NORTHWEST CROPS & SOILS PROGRAM

2022 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 corn. 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. 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 2021-2022 growing season. The experimental design was a complete randomized block with split plot design and replicated four times. 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 (*VNS*) 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 2021, 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 2022. At the time of spring green up, 5-Apr 2022, 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 20-May 2022, 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 and yield. On 31-May 2022, 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 0.7) was obtained from Seedway LLC (Hall, NY) and planted on 6-Jun 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. Plots were sprayed with Roundup PowerMAX® at a rate of 1 quart ac^{-1} on 15-Jun 2022 to control weeds. Soybeans were harvested on 13-Oct and 21-Oct using an Almaco SPC50 small plot combine. Due to the field conditions, only soybeans from the 1st, 3rd, and 5th rye planting dates were harvested. 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, 2021-2022.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Benson rocky silt loam, over shaly limestone, 8-15% slopes
Previous crop	Winter barley
Plot size (feet)	5 x 20
Replicates	4
Cover crop variety	*VNS* Winter rye (Seedway, LLC)
Cover crop termination	Roller crimped 31-May 22
Soybean variety	SG 0720XT (Seedway, LLC; maturity group 1.0, Roundup Ready®2Xtend)
Soybean row spacing (inches)	30
Soybean planting date	6-Jun 22
Soybean seeding rate (seeds ac^{-1})	180,000
Herbicide application	1 qt ac^{-1} Roundup PowerMAX®
Soybean harvest date	13- and 21-Oct 22

Table 2. Winter rye experimental treatment descriptions, Alburgh, VT, 2021-2022.

	Treatment details
Planting dates (2021)	20-Sep, 29-Sep, 7-Oct, 13-Oct, 20-Oct
Seeding rates (lbs ac^{-1})	0 (control), 15, 30, 60, 90, 120

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 example, treatment C is significantly different from treatment A but not from

Treatment	Yield
A	6.0[b]
B	7.5[ab]
C	**9.0[a]**
LSD	2.0

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.

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). The months of September and October 2021 were warmer than normal; October was especially warm with 4.21 degrees above the 30-year average. The historical first frost date for this location is 28-Sep, but the temperatures did not go below freezing until 28-Oct. All the winter rye planting dates were before the first killing frost. While precipitation had been quite low throughout most of the 2021 growing season, there was increased rainfall in September and October, with 0.82 and 2.40 inches more than the 30-year average respectively. The warm temperatures through October likely led to better winter rye establishment and survival into 2022. By the time the winter rye was rolled down, there had been an accumulated 3247 Growing Degree Days (GDDs), 277 GDDs above the 30-year normal for that time frame. Unlike 2021, 2022 was much wetter and cooler. Most of the 2022 growing season, temperatures were below average. May was particularly warm however, 2.09 degrees above normal. In June 2022, when the soybeans were planted, it was 2.18 degrees cooler than normal and there were 8.19 inches of precipitation, almost four inches above average. During the soybean growing season (June through October), there was an accumulated 2290 GDDs, which was 93 less than normal.

Table 3. Weather data for Alburgh, VT, 2021-2022.

	2021				2022							
Alburgh, VT	**Sept**	**Oct**	**Nov**	**Dec**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Average temperature (°F)	63.1	54.6	37.6	28.6	32.3	44.8	60.5	65.3	71.9	70.5	60.7	51.5
Departure from normal	0.40	4.31	-1.68	0.36	-0.03	-0.81	2.09	-2.18	-0.54	-0.20	-1.99	1.24
Precipitation (inches)	4.49	6.23	2.26	1.42	2.52	5.57	3.36	8.19	3.00	4.94	4.4	2.56
Departure from normal	0.82	2.40	-0.44	-1.08	0.28	2.50	-0.4	3.93	-1.06	1.40	0.73	-1.27
Growing Degree Days												
Winter rye (32-95°F)	933	701	232	107	170	391	883					
Departure from normal	11	133	-3	59	32	-20	65					
Soybeans (50-86°F)								459	674	630	343	184
Departure from normal								-64	-20	-11	-44	46

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 for the winter rye cover crop, but not for the soybeans (Tables 4 & 5). Spring ground cover, weed biomass, and winter rye yield all had significant planting date by seeding rate interactions, which suggests that seeding rates responded differently depending on the planting date. Spring ground cover was highest with the 120 lbs ac^{-1} seeding rate until the last planting date (Figure 1). Spring ground cover increased as seeding rate increased within each planting date, but decreases overall as the planting date gets later. The decline in ground cover is more gradual in the higher seeding rates. For the 15 lbs ac^{-1} treatment, ground cover declined by half between the 1st (20-Sep) and 2nd (29-Sep) planting dates. A similar trend was seen in the 30 lbs ac^{-1} treatment. The sharp decline in ground cover does not occur until after the 3rd planting date (6-Oct) for the three highest seeding rates. By 20-Oct, ground cover was under 5% for all seeding rates. The 120 lbs ac^{-1} seeding rate resulted in the highest winter rye yield until the last planting date (Figure 2). Additionally, there was very little difference in yields between the 60 and 90 lbs ac^{-1} rates across all planting dates. At the 1st planting date, the 60 lbs ac^{-1} treatment had a rye biomass that was only about 1.2X less than the 120 lbs ac^{-1} treatment. This highlights that doubling the seeding rate does not necessarily result in double the biomass when rye is planted early in the season, and there are enough growing degree days for the rye to have good establishment. Increasing seeding rate late in the season increased rye yields, but no significant yield benefits were seen after 30 lbs ac^{-1}. Rye planted on 20-Oct produced very similar biomass for the 60, 90, and 120 lbs ac^{-1} seeding rates. This indicates that increasing the seeding rate above 60 lbs ac^{-1} regardless of planting date may not yield better cover crop results in every year. But rye biomass was twice as high in the 30 lbs ac^{-1} treatment as it was in the 15 lbs ac^{-1} treatment. Weed biomass was quite high in the 1st planting date for the control plots. Overall, weed biomass was higher in the 1st and 5th planting dates for all seeding rates and lower in the 2nd-4th planting dates (Figure 3).

Table 4. Significance of main effects and main effect interactions, cover crop characteristics.

	Planting date	Seeding rate	PD x SR
Spring ground cover	**†	**	**
Weed biomass	**	**	**
Rye yield	**	**	*

†*0.1>p>0.05; **p<.0001

Table 5. Significance of main effects and main effect interactions, soybean characteristics.

	Planting date	Seeding rate	PD x SR
Soybean yield	*†	NS	NS
Harvest moisture	NS‡	NS	NS
Test weight	NS	NS	NS

†*0.1>p>0.05
‡NS; not statistically significant.

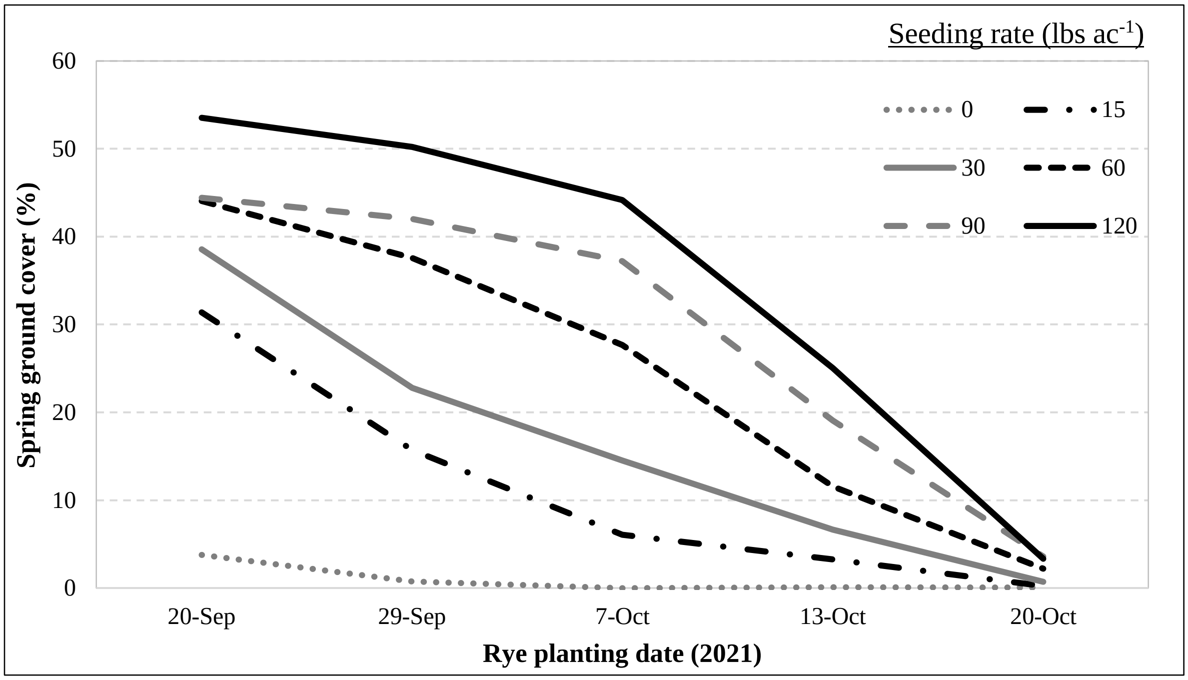

Figure 1. Seeding rate x planting date interaction for spring ground cover, Alburgh, VT, 2022.

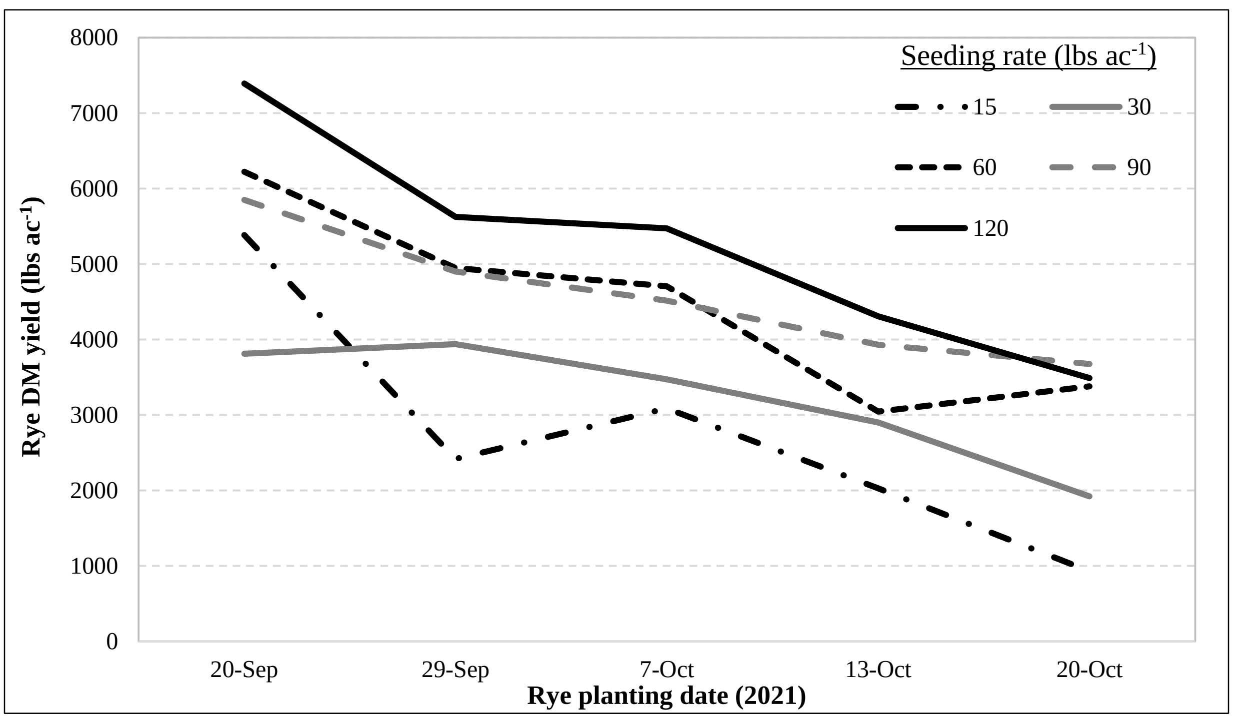

Figure 2. Seeding rate x planting date interaction for rye dry matter yield, Alburgh, VT, 2022.

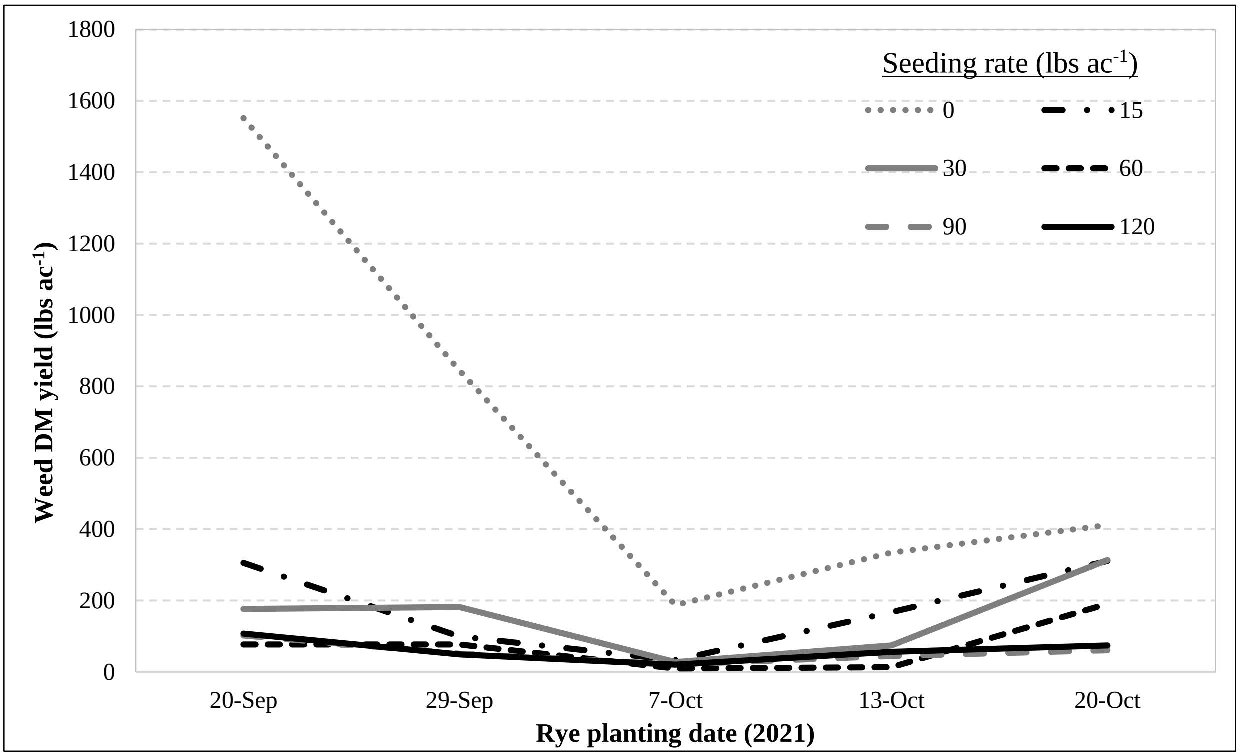

Figure 3. Seeding rate x planting date interaction for weed dry matter yield, Alburgh, VT, 2022.

Impact of winter rye planting date

Spring ground cover, weed biomass, and winter rye yields were all significantly impacted by planting date (Table 6). The 20-Sep planting date had a spring ground cover that was significantly greater than all other planting dates. The trial average was 19.7% and ranged from 1.7% (20-Oct) to 35.9% (20-Sep). Winter rye dry matter yield was greatest in the 1st planting date as well, and again this was statistically greater than the other planting dates. The trial average was 3377 lbs ac^{-1} and ranged from 2232 lbs ac^{-1} (20-Oct) to 4776 lbs ac^{-1} (20-Sep). Weed biomass ranged from 50 lbs ac^{-1} (7-Oct) to 387 lbs ac^{-1} (20-Sep) and the trial average was 199 lbs ac^{-1}. Weed biomass was statistically higher in the 1st planting date, which may be due to the fact there was more time in the fall after the field was tilled and rye planted for weeds to grow, especially since the fall was quite warm. The 5th planting date had the second highest weed biomass, which could be due to lower spring ground cover from the winter rye resulting in more space for weeds to establish.

Soybean yields were significantly impacted by winter rye planting date, but harvest moisture and test weight were not (Table 7). Soybeans that were planted into the 1st rye planting date had the highest yields, 3226 lbs or 53.8 bu ac^{-1}. This was statistically greater than soybean yields from the 20-Oct planting date, but not from the 7-Oct. The trial average was 3036 lbs ac^{-1} or 50.6 bu ac^{-1}.

Table 6. Cover crop characteristics by winter rye planting date, Alburgh, VT, 2022.

Planting date	Spring ground cover	Weed DM yield	Winter rye DM yield
	%	lbs ac^{-1}	
20-Sep	**35.9^{a}†**	**387^{a}**	**4776^{a}**
29-Sep	28.2^{b}	217^{b}	3638^{b}
7-Oct	21.6^{c}	50.0^{c}	3541^{b}
13-Oct	10.9^{d}	115^{c}	2700^{c}
20-Oct	1.69^{e}	227^{b}	2232^{c}
LSD (p=0.10)‡	2.97	94.5	524.6
Trial mean	19.7	199	3377

†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 7. Soybean harvest characteristics by winter rye planting date, Alburgh, VT, 2022.

Planting date	Soybean yield at 13% moisture		Harvest moisture	Test weight
	lbs ac^{-1}	bu ac^{-1}	%	lbs bu^{-1}
20-Sep	**3226^{a}†**	**53.8^{a}**	12.9	55.8
7-Oct	3097^{ab}	51.6^{ab}	13.1	55.6
20-Oct	2784^{b}	46.4^{b}	12.4	56.7
LSD (p=0.10)‡	327.6	5.46	NS§	NS
Trial mean	3036	50.6	12.8	56.0

†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 spring ground cover, weed biomass, and rye dry matter yields (Table 8). The highest seeding rate (120 lbs ac^{-1}) had statistically greater spring ground cover, 35.3%, than any of the other seeding rates. All seeding rates had spring ground cover statistically greater than the control (0.94%). Similarly, rye dry matter yield was highest in the 120 lbs ac^{-1} treatment, 5256 lbs ac^{-1}, and this was significantly greater than all other treatments. Unsurprisingly, weed biomass was greatest in the control plots (666 lbs ac^{-1}) and that was statistically higher than the other seeding rates. There was no statistical difference in weed biomass between the 30, 60, 90, and 120 lbs ac^{-1} treatments.

The winter rye seeding rate treatments had no significant impact on soybean yields, harvest moisture, or test weights (Table 9).

Table 8. Cover crop characteristics by winter rye seeding rate, Alburgh, VT, 2022.

Seeding rate	Spring ground cover	Weed DM yield	Winter rye DM yield
lbs ac^{-1}	%	lbs ac^{-1}	
0 (control)	0.94[f]	**666[a]**	`0[d]
15	11.3[e]	183[b]	2769[c]
30	16.6[d]	15.0[bc]	3207[c]
60	24.6[c]	74.0[c]	4459[b]
90	29.3[b]	56.0[c]	4573[b]
120	**35.3[a]**†	62.0[c]	**5256[a]**
LSD (p=0.10)‡	3.26	104	575
Trial mean	19.7	199	3377

†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 9. Soybean harvest characteristics by winter rye seeding rate, Alburgh, VT, 2022.

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)	2931	48.8	12.7	56.1
15	2825	47.1	12.6	56.0
30	3075	51.3	13.0	55.7
60	3057	51.0	12.5	56.3
90	3282	54.7	12.4	56.4
120	3043	50.7	13.7	55.5
LSD (p=0.10)‡	NS§	NS	NS	NS
Trial mean	3036	50.6	12.8	56.0

†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

The fall of 2021 was quite warm, which led to good winter rye establishment and growth. The winter rye planting dates ranged from 20-Sep to 20-Oct, which was intended to span optimal and sub-optimal fall planting dates. However, October was unseasonably warm, and all five rye planting dates occurred before the first frost. Spring rye biomass was high this season, but in years with more typical conditions, there may be increased risk of poor cover crop establishment with later plantings. In 2022, it was particularly cool and wet. Wet springs and poor field conditions can be a challenge, delaying cover crop termination and cash crop planting. In the spring, winter rye may reduce soil moisture, which would be beneficial in a wet year and allow for more timely soybean planting. In a past research trial looking at the impact of winter rye termination method on subsequent soybean yields, UVM Extension NWCS found that soil moisture was significantly lower in plots where winter rye was sprayed with herbicide after soybean planting compared to plots where the rye was tilled under or sprayed with herbicide a week prior to planting. In a year like 2021 where drought conditions persisted throughout the growing season, any loss of moisture to a cover crop can be detrimental to the soybean crop. But in a wet year like 2022, the ability of winter rye to reduce soil moisture may be beneficial.

Regardless of seeding rate, rye biomass decreased as the fall planting date got later in the season. Subsequently, the earlier the planting date, the more biomass there will be in the spring, regardless of seeding rate. This is important for farmers because they may still be able to achieve good cover crop establishment with a lower seeding rate if they are able to plant earlier in the season. On the other hand, if the cover crop must be planted later in the season, increasing the seeding rate will be necessary to achieve good spring cover and biomass. But it is important to note that there was little difference in biomass production between rye planted at 60 and 90 lbs ac^{-1} for every planting date, and by the last planting date, there was little difference between 60, 90, and 120 lbs ac^{-1} seeding rates in terms of rye biomass.

The no-till soybeans performed best when planted into the earliest rye planting date, and yields were significantly reduced when planted into the latest planting date. This may be because the soybeans were planted in early June following a few large rain events. The higher rye biomass in the earliest planting date may have resulted in decreased soil moisture and could have improved soil conditions at planting. This year soil moisture was not measured in this trial. Soils that are too wet can reduce soybean germination. The average yield of no-till soybeans in this trial (3036 lbs ac^{-1} or 50.6 bu ac^{-1}) was 1.5X lower than the average yield of other conventional soybeans (4274 lbs ac^{-1} or 71.2 bu ac^{-1}) grown at Borderview Research Farm this year. In this trial, soybeans planted into the 1st rye planting date produced about 1.2X more than soybeans planted into the 5th rye planting date. Overall, rye seeding rate had no impact on the no-till soybean yield. It is important to note that these represent one year of research at one location, and additional research is needed to better understand the impact of rolled down rye on no-till soybeans in our region. The University of Vermont Extension NWCS Program plans to repeat this trial again in the 2022-2023 season.

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