2019 Cover Crop Planting Date Trial

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Maintaining and improving soil health is critical to crop productivity. Cover cropping is one way to prevent soil erosion, maintain and/or improve soil nutrients, improve soil aggregation, prevent nutrient loss from runoff, and increase water retention. Such soil improvements can promote conditions that add resiliency to a crop, especially in light of extreme weather patterns that may affect yields. It can be challenging to grow a successful cover crop, given other demands from a farm operation and weather limitations. In this trial, our goals were to evaluate the effect of cover crop planting dates and cover crop mixes on biomass production and soil coverage.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of planting date and cover crop mixture on biomass yield and soil coverage at the end of the growing season and after the winter. The experimental design was a randomized complete block with four replications.

Table 1. Agronomic information for the cover crop planting date trial, Alburgh, VT, 2019.

Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam, 8-15% slope
Previous crop	Soybeans
Plot size (ft.)	5 x 20
Planting date	24-Aug, 7-Sep, 19-Sep 2018
Planting equipment	Great Plains NT60 Cone Seeder

Nine cover crop mixes (Table 2) were planted on three planting dates: 24-Aug, 7-Sep, and 19-Sep 2018. These mixes represent both overwintering and winterkilled cover crops. On 22-Oct 2018, plots were photographed in order to assess the percent soil cover provided by the cover crops. Digital images were analyzed with the automated imaging software, IMAGING crop response analyzer, which was programmed in MATLAB (MathWorks, Inc., Natick, MA) and later converted into a free web-based software (www.imaging-crop.dk). At the time of photographing, the biomass within a 0.25 m^2 quadrat was harvested per plot. The biomass was dried at 105º F until a stable weight was reached, and dry matter yields were calculated. The following spring, percent cover and biomass were measured on 1-May 2019. The beaded string method (Sloneker and Moldenhauer, 1977) was used to calculate percent soil cover. Both living and dead plant biomass provided soil coverage and protection prior to the cover crop termination in late May. The spring biomass was measured in the overwintering cover crop treatments by harvesting a 0.25 m^2 quadrat from each plot. Soils were analyzed for nitrate-N (NO_3) concentration every other week starting in late May when the cover crops were terminated until mid-July.

Table 2. Cover crop mixes grown in the cover crop planting date trial, Alburgh, VT, 2019.

Mix	Species	Variety	Overwinters?	Seeding rate lbs ac^{-1}
1	Annual ryegrass	Centurion	No	15
	Crimson clover	Dixie		8
	Radish	Eco-till		2
2	Oats	Shelby	No	70
	Crimson clover	Dixie		15
	Radish	Eco-till		3
3	Winter rye	VNS	Yes	50
	Red clover	Medium		12
	Radish	Eco-till		3
4	Winter rye	VNS	Yes	50
	Hairy vetch	VNS		20
5	Winter rye	VNS	Yes	75
6	Annual ryegrass	Centurion	No	25
7	Radish	Eco-till	No	6
8	Crimson clover	Dixie	No	15
9	Red clover	Medium	Yes	15
10	No cover crop		No	N/A

The data was analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and varieties were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered 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 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 (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown, except where analyzed by pairwise comparison (t-test). 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. Treatments that were not significantly lower in performance than the top-performing treatment in a particular column are indicated with an asterisk. In this 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. The asterisk indicates that treatment B was not significantly lower than the top yielding treatment C, indicated in bold.

Treatment	Yield
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

RESULTS

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 3). In August and September 2018, it was warmer and wetter than average. By October temperatures dropped below average and this trend continued all the way through May 2019. November and December 2018 experienced above average precipitation but by late winter precipitation was a little lower than the 30 year average. Overall there were a total of 1469 growing degree days (GDDs), which was 65 less than historical average.

Table 3. Seasonal weather data collected in Alburgh, VT, 2018-2019.

	2018					2019				
Alburgh, VT	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Average temperature (°F)	72.8	63.4	45.8	32.2	25.4	15.0	18.9	28.3	42.7	53.3
Departure from normal	3.96	2.76	-2.36	-5.99	-0.55	-3.77	-2.58	-2.79	-2.11	-3.11
Precipitation (inches)	2.96	3.48	3.53	4.50	2.96	1.53	1.70	1.36	3.65	4.90
Departure from normal	-0.95	-0.16	-0.07	1.38	0.59	-0.52	-0.06	-0.85	0.83	1.45
Growing Degree Days (50-86°F)	696	427	81	3	5	0	0	9	59	189
Departure from normal	114	67	-51	-31	1	-3	-2	-13	-52	-103

Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Results by planting date

Unsurprisingly, the 24-Aug planting date generated the most biomass in the fall, and was significantly higher than the other two planting dates (Table 4). The fall percent cover was highest in the 7-Sep planting date (79.2%), but was statistically similar to the 24-Aug planting date which had a fall cover of 70.0%. The 7-Sep planting date generated the most biomass in the spring (534 lbs ac^{-1}), but was statistically similar to the 24-Aug planting date (471 lbs ac^{-1}). The opposite was observed in spring ground cover. The 24-Aug planting date had the highest percent cover (53.9%), but was statistically similar to the 7-Sep planting date (50.9%). The latest planting date, 19-Sep, resulted in the lowest biomass and ground cover in both the spring and fall.

Table 4. Cover crop yield and soil cover for each planting date across all mixtures, Alburgh, VT, 2018-2019.

Planting date	Fall 2018		Spring 2019	
	Dry matter yield	**Soil cover**	**Dry matter yield**	**Soil cover**
	lbs ac^{-1}	**%**	**lbs ac^{-1}**	**%**
24-Aug	**1323 [a]**	79.0 [a]	471 [a]	**53.9 [a]**
7-Sep	926 [b]	**79.2 [a]**	**534 [a]**	50.9 [a]
19-Sep	130 [c]	16.7 [b]	238 [b]	22.3 [b]
LSD (0.10)	156	3.1	71	6.2
Trial mean	793	58.3	414	42.4

*Within a column, treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**
LSD-Lease significant difference.

The 19-Sep planting had lower soil nitrate-N concentrations compared to the first two plantings (Table 5). The 24-Aug and 7-Sep plantings were statistically higher than the third planting for all soil sampling times throughout the season. For the 24-Aug and 19-Sep plantings, soil nitrate levels peaked in mid-late June, although the release of nitrogen was gradual for all three plantings (Figure 1). The soil nitrate-N concentrations in the 7-Sep planting continued to increase and were highest in early-mid July. Soil sampling did not continue through the end of the summer, but it is expected that nitrate levels will begin to decrease later in the summer. Soil nitrate levels coincide with higher cover crop biomass yields and percent cover observed in 24-Aug and 7-Sep plantings in both the fall and the spring.

Table 5. Soil nitrate-N (NO_3) by cover crop planting date, Alburgh, VT, 2019.

Planting date	Soil nitrate-N (NO_3, ppm) 2019			
	Late May	Early June	Mid-Late June	Early-Mid July
24-Aug	**13.7 [a]**	**23.1 [a]**	**36.8 [a]**	36.2 [a]
7-Sep	12.8 [a]	21.3 [a]	32.4 [a]	**38.7 [a]**
19-Sep	9.07 [b]	14.9 [b]	23.4 [b]	22.7 [b]
LSD (0.10)	1.86	3.47	5.00	5.21
Trial mean	11.9	19.7	30.9	32.5

*Within a column, treatments marked with the same letter were statistically similar (p=0.10).
Top performers are in **bold.**
LSD-Lease significant difference.

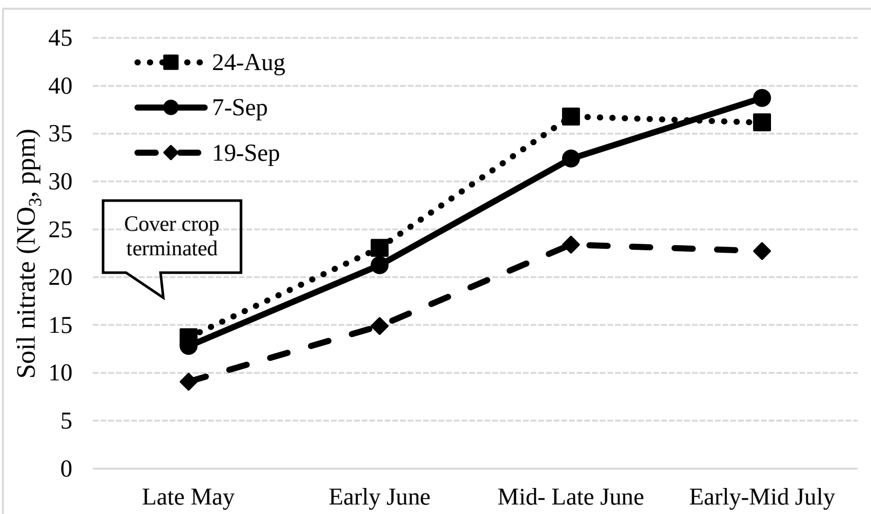

Figure 1. Soil nitrate-N (NO_3) by cover crop planting date, Alburgh, VT, 2019.

Results by cover crop treatment

Fall dry matter yield ranged from 300 to 1281 lbs ac^{-1} (Table 6). The top performer for fall yield was treatment 3 (winter rye, red clover, radish), while treatment 2 (oats, crimson clover, radish), 4 (winter rye, hairy vetch), and 7 (radish) performed comparably. Treatment 3 also had the highest soil cover in the fall (74.9%), with treatments 4, 5, and 7 being statistically similar. The highest fall cover was in cover crop treatments with winter rye. Spring biomass from winter terminated cover crops was not collected. Treatment 5 (winter rye) had the highest spring yield (1549 lbs ac^{-1}), but treatment 4 was significantly similar. Spring soil coverage ranged from 15.4% to 79.0% and it was treatment 5 that had the highest soil coverage, with treatment 4 being statistically similar. For the overwintered cover crops, treatment 2 had the highest spring soil coverage (42.9%). Other over-killed treatments that had higher soil coverage in the spring were treatments 1 (annual ryegrass, crimson clover, radish) and 6 (annual ryegrass) with 34.4% and 37.7% soil cover respectively.

Table 6. Cover crop yield and soil cover by each cover crop treatment, Alburgh, VT, 2018-2019.

Mix	Species	Overwinters?	Fall 2018		Spring 2019	
			Dry matter yield	Soil cover	Dry matter yield	Soil cover
			lbs ac^{-1}	%	lbs ac^{-1}	%
1	Annual ryegrass/crimson clover/radish	No	806	62.3	0	34.4
2	Oats/crimson clover/radish	No	1073*	68.5	0	42.9
3	Winter rye/red clover/radish	Yes	**1281**	**74.9**	1102	71.5
4	Winter rye/hairy vetch	Yes	1032*	70.5*	1492*	76.9*
5	Winter rye	Yes	962	73.5*	**1549**	**79.0**
6	Annual ryegrass	No	538	58.8	0	37.7
7	Radish	No	1136*	68.8*	0	23.3
8	Crimson clover	No	444	43.9	0	21.9
9	Red clover	Yes	300	33.4	0	20.6
Control	No cover crop	No	360	28.4	0	15.4
LSD (0.10)	N/A	N/A	294	6.3	130	6.42
Trial mean	N/A	N/A	793	58.3	414	42.4

*Treatments marked with an asterisk were statistically similar to the top performing treatment in **bold.**
LSD-Least significant difference.
N/A-Not applicable; statistical analysis not performed on the parameter.

Results from the planting date by variety interaction

The interaction of planting date and cover crop treatment was significant for fall yield ($p=0.0002$), fall soil coverage ($p<0.0001$), spring yield ($p<0.0001$), and spring soil coverage ($p=0.0009$), meaning that cover crop mixture performance differed by planting date. In general, the 19-Sep planting date resulted in the lowest yields and soil coverage in both the fall and the spring. The largest differences in fall yields between planting dates were seen in treatments 2 (oats, clover, radish), 3 (winter rye, clover, radish), and 7 (radish) (Figure 2). Oats, winter rye, and radish are all cover crops that can establish quickly and produce a lot of biomass. Treatment 6 (annual ryegrass) was the only cover crop to have a higher biomass in the 7-Sep planting than the 24-Aug planting. Annual ryegrass is not drought tolerant, and there was little precipitation around the 24-Aug planting, but by the 7-Sep planting, there was increased rainfall immediately before and after planting. All cover crop treatments had only slight differences in fall soil coverage between the 24-Aug and 7-Sep planting date, and consistently lower soil coverage in the 19-Sep planting date (Figure 3). Most fall-planted cover crops, with the exception of winter rye, need to be planted by early September in order to establish and provide ample ground cover. Spring biomass was only collected for the overwintering treatments (treatments 3, 4, & 5). Treatments 4 (winter rye, hairy vetch) and 5 (winter rye) had similar dry matter yields in the 24-Aug and the 7-Sep plantings and a much lower yield in the 19-Sep planting (Figure 4). Treatment 3 had a greater difference in spring yield between each planting date, with the highest yield being in the 7-Sep planting, followed by the 24-Aug and then the 19-Sep planting. Spring soil coverage was similar for all cover crop treatments between the 24-Aug and 7-Sep plantings, and much lower in the 19-Sep planting. The one exception was that treatment 3 had a similar spring coverage in all three planting dates (Figure 5). Due to these highly significant interaction, cover crops were analyzed for differences for each planting date.

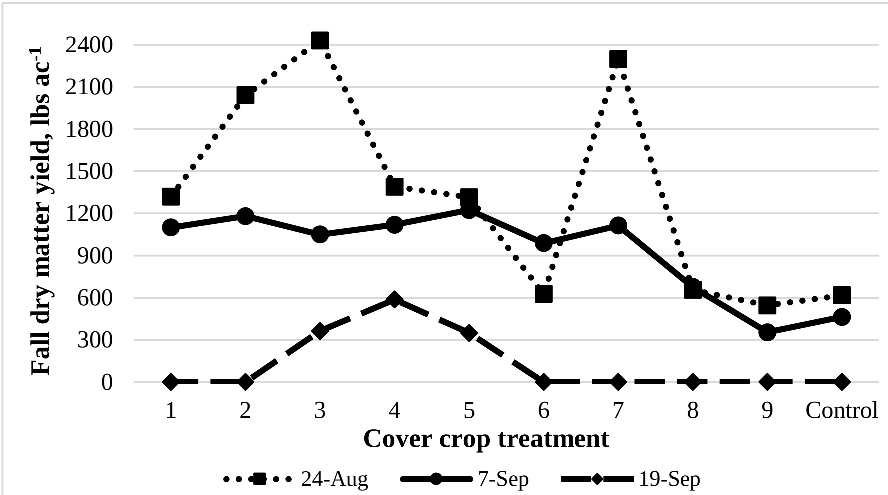

Figure 2. Fall dry matter yield by cover crop treatment for each planting date, Alburgh, VT, 2018.

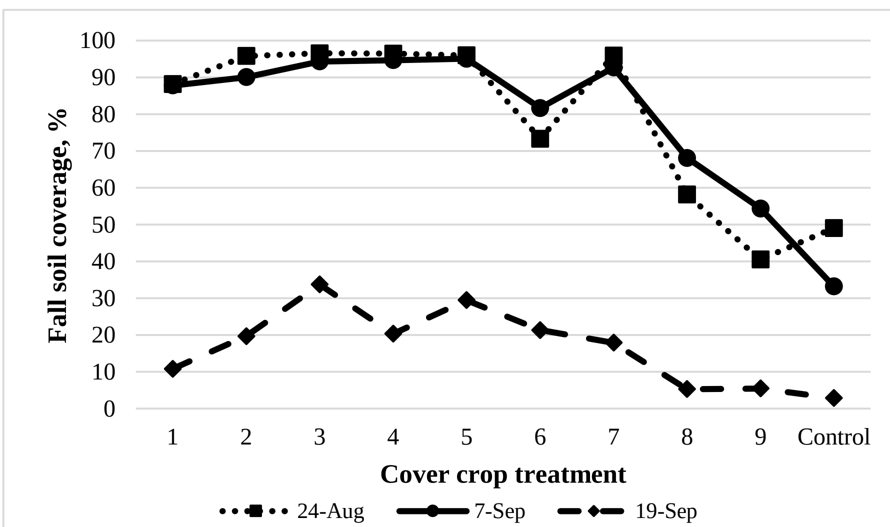

Figure 3. Fall soil coverage by cover crop treatment for each planting date, Alburgh, VT, 2018.

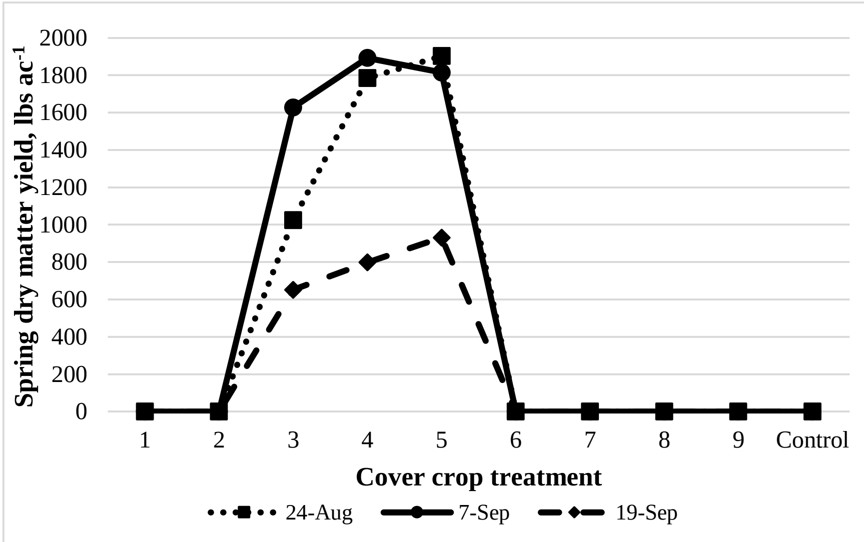

Figure 4. Spring dry matter yield by cover crop treatment for each planting date, Alburgh, VT, 2019.

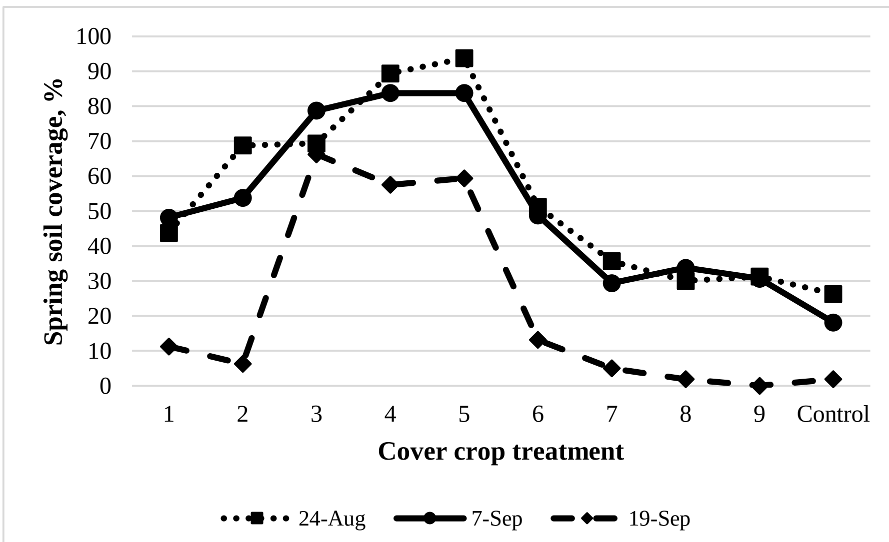

Figure 5. Spring soil coverage by cover crop treatment for each planting date, Alburgh, VT, 2019.

Results for each planting date

From the 24-Aug planting, treatment 3 (winter rye, clover, radish) had the highest dry matter yield (2430 lbs ac^{-1}) and soil cover (96.5%) in the fall (Table 7). Treatments 2 (oats, clover, radish) and 7 (radish) resulted in similarly high fall yields. Fall cover ranged from 40.5%-96.5%, and the top performer, treatment 3 (winter rye, red clover, radish) was statistically similar to five other treatments. Treatments 5 (winter rye) and 4 (winter rye, hairy vetch) were top performers with spring dry matter yields of 1903 lbs ac^{-1} and 1785 lbs ac^{-1} respectively. This makes sense considering that winter rye and vetch will over winter and continue to grow in the spring. The same trend was seen for spring cover, which ranged from 26.3% (control) to 93.8% (treatment 5); Treatment 4 was statistically similar to the top performer.

Table 7. Cover crop yield and coverage for the 24-Aug 2018 planting date, Alburgh, VT, 2018-2019.

Mix	Species	Fall 2018		Spring 2019	
		Dry matter yield	Soil cover	Dry matter yield	Soil cover
		lbs ac^{-1}	%	lbs ac^{-1}	%
1	Annual ryegrass/crimson clover/radish	1318	88.2*	0	43.8
2	Oats/crimson clover/radish	2039*	95.8*	0	68.8
3	Winter rye/red clover/ radish	**2430**	**96.5**	1025	69.4
4	Winter rye/hairy vetch	1390	96.4*	1785*	89.4*
5	Winter rye	1315	96.0*	**1903**	**93.8**
6	Annual ryegrass	626	73.3	0	51.3
7	Radish	2296*	95.9*	0	35.6
8	Crimson clover	655	58.2	0	30.0
9	Red clover	545	40.5	0	31.3
Control	No cover crop	617	49.1	0	26.3
LSD (0.10)	N/A	826	13.0	221	11.1
Trial mean	N/A	1323	79.0	471	53.9

*Treatments marked with an asterisk were not statistically different compared to the top performing treatment (p=0.10) in **bold.**
LSD-Least significant difference. N/A-Not applicable; statistical analysis not performed on the parameter.

From the 7-Sep planting, the top performer for fall yield was treatment 5 (winter rye) with a dry matter yield of 1223 lbs ac^{-1} (Table 8); six other treatments were statistically similar. The treatments generally performed well for soil cover in the fall, with percent cover ranging from 33.2% (control) to 95.0% (treatment 5). In the spring, treatment 4 (winter rye, hairy vetch) was the top performer with a yield of 1892 lbs ac^{-1}, but was statistically similar to the other two overwintering treatments. Spring cover ranged from 18.1% to 83.8%. The treatment with the highest spring cover was treatment 5, but this was statistically similar to treatments 3 and 4.

Table 8. Cover crop yield and coverage for the 7-Sep 2018 planting date, Alburgh, VT, 2018-2019.

Mix	Species	Fall 2018		Spring 2019	
		Dry matter yield	Soil cover	Dry matter yield	Soil cover
		lbs ac^{-1}	%	lbs ac^{-1}	%
1	Annual ryegrass/crimson clover/radish	1100*	87.8*	0	48.1
2	Oats/crimson clover/radish	1180*	90.0*	0	53.8
3	Winter rye/red clover/ radish	1050*	94.3*	1628*	78.8*
4	Winter rye/hairy vetch	1118*	94.6*	**1892**	83.8*
5	Winter rye	**1223**	**95.0**	1815*	**83.8**
6	Annual ryegrass	988*	81.7	0	48.8
7	Radish	1113*	92.6*	0	29.4
8	Crimson clover	676	68.1	0	33.8
9	Red clover	353	54.4	0	30.6
Control	No cover crop	463	33.2	0	18.1
LSD (0.10)	N/A	264	10.5	295	10.7
Trial mean	N/A	926	79.2	534	50.9

*Treatments marked with an asterisk were not statistically different compared to the top performing treatment (p=0.10) in **bold.**
LSD-Least significant difference. N/A-Not applicable; statistical analysis not performed on the parameter.

From the 19-Sep planting, in both the fall and the spring, only treatment 3 (winter rye, clover, radish), 4 (winter rye, hairy vetch), and 5 (winter rye) resulted in dry matter yields (Table 9). In the fall, treatment 4 had the highest yield of 587 lbs ac^{-1}, which was significantly higher than the other treatments. Fall soil cover ranged from 2.9% (control) to 33.7% (treatment 3). While treatment 3 had the highest fall cover, it was statistically similar to treatment 5. Overall, the fall coverage was low across all cover crop treatments. And in the spring, treatment 5 had the highest yield (931 lbs ac^{-1}), which was statistically similar to treatment 4. Spring soil cover ranged from 0% (treatment 9) to 59.4% (treatment 5), but there were no significant differences between treatments.

Table 9. Cover crop yield and coverage for the 19-Sep 2018 planting date, Alburgh, VT, 2018-2019.

Mix	Species	Fall 2018		Spring 2019	
		Dry matter yield	Soil cover	Dry matter yield	Soil cover
		lbs ac^{-1}	%	lbs ac^{-1}	%
1	Annual ryegrass/crimson clover/radish	0	10.8	0	11.3
2	Oats/crimson clover/radish	0	19.7	0	6.25
3	Winter rye/red clover/radish	362	**33.7**	652	66.3
4	Winter rye/hairy vetch	**587**	20.3	799*	57.5
5	Winter rye	349	29.5*	**931**	59.4
6	Annual ryegrass	0	21.3	0	13.1
7	Radish	0	17.9	0	5.00
8	Crimson clover	0	5.3	0	1.88
9	Red clover	0	5.5	0	0
Control	No cover crop	0	2.9	0	1.87
LSD (0.10)	N/A	175	8.9	161	NS
Trial mean	N/A	130	16.7	238	22.3

*Treatments marked with an asterisk were not statistically different compared to the top performing treatment (p=0.10) in **bold.**
LSD-Least significant difference. N/A-Not applicable; statistical analysis not performed on the parameter.

DISCUSSION

The first two planting dates (24-Aug and 7-Sep) had higher yields and soil cover in the fall and spring across all cover crop treatments. Similarly, the concentration of soil nitrate-N was higher in the first two planting dates compared to the last planting (19-Sep), but overall the release of nitrogen into the soil was gradual. Cover crops planted between the end of August and the beginning of September had more time to establish and produce substantial biomass before winter which likely resulted in higher yields and soil coverage the following spring. Cover crop treatment 3 (winter rye, red clover, radish) had the highest fall percent cover and dry matter yield across all planting dates. This is likely due to the ability of winter rye and radish to grow quickly in the fall, produce high yields, and provide substantial ground coverage. In the spring, the top performers were treatment 4 (winter rye, hairy vetch) and treatment 5 (winter rye). Winter rye and vetch are cover crops that will continue to grow in the spring and produce a lot of biomass compared to a variety like red clover, which overwinters but produces less biomass. Using a winterkilled cover crop variety may also provide the benefit of not having to manage terminating the crop in the spring, when timing of this may be difficult due to wet, spring conditions. Fall dry matter yield varied most between varieties in the first planting date (24-Aug). The top performers were cover crop mixtures that would not only grow quickly but provide good biomass and ground cover such as winter rye, radish, and oats. The lowest performers were single species cover crops such as annual ryegrass, crimson clover, and red clover. It is important that the results of this trial represent one year and one location. Cover cropping decisions will have to be made based off of the demands within each operation and field management considerations.

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ACKNOWLEDGEMENTS

The UVM Extension Northwest Crops and Soils Program would like thank the USDA (SARE) Sustainable Agriculture Research and Education Program for funding this research. Special thanks to Roger Rainville and the staff at Borderview Research Farm for their generous help with the trials. We would like to acknowledge John Bruce, Catherine Davidson, Hillary Emick, Amanda Gervais, Haley Jean, Shannon Meyler, and Lindsey Ruhl for their assistance with data collection, and data entry. This information is presented with the understanding that no product discrimination is intended and neither endorsement of any product mentioned, nor criticism of unnamed products, is implied.

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