2023 Impact of Winter Rye Planting Date and Seeding Rate on No-till Soybeans

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THE UNIVERSITY OF VERMONT EXTENSION

2023 IMPACT OF WINTER RYE PLANTING DATE AND SEEDING RATE ON NO-TILL SOYBEANS

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Soybeans are grown for human consumption, animal feed, and biodiesel. Locally, soybean production is increasing as farms strive to build sustainability and resiliency on their farms. Cover crops are an integral component of the Vermont agricultural system. Cereal or winter rye is commonly planted in this region as a cover crop because it is a cold-hardy species that grows quickly in the fall and continues to produce more biomass the following spring. Because winter rye can be planted late in the season, it allows farmers the opportunity to plant a fall cover crop even after harvesting full season crops like soybeans. Farmers are looking to maximize the benefits of cover crops while minimizing any negative impact on the cash crops. Timely termination in the spring is crucial; winter rye can tie up resources like water and nitrogen in the soil, making them less available to the cash crop. Additionally, rye can continue to grow if not terminated properly resulting in weed pressure and resource competition during the season. Evaluating the impact of cereal rye planting date and seeding rate on cover crop establishment will help us determine if seeding rate should be increased as planting dates get later. We would expect that as planting dates of cereal rye extend into October, higher seeding rates may allow for increased soil protection late in the season. In addition, we expect that earlier planting dates and higher seeding rate will also have an impact on spring cover crop biomass. We will evaluate spring biomass followed by termination of the cover through rolling and crimping. Finally, we will determine the impact of these cover crop practices on soybean yields. The University of Vermont Extension Northwest Crops and Soils (NWCS) Program, as part of a grant from the Eastern Soybean Board, and in collaboration with the Northeast Cover Crop Council (NECCC), conducted a trial with the goal to 1) understand the impact of winter rye planting date and seeding rate on establishment and biomass production, and 2) investigate the yield response of no-till soybeans planted into rolled down winter rye.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT in the 2022-2023 growing season. The experimental design was a complete randomized block with split plots and four replicates. See Table 1 below for trial management information. Main plots were winter rye planting dates and split plots were winter rye seeding rates. Winter rye seed (var. *Danko*) was obtained from Seedway, LLC (Hall, NY) for this trial. Rye planting date and seeding rate information can be found in Table 2. In the fall of 2022, stand counts were done 2 to 3 weeks after planting by counting the number of seedlings within a 0.25 m^2 quadrat. Quadrat locations were marked with flags so that the same 0.25 m^2 area could be used for spring ground cover and biomass assessments in 2023. At the time of spring green up, 10-Apr 2023, percent ground cover was measured by processing photographs using the Canopeo© smartphone application. When the winter rye reached 50% anthesis (Zadok's 65; Feekes 10.5.2), on 30-May 2023, cover crop and weed biomass were measured by collecting all plant material within the 0.25 m^2 quadrat and separating weeds from the winter rye. The separated weeds and rye were then weighed, dried, and re-weighed to calculate dry matter yield. On 30-May 2023, the winter rye was rolled and crimped using a 10 foot I&J Crop Roller Crimper (Camp Douglas, WI). The soybean variety, SG 0720XT (maturity group 0.70) was obtained from Seedway LLC (Hall, NY) and planted on 31-May using a John Deere no-till planter at a rate of 180,000 seeds ac^{-1} with 30" row spacing and 2 rows per plot. Soybeans were harvested on 5-Oct using an Almaco SPC50 small plot combine. Seed was weighed for plot yield and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture/test weight meter.

Table 1. Trial management details, Alburgh, VT, 2022-2023.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Benson rocky silt loam, over shaly limestone, 8-15% slopes
Previous crop	Spring barley
Plot size (feet)	5 x 20
Replicates	4
Cover crop variety	Danko winter rye (Seedway, LLC)
Manure application	2 tons ac^{-1} chicken manure (3-Oct 22)
Cover crop termination	Roller crimped 30-May 23
Soybean variety	SG 0720XT (Seedway, LLC; maturity group 0.7, Roundup Ready®2Xtend)
Soybean row spacing (inches)	30
Soybean planting date	31-May 23
Soybean seeding rate (seeds ac^{-1})	180,000
Fertilizer application	300 lbs 19-19-19 (8-May 23)
Herbicide application	1 qt. ac^{-1} Cornerstone® Plus (30-Jun 23)
Soybean harvest date	5-Oct 23

Table 2. Winter rye experimental treatment descriptions, Alburgh, VT, 2022-2023.

	Treatment details
Planting dates (2022)	12-Sep, 19-Sep, 24-Sep, 3-Oct, 10-Oct
Seeding rates (lbs ac^{-1})	0 (control), 15, 25, 50, 80, 105

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 1999). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at 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 treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table an LSD value is presented for each variable (i.e., yield). Least Significant Differences (LSDs) at the 0.10 level of significance 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 that for 9 out of 10 times, there is a real difference between the two treatments. In this

Treatment	Yield
A	6.0^{b}
B	7.5^{ab}
C	**9.0^{a}**
LSD	2.0

example, treatment C is significantly different from treatment A but not from treatment B. The difference between C and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these treatments did not differ in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these treatments were significantly different from one another.

Additionally, data were analyzed using the bivariate Pearson Correlation of SAS (SAS Institute, 1999). The Pearson Correlation is used to assess the strength and direction of a linear relationship between two continuous numeric variables (i.e., winter rye yield and soybean yield). The strength and direction of the linear relationship is measured by the sample correlation coefficient, *r*, and considered significant at $p<0.10$. Correlation can range in value from -1 to 1 and the sign of the correlation coefficient (- or +) indicates the direction of the relationship, while the magnitude of the correlation (how close it is to -1 or +1) indicates the strength of the relationship.

RESULTS

Weather data were recorded throughout the season with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). In 2022, temperatures were cooler than average during September with a monthly average temperature of 60.2°F, 2.52 degrees below average. There was a light frost the first week of October 2022, but it wasn't until 28-Oct 2022 that Alburgh, VT had a hard frost. In November and December, it was approximately 2.5 degrees above average and in January the monthly average temperature was 6.01 degrees warmer than normal. Beginning in May 2023, all the way through August temperatures remained cool, particularly in August where the average temperature was 3.73 degrees less than the 30-year normal. The 2023 growing season ended with above average temperatures in September and October. Alburgh, VT did not receive a hard frost until the last week of October 2023, approximately three weeks later than the historical first frost date.

There was a total of 12.4 inches of rain from September to December 2022 which is typical for that time of year. In 2023, excessive rainfall persisted during the soybean season, and there was a total of 31.2 inches of rain, 8.06 inches more than normal. Overall, there was a total of 3438 accumulated Growing Degree Days for winter rye, 285 GDDs above the 30-year normal for the 2022-2023 season. During the 2023 soybean growing season there was a total of 2409 accumulated GDDs for soybeans, which was similar to the 30-year average for that period.

Table 3. Weather data for Alburgh, VT, 2022-2023.

	2022				2023									
Alburgh, VT	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Average temperature (°F)	60.2	51.3	41.5	30.7	26.9	23.6	32.2	48.3	57.1	65.7	72.2	67.0	63.7	54.4
Departure from normal	-2.52	0.96	2.24	2.5	6.01	0.65	-0.07	2.70	-1.28	-1.76	-0.24	-3.73	1.03	4.11
Precipitation (inches)	4.40	2.56	3.01	2.43	2.04	1.36	2.00	4.94	1.98	4.40	10.8	6.27	2.40	5.38
Departure from normal	0.73	-1.27	0.31	-0.07	-0.09	-0.41	-0.24	1.87	-1.78	0.14	6.69	2.73	-1.27	1.55

Growing Degree Days														
Winter rye (32-95°F)	861	607	346	112	42	77	103	524	766					
Departure from normal	-61	39	111	64	42	66	-35	112	-53					
Soybeans (50-86°F)										483	712	540	449	225
Departure from normal										-41	17	-101	62	87

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) from Burlington, VT.

Interactions

There were significant interactions between main effects (planting date x seeding rate) for the winter rye cover crop, but not for the soybeans (Table 4). Spring ground cover, weed biomass, and winter rye biomass all had significant planting date by seeding rate interactions, which suggests that seeding rates responded differently at different planting dates. There was a lot of variation in spring ground cover between seeding rates and planting dates (Figure 1). Except for the first planting date, the 15 and 25 lbs ac^{-1} seeding rates consistently provided the lowest ground cover. Within the first planting date, there was little overall difference in ground cover between the seeding rates. By the 19-Sep seeding rates over 50 lbs ac^{-1} produced similar ground cover until October where seeding rate over 80 lbs ac^{-1} produced ground cover over 40%. The data suggests that seeding rates should be increased to a rate between 50 and 80 lbs ac^{-1} near the end of September and into October to obtain more ground cover.

The interaction between winter rye seeding rate and planting date on rye biomass is shown in Figure 2. The 15 lbs ac^{-1} seeding rate had the lowest rye biomass at all but the fourth planting date. At the fourth planting date, the 25 lbs ac^{-1} seeding rate had the least amount of biomass. Overall, rye biomass was similar between the 80 and 105 lbs ac^{-1} seeding rates in the later three planting dates. But at the first planting date, the highest seeding rate, 105 lbs ac^{-1}, had a much higher amount of biomass compared to the other seeding rates. For the October planting dates, the lowest seeding rates produced the least amount of dry matter yield in the following spring. Overall, there is a decrease in spring ground cover and biomass production when winter rye is planted at increasingly later dates and the data suggests that increasing seeding rates can help to overcome these impacts from late planting.

Weed biomass production was much higher in the control plots (Figure 3) compared to all other seeding rates. Weed biomass in the control was over 1200 lbs ac^{-1} in the first two planting dates. Weed biomass did decrease with later planting dates, but even within the last planting date, weed biomass was about 200 lbs ac^{-1} more in the no cover crop control than all the other seeding rate treatments. Across all other seeding rates and planting dates there was little to no weed biomass production. This is likely due to the high rye biomass production across this year’s trial.

Table 4. Significance of main effects and main effect interactions.

	Planting date (PD)	Seeding rate (SR)	PD x SR
Cover crop characteristics			
Fall seedling density	**†	****	NS
Spring ground cover	****	****	***
Weed biomass	*	****	**
Rye biomass	****	***	**
Soybean characteristics			
Yield at 13% moisture	*	*	NS
Harvest moisture	****	NS	NS
Test weight	NS§	NS	NS

†*0.10>p>0.05; **0.05>p>0.01; ***0.01>p>.0001; ****p<.0001
‡NS; not statistically significant.

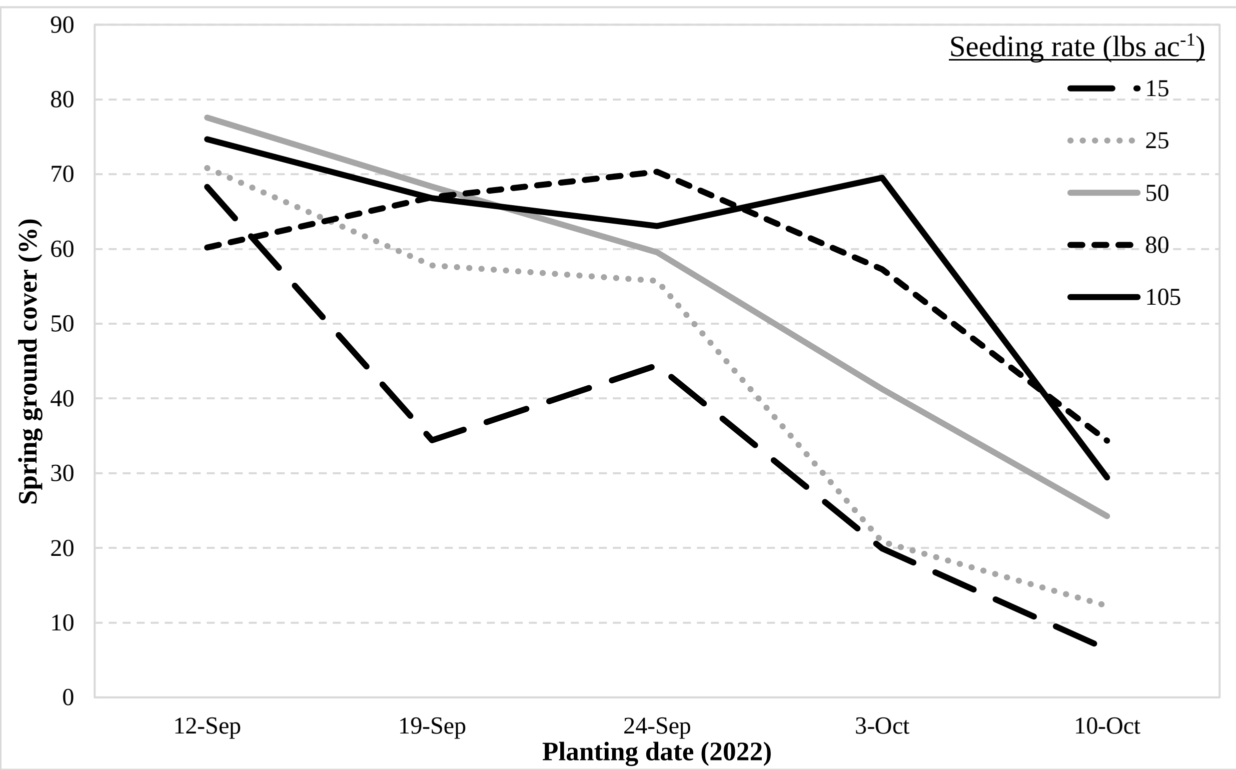

Figure 1. Seeding rate x planting date interaction for spring ground cover, Alburgh, VT, Spring 2023.

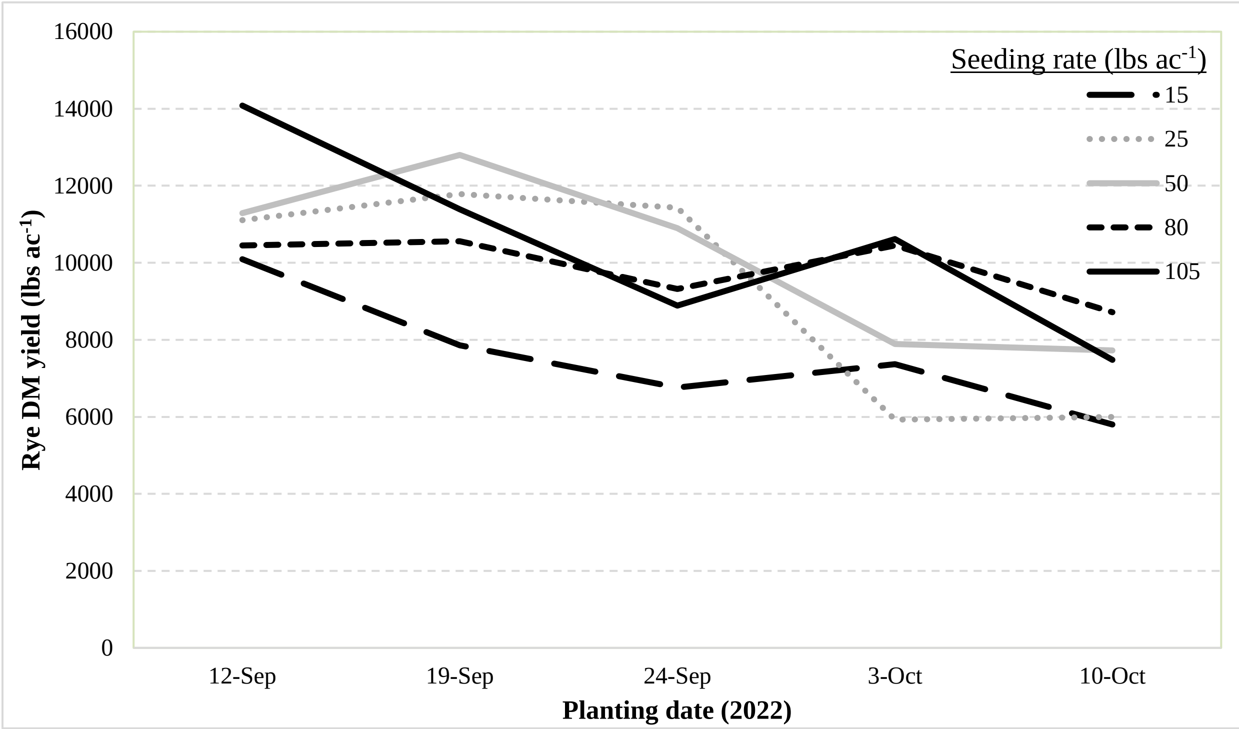

Figure 2. Seeding rate x planting date interaction for rye dry matter yield, Alburgh, VT, Spring 2023.

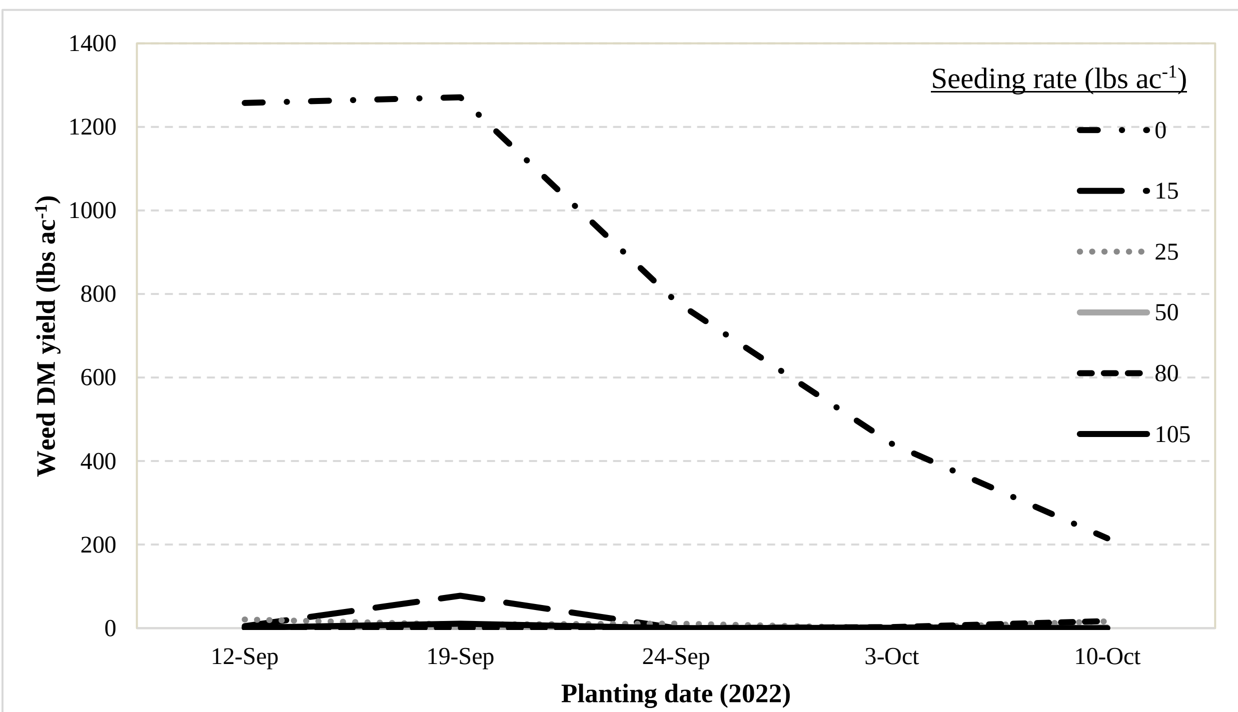

Figure 3. Seeding rate x planting date interaction for weed dry matter yield, Alburgh, VT, Spring 2023.

Impact of winter rye planting date

The winter rye cover crop was significantly impacted by planting date (Table 5). In the fall, rye seedling density was assessed two-three weeks after planting. Rye seedling density was highest in the first planting date (12-Sep), and this was not statistically different from the fourth planting date (3-Oct). In the spring, ground cover was statistically higher in the first planting date than any other planting date. There was no significant difference in ground cover between the second and third planting dates (19- and 24-Sep). The latest planting date (10-Oct) had significantly lower ground cover than all other planting dates. Overall, weed biomass was low across the planting dates, with a trial average of 138 lbs ac^{-1}. While weed biomass was greatest in the second planting date, there was no statistical difference between the first three planting dates. Rye biomass production was very high in this year's trial, with an average of 9467 lbs ac^{-1} or 4.73 tons ac^{-1}. Rye biomass was also the greatest in the first planting date, but not statistically different from the second planting date. The latest planting date did have statistically lower rye biomass than all other planting dates. Earlier planting dates allow the plant to produce more tillers (side shoots). Hence, even though similar fall seedling densities were observed between 12-Sep and 3-Oct, the spring ground cover was 41% higher in the 12-Sep planting date.

Soybean harvest characteristics were also significantly impacted by the winter rye planting date (Table 6). Soybean yield was highest when planted into the latest winter rye planting date, but this was not statistically different from soybeans planted into the third or fourth planting date. Soybean yields were good this year with an average harvest yield of 3997 lbs ac^{-1} or 66.6 bu ac^{-1}. Soybean harvest moisture was significantly lower in the first planting date than all other planting dates. And soybean harvest moisture was statistically highest in the latest planting date. There was no significant difference in soybean test weight between planting dates.

Table 5. Cover crop characteristics by winter rye planting date, Alburgh, VT, 2022-2023.

Planting date	Fall seedling density	Spring ground cover	Weed biomass	Winter rye biomass
	plants ac^{-1}	%	DM yield lbs ac^{-1}	
12-Sep	**796711**[a]†	**70.3**[a]	214[a]	**11403**[a]
19-Sep	667974[bc]	58.8[b]	**228**[a]	10878[a]
24-Sep	667974[bc]	58.6[b]	132[ab]	9460[b]
3-Oct	709267[ab]	41.8[c]	74.5[b]	8449[b]
10-Oct	603201[c]	21.3[d]	41.6[b]	7144[c]
LSD (*p*=0.10)‡	92319	5.74	130	1142
Trial mean	689025	50.2	138	9467

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.

Table 6. Soybean harvest characteristics by winter rye planting date, Alburgh, VT, 2023.

Planting date	Soybean yield at 13% moisture		Harvest moisture	Test weight
	lbs ac^{-1}	bu ac^{-1}	%	lbs bu^{-1}
12-Sep	3830[b]	63.8[b]	**13.0[a]**	56.9
19-Sep	3860[b]	64.3[b]	13.3[b]	56.9
24-Sep	3939[ab]	65.6[ab]	13.4[b]	56.9
3-Oct	4153[a]	69.2[a]	13.4[b]	56.3
10-Oct	**4207[a]**†	**70.1[a]**	13.6[c]	56.7
LSD (*p*=0.10)‡	286.8	4.78	0.14	NS§
Trial mean	3997	66.6	13.4	56.7

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Impact of winter rye seeding rate

Winter rye seeding rate significantly impacted fall seedling density, spring ground cover, and weed and rye biomass production (Table 7). Winter rye was not planted in the control plots (0 lbs ac^{-1}) therefore, fall seedling density, ground cover, and rye biomass are not reported for this treatment. Fall seedling density was significantly greater in the 105 lbs ac^{-1} seeding rate than all other seeding rates. Each seeding rate had a statistically lower seedling density than the previous seeding rate. Spring ground cover was also greatest in the highest seeding rate, but was not statistically different from the next highest seeding rate (80 lbs ac^{-1}). The lowest seeding rate (15 lbs ac^{-1}) had about half of the spring ground cover as the highest seeding rate. Weed biomass production was statistically greater in the control than all the other seeding rates, with an average of 793 lbs ac^{-1} of biomass. All other seeding rates had an average weed biomass of less than 20 lbs ac^{-1}, and there was no significant difference between the treatments. Winter rye biomass production was highest in the 105 lbs ac^{-1} seeding rate but was not statistically different from the 50 and 80 lbs ac^{-1} seeding rates. The 15 lbs ac^{-1} seeding rate did have significantly less rye biomass than the other seeding rates.

Soybean yields were also significantly impacted by winter rye seeding rate (Table 8). Soybean yields were greatest in the control, although not statistically different from the 15 lbs ac^{-1} seeding rate. Soybean harvest moisture and test weight were not impacted by winter rye seeding rate. The average harvest moisture was 13.4% and the average test weight was 56.7 lbs bu^{-1}.

Table 7. Cover crop characteristics by winter rye seeding rate, Alburgh, VT, 2022-2023.

Seeding rate	Fall seedling density	Spring ground cover	Weed biomass	Winter rye biomass
lbs ac^{-1}	plants ac^{-1}	%	DM yield lbs ac^{-1}	
0 (control)	--	--	**793^{a}**	--
15	219419^{e}	34.7^{d}	17.0^{b}	7577^{c}
25	387020^{d}	43.5^{c}	11.3^{b}	9248^{b}
50	689835^{c}	54.2^{b}	0.54^{b}	10121^{ab}
80	987792^{b}	57.8^{ab}	4.28^{b}	9899^{ab}
105	**1161060^{a}**†	**60.7^{a}**	2.50^{b}	**10489^{a}**
LSD (*p*=0.10)‡	92319	5.74	142	1142
Trial mean	689025	50.2	138	9467

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.

Table 8. Soybean harvest characteristics by winter rye seeding rate, Alburgh, VT, 2023.

Seeding rate	Soybean yield at 13% moisture		Harvest moisture	Test weight
lbs ac^{-1}	lbs ac^{-1}	bu ac^{-1}	%	lbs bu^{-1}
0 (control)	**4354^{a}**†	**72.6^{a}**	13.5	56.2
15	4064^{ab}	67.7^{ab}	13.3	56.6
25	3827^{b}	63.8^{b}	13.4	57.0
50	3886^{b}	64.8^{b}	13.3	57.1
80	3855^{b}	64.3^{b}	13.4	56.7
105	3998^{b}	66.6^{b}	13.3	56.8
LSD (*p*=0.10)‡	314.1	5.24	NS§	NS§
Trial mean	3997	66.6	13.4	56.7

†Within a column, treatments marked with the same letter were statistically similar (p=0.10).
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

DISCUSSION

During the 2022-2023 season, the UVM Northwest Crops and Soils Program conducted the second year of this research trial to 1) understand the impact of winter rye planting date and seeding rate on establishment and biomass production, and 2) investigate the yield response of no-till soybeans planted into rolled down winter rye. Winter rye was planted in the fall of 2022 at five planting dates beginning 12-Sep and ending 10-Oct. The average temperature in September was about 2.5 degrees below normal, but that was followed by above average temperatures from November through January of 2023. The monthly average temperature in January was 6 degrees warmer than normal. Despite cool temperatures in September, winter rye planted in September and October was able to establish well. A light frost occurred between the third and fourth planting dates, but there wasn't a hard frost until the end of October after the last planting dates. The following spring, the winter rye grew rapidly with warm temperatures and adequate rainfall in April and put on a lot of biomass prior to termination. Rye biomass yields were very high in this year's trial, with an average yield of 9467 lbs ac^{-1} but some treatments had rye biomass between 10,000 and 11,000 lbs ac^{-1}. This is comparable to the winter rye yields in other research trials at Borderview Research Farm in 2022-2023, where the average yield was approximately 10,500 lbs or 5.25 tons ac^{-1}. The average yield in 2023 was about 1.4X greater than the average yield in 2022 (6560 lbs or 3.3 tons ac^{-1}). Figure 4 below shows the spring rye biomass in 2022 compared to 2023 across the five planting dates. Despite higher yields in 2023, the general trend is the same. Rye biomass was statistically greater when planted earlier in September and then decreased as the planting date approached the end of October.

The winter rye was roller crimped on 30-May and soybeans were planted into the rye residue on 31-May using a no-till planter. Weather conditions in May were cool and dry, but excessive rainfall became the biggest challenge during the remainder of the season. Below average temperatures also continued through August. Despite these weather conditions, no-till soybeans in this trial established well and produced good yields, with a trial average of 3997 lbs or 66.6 bu ac^{-1}. Soybeans in this trial performed similarly to other conventional soybean varieties grown at Borderview Research Farm in 2023. In 2023, soybean yields were significantly impacted by winter rye planting date and seeding rate. Those treatments that produced more than 9000 lbs of winter rye biomass per acre resulted in the lowest soybean yields. In this year's trial there was a significant negative correlation between winter rye biomass and soybean yield ($p=0.001$). This correlation indicates that across all planting dates and seeding rates, as winter rye biomass increases, soybean yield decreases. This trend is opposite of what was observed in 2022, where no-till soybeans had statistically greater yields when planted into the earlier rye planting date. Figure 5 below shows the relationship between fall rye planting date and subsequent soybean yields in 2022 and 2023. In 2022, due to adverse field conditions, only soybeans from planting dates 1, 3, and 5 were harvested, therefore only those three planting dates are shown in Figure 5. Soybean yields in 2022 were not significantly impacted by winter rye biomass, however the biomass levels were quite low. This data indicates that moderate levels of winter rye biomass will likely not negatively impact soybean yield in a cool and wet growing season.

These data suggest that winter rye planted in mid to late September will establish better in the fall, provide more spring ground cover, and produce higher biomass the following year compared to winter rye that is not planted until early October, even when weather conditions remain warm in the fall. The warm fall temperatures and delayed frost likely result in the high rye biomass observed in this year's trial. Increasing seeding rates will also increase fall establishment, spring ground cover, and spring biomass production for winter rye. The negative correlation between rye biomass and soybean yield emphasizes the importance of management decisions and the trade-offs that farmers must consider if they plan on adopting these conservation practices. Winter rye is a commonly used fall cover crop in the Northeast because it can tolerate the cold climate and establish well after a long season crop like soybeans. In a no-till system, high spring cover crop biomass can reduce subsequent soybean yields, as seen in this year's trial. Good ground coverage and weed suppression was achieved even at the lowest seeding rate (15 lbs ac^{-1}) and at this seeding rate, it did not compromise soybean yields. With increasing fall temperatures and delayed frost, higher seeding rates of cover crops like winter rye could continue to negatively impact soybean yields. Increasing winter rye seeding rates to 50-100 lbs ac^{-1} may be beneficial for farmers if they must plant their cover crop much later in the season, to get good establishment before winter and provide decent weed suppression in the spring. It is important to note that these data represent one year of research at one location, and continued research is needed to better understand the impact of rolled down rye on no-till soybeans in our region.

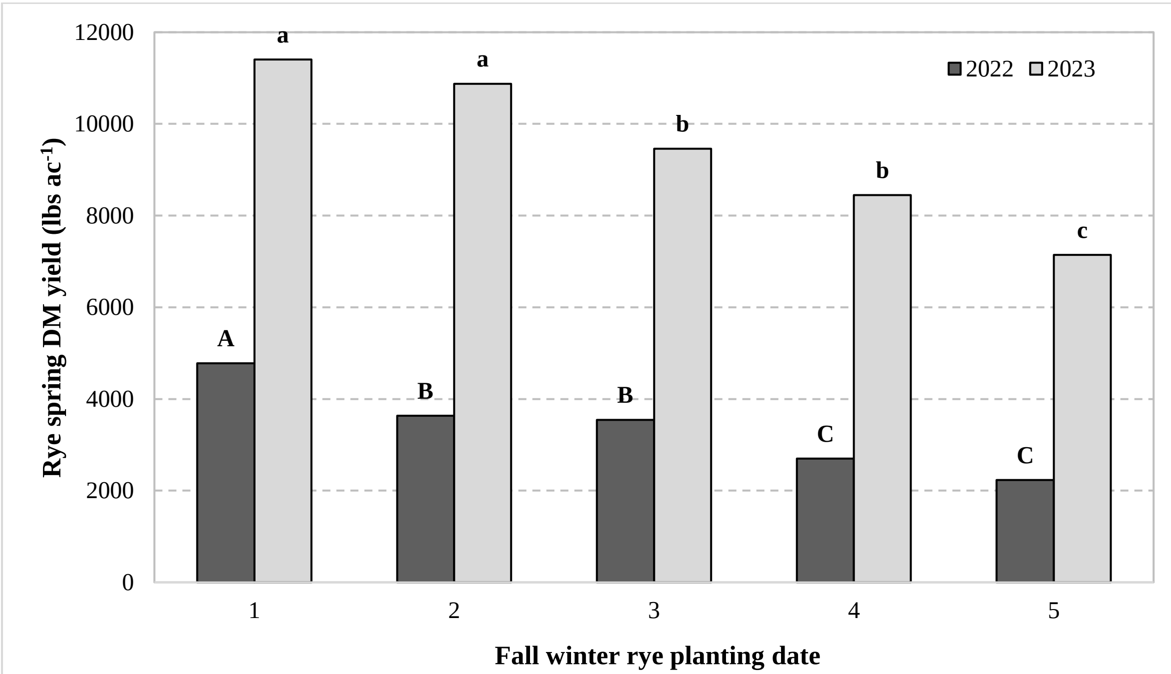

Figure 4. Winter rye biomass by fall planting date in 2022 and 2023, Alburgh, VT.
For each year, columns that share a letter are not statistically different (p=0.10).

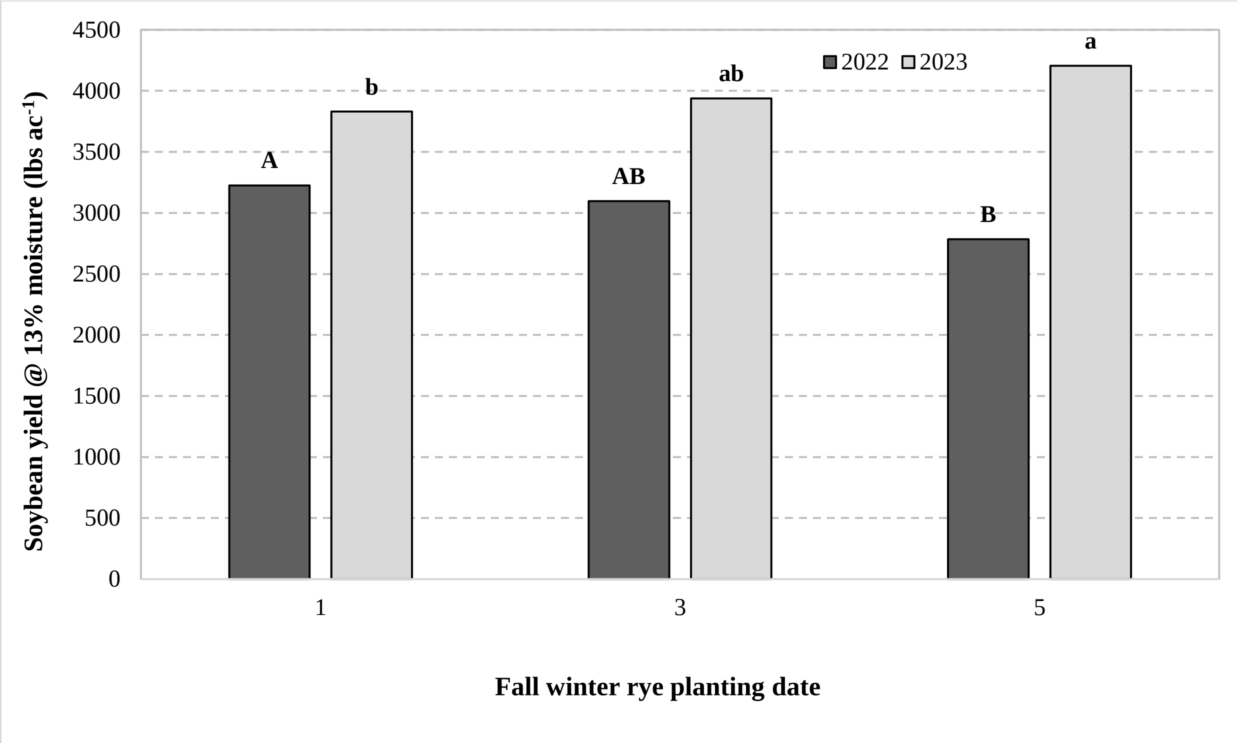

Figure 5. Soybean yield by fall planting date in 2022 and 2023, Alburgh, VT.
For each year, columns that share a letter are not statistically different (p=0.10).

ACKNOWLEDGEMENTS

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