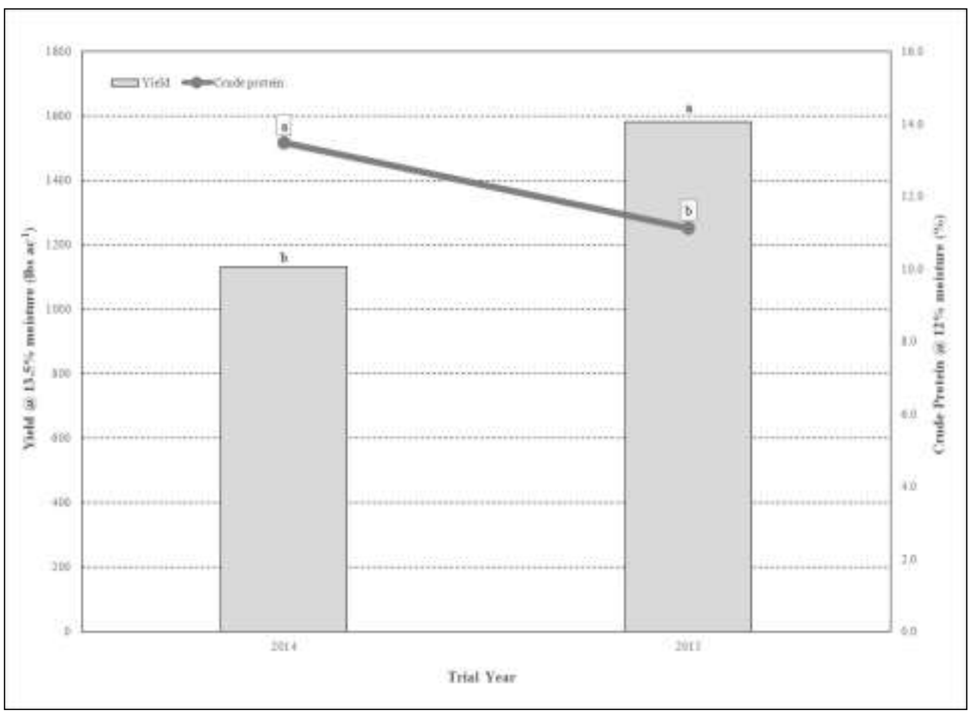

Figure 2. Yield and protein of heirloom spring wheat varieties based on year, Alburgh, VT, 2014-2015.
Varieties with the same letter are not significantly different from one another.

Seeding Rate

There were no signifcant differences in plant populations, plant height or lodging across seeding rates in the combined data from 2014-2015 (Table 6). The highest plant population (1,402,995 plants ac^{-1}) was the highest seeding rate (150 lbs ac^{-1}), and the lowest plant population (765,930 plants ac^{-1}) was the lowest seeding rate (50 lbs ac^{-1}). The tallest plants (45.2 inches) were measured in the lowest seeding rate while the shortest plants (42.9 inches) were in the highest seeding rate (150 lbs ac^{-1}). The least amount of lodging (0.63%) was the lowest seeding rate and the most lodging (10.9%) was found in the highest seeding rate.

Table 6. The impact of seeding rate on plant populations, heights, and lodging, Alburgh, VT 2014-2015.

Seeding rate	Plant population	Plant height	Lodging
lbs ac^{-1}	plants ac^{-1}	inches	%
50	765,930	**45.2**	**0.63**
75	1,000,065	44.7	3.75
100	1,038,180	43.3	9.06
125	1,206,975	44.1	7.50
150	**1,402,995**	42.9	10.9
LSD (0.10)	NS	NS	NS
Trial mean	1,082,829	44.1	6.38

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

There were signicant differences in seeding rates across 2014-2015 in harvest moisture, crude protein, and DON (Table 7). However, there were no signicicant differences in yield, test weight and falling number across seeding rates. The lowest harvest mositure (17.4 %) was the highest seeding rate (150 lbs ac^{-1}) and the highest moisture (18.5%) was found in the lowest seeding rate (50 lbs ac^{-1}). All moistures were above the 14% moisture, necssary for long term grain storage, and therefore needed to be dried down.The highest crude protein (12.8%) was the seeding rate of 150 lbs ac^{-1} (Figure 3). Crude protein levels for all the seeding rates met industry standards of 12-14% protein. All of the seeding rate treatments had DON levels above 1ppm and therefore were not suitable for human consumption. The seeding rate of 50 lbs ac^{-1} had significantly higher DON concentrations compared to all other seeding rates.

Table 7. The impact of seeding rate on wheat harvest and quality, Alburgh, VT, 2014-2015.

Seeding rate	Yield @ 13.5% moisture	Harvest moisture	Test weight	Crude protein @ 12% moisture	Falling number	DON
lbs ac^{-1}	lbs ac^{-1}	%	lbs bu^{-1}	%	seconds	ppm
50	1268	18.5	52.7	12.4	289	2.58
75	1351	18.1	53.5	12.0	294	2.08*
100	1377	17.7*	**53.8**	12.1	**304**	2.05*
125	**1471**	17.5*	53.7	12.2	302	**1.76***
150	1325	**17.4***	53.6	**12.8**	297	1.78*
LSD (0.10)	NS	0.48	NS	0.39	NS	0.41
Trial mean	1358	17.8	53.5	12.3	297	2.05

Values shown in **bold** are of the highest value or top performing.
*Seeding rates that are not significantly different than the top performing seeding rate in a column are indicated with an asterisk.
NS - None of the varieties were significantly different from one another.

Although not significantly different, the top yielding seeding rate was 125 lbs ac^{-1} (1471 lbs ac^{-1}). The highest test weight was the seeding rate of 100 lbs ac^{-1} (53.8 lbs bu^{-1}). All the test weights were below industry standards of 60 lbs bu^{-1}. The seeding rate of 100 lbs ac^{-1} also had the highest falling number (304 seconds).

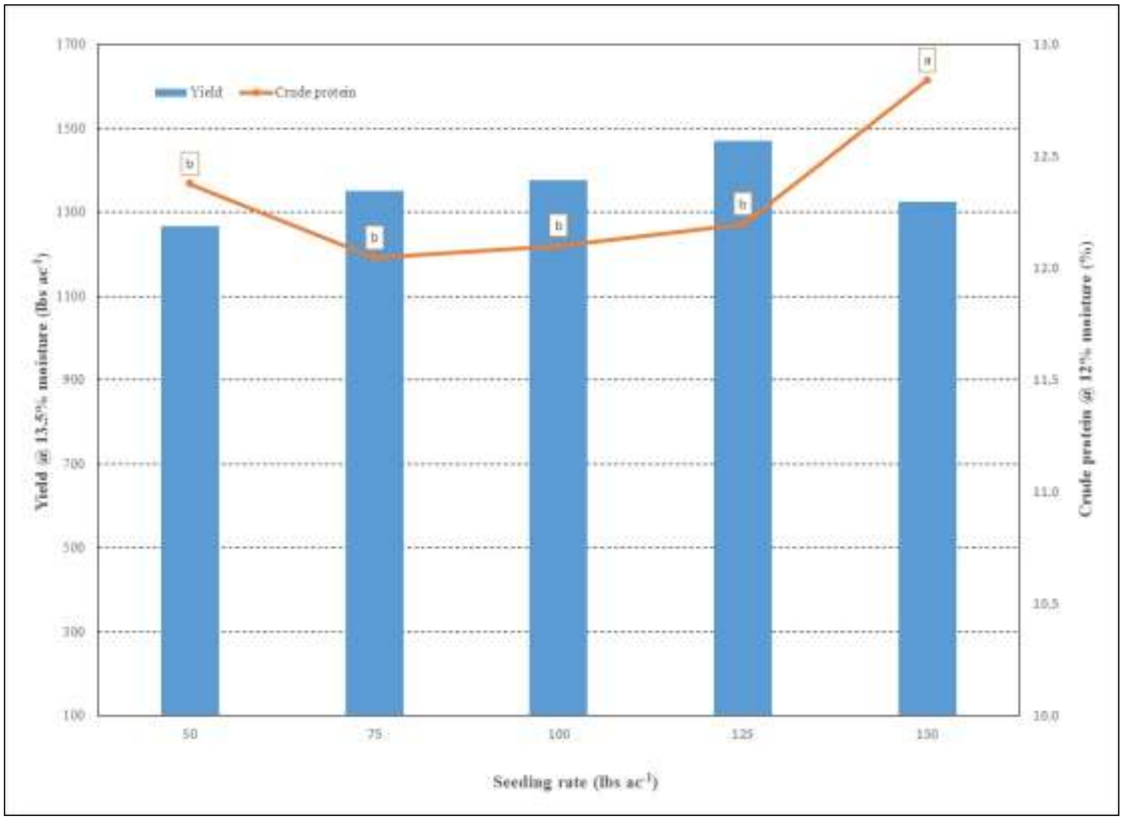

Figure 3. Yield and protein of heirloom spring wheat varieties across on seeding rate, Alburgh, VT, 2014-2015. Varieties with the same letter are not significantly different from one another.

Variety

There were no significant differences between the two heirloom varieties in plant population, plant height, and lodging (Table 8).

Table 8. The impact of variety on plant populations, heights, and lodging, Alburgh, VT 2014-2015.

Variety	Plant population	Plant height	Lodging
	plants ac^{-1}	inches	%
Ladoga	**1,131,834**	**44.5**	8.25
Red Fife	1,033,824	43.7	**4.50**
LSD (0.10)	NS	NS	NS
Trial mean	1,082,829	44.1	6.38

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

Table 9. The impact of variety on wheat harvest and quality, Alburgh, VT, 2014-2015.

Variety	Yield @ 13.5% moisture	Harvest moisture	Test weight	Crude protein @ 12% moisture	Falling number	DON
	lbs ac^{-1}	%	lbs bu^{-1}	%	seconds	ppm
Ladoga	**1430**	**15.9**	**54.8**	**12.3**	**323**	**1.64**
Red Fife	1287	19.8	52.1	**12.3**	271	2.46
LSD (0.10)	NS	0.30	0.50	NS	10.0	0.26
Trial mean	1358	17.8	53.5	12.3	297	2.05

Values shown in **bold** are of the highest value or top performing.
NS - None of the varieties were significantly different from one another.

Harvest moisture, test weight, falling number, and DON concentration were significantly different by variety. Ladoga had the lowest harvest moisture (15.9%), highest test weight (54.8 lbs bu^{-1}), highest falling number (323 seconds), and lowest DON concentration at 1.64 ppm. Although not significant, Ladoga also yielded the highest (1430 lbs ac^{-1}) (Figure 4). Interestingly, both Red Fife and Ladoga had the same protein content 12.3%, meeting industry standards of 12-14%.

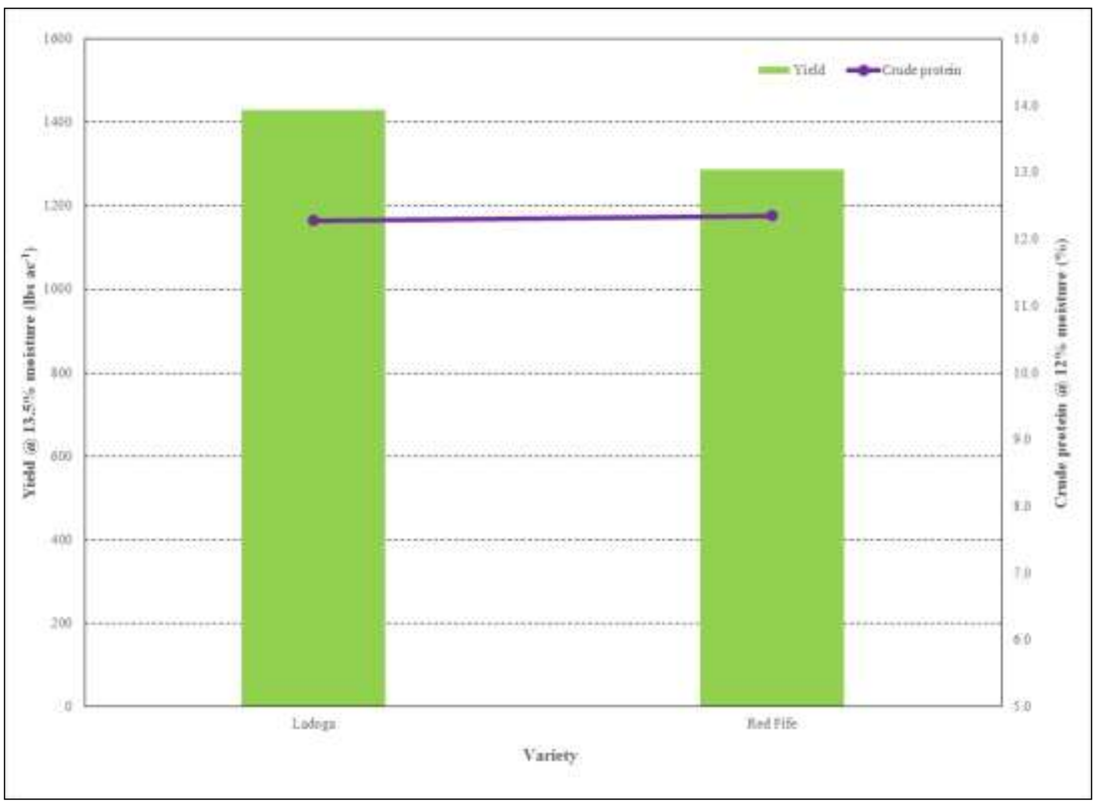

Figure 4. Yield and protein of heirloom spring wheat varieties based on variety, Alburgh, VT, 2014-2015.

DISCUSSION

There were few significant interactions between seeding rate and variety and year, thus indicating that varieties responded similarly to seeding rate regardless of year. Compiling the research data from the last few years (2014-2015) generated some interesting results. In both trial years, the weather created different challenges for growing spring grains. In 2014, the prolonged cool and wet spring delayed wheat planting and impacted stand establishment and plant tillering. The combination of these two factors likely led to the lower overall plant populations and yield observed in 2014. The below average temperatures, and above average rainfall, persisted throughout the growing season which resulted in delayed wheat development and dry down which might help explain the high moistures at harvest. In 2015, the relatively dry conditions in April allowed for timely planting of this trial. However, the cool temperatures and excessive rain in June delayed plant development and caused nutrient leaching which could have contributed to the reduction in grain protein for both varieties this year. Excessive and prolonged precipitation in 2015 also led to higher DON concentrations than those observed in 2014.

Across years, the seeding rate appeared to have little effect on yield of the heirloom wheat. There was no significant difference found between the actual plant populations recorded for each seeding rate. The variable populations were likely due to poor establishment conditions in either year. This may have led to lack of significant yield differences in the experiment. Based on the 2 years of data, it appears that heirloom varieties do not require low seeding rates to produce high yields. The data suggests that the heirlooms in this trial performed similarly across multiple seeding rates. Seeding rate did have a significant impact on crude protein and DON concentrations. The lowest DON concentrations and highest protein levels were found in the highest seeding rates. Increased number of spikes may have helped lower DON due to less overall spikes becoming infected in the higher seeding rates. Increased number of spikes may have helped lower DON due to less overall spikes becoming infected in the higher seeding rates. Increased competition for nutrients between the highest seeding rate plants could have reduced the number of total plants surviving to maturity. This might explain the lower yields and higher protein levels of this treatment. The heirloom variety Ladoga was the top performer when it came to yield, harvest moisture, test weight, falling number, and DON. The varieties performed similarly in terms of crude protein concentrations.

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