2021 Soybean Cover Crop Termination Trial

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2021 SOYBEAN COVER CROP TERMINATION TRIAL

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In 2021, the University of Vermont Extension Northwest Crops and Soils Program investigated the impact of a winter rye cover crop on a subsequent soybean crop's yield and quality at Borderview Research Farm in Alburgh, VT. Soybeans are grown for human consumption, animal feed, and biodiesel, and can be a useful rotational crop in corn silage and grass production systems. Cereal or winter rye is commonly planted in this region as a cover crop. As cover cropping expands throughout Vermont, it is important to understand the potential benefits, consequences, and risks associated with growing cover crops in various cropping systems. In an effort to support the local soybean market and to gain a better understanding of cover cropping in soybean production systems, the University of Vermont Extension Northwest Crop and Soils (NWCS) Program, as part of a grant from the Eastern Soybean Board, conducted a trial in 2021 to investigate the impacts of winter rye biomass and spring termination methods on the yield and quality of the subsequent soybean crop.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm, Alburgh, VT in 2020-2021. The experimental design was a complete randomized block design with split plots and four replications (Table 1). The main plots were three spring cover crop termination methods. See Table 2 below for a description of termination treatments. Subplots were four winter rye seeding rates, which included a Control (0 lbs. ac^{-1}), 50, 100, and 150 lbs. ac^{-1} of Hazlet winter rye. The winter rye was planted on 6-Oct 2020. In the spring prior to cover crop termination, ground cover was measured in all three treatment blocks by processing photographs using the Canopeo© smartphone application on 12-May 2021. Cover crop biomass was measured just prior to termination on 12-May 2021 in the tillage and herbicide treatments and on 21-May 2021 in the plant green treatment. A 0.25m^2 area in each plot was harvested using hand clippers and a quadrat. Samples were weighed prior to and after drying to determine dry matter content and calculate yield. The dried samples were then ground to a 2mm particle size using a Wiley sample mill and sent to Dairy One Forage Laboratories (Ithaca, NY) to be analyzed for carbon and nitrogen content. On 21-May 2021, the soybeans were planted using a 4-row John Deere 1750 four-row planter fitted with bean cups at a rate of 200,000 seeds ac^{-1}. The variety SG 1077 (maturity group 1.0) soybean was obtained from Seedway, LLC (Hall, NY) for the trial.

Table 1. Trial management details, Alburgh, VT, 2020-2021.

Location	Borderview Research Farm-Alburgh, VT
Soil type	Covington silty clay loam, 0-3% slopes
Previous crop	Corn silage
Plot size (feet)	10 x 20
Row spacing (inches)	30
Replicates	4

Cover crop planting date	6-Oct 2020
Cover crop variety	Hazlet winter rye
Cover crop seeding rates (lbs. ac^{-1})	0, 50, 100, 150
Soybean variety	SG 1077 (maturity group 1.0, Roundup Ready®2Xtend)
Starter fertilizer	10-20-20 (250 lbs. ac^{-1})
Soybean planting date	21-May 2021
Soybean seeding rate (seeds ac^{-1})	200,000
Soybean harvest date	27-Oct 2021

Table 2. Cover crop termination treatments, Alburgh, VT, 2021.

Treatment	Cover crop termination details
Tillage	Tilled under with moldboard plow and disc harrow one week prior to soybean planting
Herbicide	Sprayed with Roundup PowerMAX® at 1qt ac^{-1} one week prior to soybean planting
Plant green	Soybeans were planted into living cover crop and sprayed with Roundup PowerMAX® at 1qt ac^{-1} at time of planting

To determine if the seeding rate of the fall planted cover crop had an impact on any soil properties, soil samples were collected on 12-May prior to cover crop termination and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis (Ithaca, NY). Soils were also analyzed for soil nitrate-N (NO3) content at the UVM Agricultural and Environmental Testing Laboratory in Burlington, VT. Approximately 10 soil cores at a 12" depth within each plot were taken using a soil probe, then immediately dried and transported to the lab for analysis. To understand the nutrient release rates of the winter rye and how this was impacted by termination method and seeding rate, soil samples were collected at four key times: one week prior to soybean planting, at soybean planting, two weeks after planting, and one month after planting. Soil moisture and temperature was measured approximately every other week from 12-May 2021 through 26-Aug 2021 using a soil moisture meter and a digital soil thermometer. Mid-season soybean establishment was measured on 9-Jul 2021 by counting the number of plants in three 1ft sections per plot and calculating the total plants ac^{-1}. On 27-Oct 2021, the soybeans were harvested using an Almaco SPC50 small plot combine. They were then weighed for plot yield and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture/test weight meter.

Data were analyzed using the mixed model procedure in SAS (SAS Institute, 1999) with the Tukey-Kramer adjustment, which means that each main effect was analyzed with a pairwise comparison (i.e. 'planting green' statistically outperformed 'tillage termination', 'herbicide termination' statistically outperformed 'tillage termination', etc.). Replications were treated as a random effect and cover crop seed rate, and termination treatments were treated as fixed. Sample date for temperature, moisture, and nitrate-N was treated as repeated samples. Treatments were considered different at the 0.10 level of significance. 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.

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). Precipitation was much lower this season than normal. From May-Oct, there was a total of 19.25 inches of rain, nearly 4 inches below the 30-year average for that same time frame. Precipitation did increase by the end of the season, but the increased rainfall in October posed a challenge to timely soybean harvest. Warm temperatures in June were followed by unseasonably cool temperatures in July. The warm temperature persisted through October, which was over 4 degrees warmer than normal. These temperatures contributed to a total of 2830 accumulated Growing Degree Days (GDDs), which is 143 above average the 30-year average.

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

Alburgh, VT	May	Jun	Jul	Aug	Sep	Oct
Average temperature (°F)	58.4	70.3	68.1	74.0	62.8	54.4
Departure from normal	-0.03	2.81	-4.31	3.25	0.14	4.07
Precipitation (inches)	0.66	3.06	2.92	2.29	4.09	6.23
Departure from normal	-3.10	-1.20	-1.14	-1.25	0.42	2.40
Growing Degree Days (base 50°F)	334	597	561	727	394	217
Departure from normal	33	73	-134	85	7	79

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. There was a cover crop termination method by sample date interaction for soil nitrate-N ($p<.0001$). Before the cover crop was terminated, the soil nitrate-N levels were similar in the three treatment blocks (Figure 1). Plots where the winter rye was tilled and incorporated had higher soil nitrate-N levels overall, likely because the rye decomposed quickly and released nitrogen back into the soil without getting tied up in the cover crop residue. The plant green plots were terminated a week after the tillage and herbicide treatments, and that resulted in a much slower release of nitrogen. However, by the end of June (roughly 1 month after soybean planting), the plant green block had higher levels of soil nitrate-N than the herbicide treatment. The earlier termination of the winter rye in the herbicide plots may have resulted in more available nitrogen initially, but the slow release of nitrogen from winter rye in the plant green treatment may provide additional nitrogen to the soybeans later in the season. Sampling did not continue into July so it is unknown if there would have been a similar drop in soil nitrate-N in the tillage or plant green blocks later in the season.

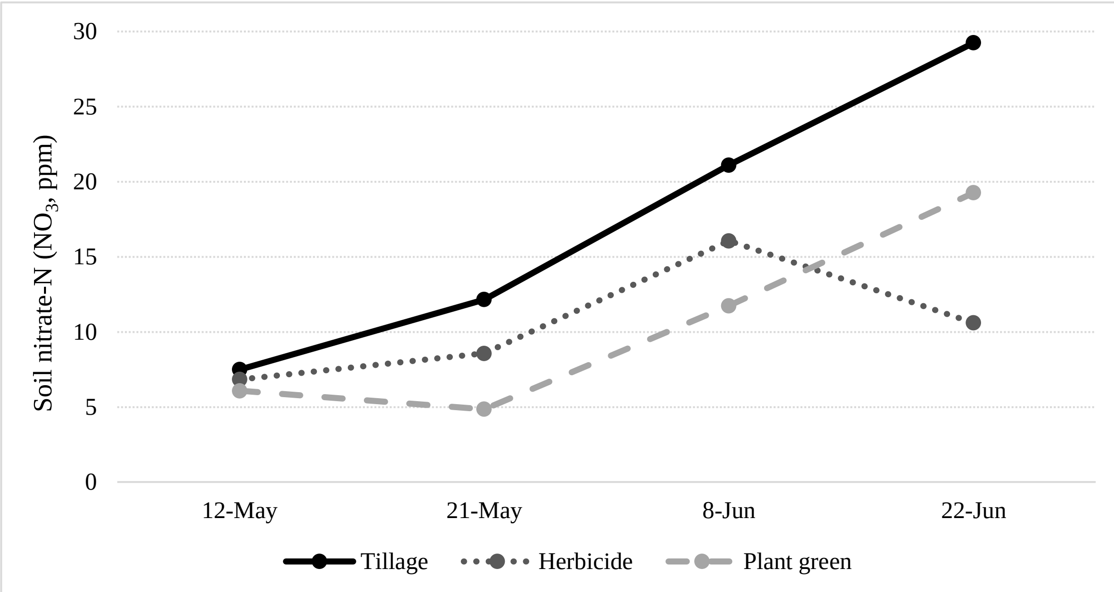

Figure 1. Cover crop termination x sample date interaction for soil nitrate-N.

Impact of Seeding Rate

To see if the winter rye seeding rate had an impact on the soil characteristics, soil health samples were taken before the cover crops were terminated. There were very few differences in soil characteristics between the seeding rates (Table 4). Soil respiration was the only metric in which there was a statistical difference between the control and one of the treatments (50 lbs. ac^{-1}); the 100 and 150 lbs. ac^{-1} treatments were not significantly different from the control. This difference may be the result of past management practices on the field.

Table 4. Spring soil health by winter rye seeding rate for Alburgh, VT, 2021.

Seeding rate (lbs. ac^{-1})	Organic matter %	Active carbon ppm	Total carbon %	Total nitrogen %	Aggregate stability %	Available water capacity g/g	Soil proteins N mg/soil g	Soil respiration CO2 mg/soil g	pH	Overall score
Control	6.20	940	3.94	0.343	34.3	0.253	12.3	0.835[b]†	7.17	83.0
50	6.00	937	3.94	0.338	41.2	0.257	12.6	**0.930[a]**	7.32	85.3
100	6.12	947	3.94	0.337	39.0	0.262	12.2	0.868[ab]	7.34	85.3
150	6.20	963	3.87	0.330	42.4	0.259	13.0	0.927[ab]	7.25	84.9
LSD (0.10)‡	NS§	NS	NS	NS	NS	NS	NS	0.0942	NS	NS
Trial Mean	6.13	947	3.92	0.337	39.2	0.258	12.5	0.890	7.27	84.6

†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.

Spring soil coverage differed by winter rye seeding rate (Table 5). The 50, 100, and 150 lbs. ac^{-1} treatments all had greater soil cover than the control. The 100 and 150 lbs. ac^{-1} treatments were not statistically different. Spring biomass was not measured in the control plots and there was no statistical difference in cover crop yield between the three seeding rates; the trial average was 1.88 tons ac^{-1}. Soybean population and harvest moisture were not different between treatments. The 50 lbs. ac^{-1} treatment resulted in statistically lower soybean yields (2493 lb. ac^{-1}; 41.6 bu. ac^{-1}) than the other seeding rates and the control. The control had the greatest soybean yield (2910 lb. ac^{-1}; 48.5 bu. ac^{-1}), but was not statistically different from the 100 and 150 lbs. ac^{-1} treatments. The 50 lbs. ac^{-1} treatment had the highest test weight, 53.0 lbs. bu^{-1}, but all samples were below the industry standard of 60 lbs. bu^{-1}.

Table 5. Cover crop and soybean harvest characteristics by seeding rate, Alburgh, VT, 2021.

Seeding rate	Prior to cover crop termination		Soybean harvest				
	Spring soil coverage	Cover crop DM yield	Soybean population	Harvest moisture	Yield at 13% moisture		Test weight
Lbs. ac^{-1}	%	tons ac^{-1}	plants ac^{-1}	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
Control	0.52^{c}†	--	166012	23.5	2910^{a}	48.5^{a}	52.6^{b}
50	67.8^{b}	1.79	135036	23.4	2493^{b}	41.6^{b}	53.0^{a}
100	86.3^{a}	1.86	146168	23.4	2895^{a}	48.2^{a}	52.9^{ab}
150	88.8^{a}	1.99	158268	23.2	2882^{a}	48.0^{a}	52.9^{ab}
LSD (p = 0.10)‡	13.1	NS§	NS	NS	385	64.2	0.342
Trial mean	60.9	1.88	151371	23.4	2795	46.6	52.9

†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.

Soil nitrate-N (NO_3) was significantly impacted by the interseeded winter rye (Table 6). The average level of soil nitrate-N in the control plots (16.9 ppm) was statistically greater than the other seeding rates, which were not statistically different from one another. This indicates that the winter rye scavenged nitrogen in the soil, making it less available to the subsequent soybean crop. However, soybean yield loss was only observed in one of the treatments (50 lbs. ac^{-1}), even with less available nitrogen. Soil temperature was impacted by seeding rate. The control had statistically warmer soil temperatures on average (66.9° F) than the 100 and 150 lbs. ac^{-1} treatments, but not the 50 lbs. ac^{-1} treatment. The 150 lbs. ac^{-1} seeding rate had the lowest average soil temperature (66.4° F). The higher seeding rate produced ground coverage which resulted in cooler soil temperatures compared to a control with bare soil. However, there was no significant impact on soil moisture, and the trial average was 15.5%.

Table 6. Soil nitrate-N (NO_3), temperature and moisture by seeding rate, Alburgh, VT, 2021.

Seeding rate	Soil nitrate-N (NO_3)	Soil temperature	Soil moisture
lbs. ac^{-1}	ppm	°F	%
Control	16.9[a]†	66.9[a]	16.0
50	11.2[b]	66.8[ab]	15.7
100	11.6[b]	66.5[bc]	15.3
150	11.7[b]	66.4[c]	15.1
Level of significance	***¥	**	NS§
Trial mean	12.8	66.6	15.5

†Within a column, treatments marked with the same letter performed statistically similar.
¥Treatments were significantly different at the following p values *0.1< p >0.05; ** 0.05 < p > 0.01; ***p < 0.01.
§NS; No significant difference between treatments.

Impact of Termination Method

There was a statistical difference in spring soil coverage between the termination treatments prior to treatment implementation (Table 7). The ground cover was significantly lower in the tillage block (50.6%) and there was no statistical difference between the herbicide (65.2%) and the plant green (66.7%) blocks. There was poor fall emergence of the winter rye in some of the plots of the tillage block that likely resulted in less spring soil coverage. There was a significant impact of termination method on the spring cover crop biomass. The plant green block was terminated a week later and produced statistically more biomass (2.82 tons ac^{-1}) than the other two treatments. There was no statistical difference in cover crop yield between the tillage (1.46 tons ac^{-1}) and herbicide (1.36 tons ac^{-1}), which were terminated on the same date. The tillage block had less spring ground cover, but that did not lower biomass production compared to the herbicide treatment. Adequate soybean populations were achieved in all treatment blocks and there was no statistical difference in the total plants ac^{-1} at harvest. Soybean harvest moisture did not differ between treatments. The trial average was 23.4% and therefore, all samples required additional drying for safe storage. The herbicide treatment had statistically lower test weight than the other two treatments, but all were below the industry standard of 60 lbs. bu^{-1}. Soybean yields were highest in the tillage (3060 lbs. ac^{-1}; 51.0 bu. ac^{-1}) and herbicide (3030 lbs. ac^{-1}; 50.5 bu. ac^{-1}) treatments. The plant green treatment (2296 lbs. ac^{-1}; 38.3 bu. ac^{-1}) had a statistically lower yield, about 1.3 times less than the other termination treatments. These results suggest that the plant green treatment had greater biomass because the cover crop was terminated about a week later, and that extra biomass may have resulted in soybean yield loss (Figure 2). This indicates that the timing of cover crop termination in the spring can impact soybean yields due to an increase in cover crop biomass production.

Table 7. Cover crop and soybean harvest characteristics by termination method, Alburgh, VT, 2021.

Termination method	Prior to cover crop termination		Soybean harvest				
	Spring soil coverage	Cover crop DM yield	Population	Harvest moisture	Yield at 13% moisture		Test weight
	%	tons ac^{-1}	plants ac^{-1}	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
Tillage	50.6^{b}†	1.46^{b}	142296	23.5	3060^{a}	51.0^{a}	53.0^{a}
Herbicide	65.2^{a}	1.36^{b}	154638	23.1	3030^{a}	50.5^{a}	52.6^{b}
Plant green	66.7^{a}	2.82^{a}	157179	23.5	2296^{b}	38.3^{b}	52.9^{a}
LSD (p = 0.10)‡	11.3	0.399	NS§	NS	334	5.56	0.296
Trial mean	60.9	1.88	151371	23.4	2795	46.6	52.9

†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.

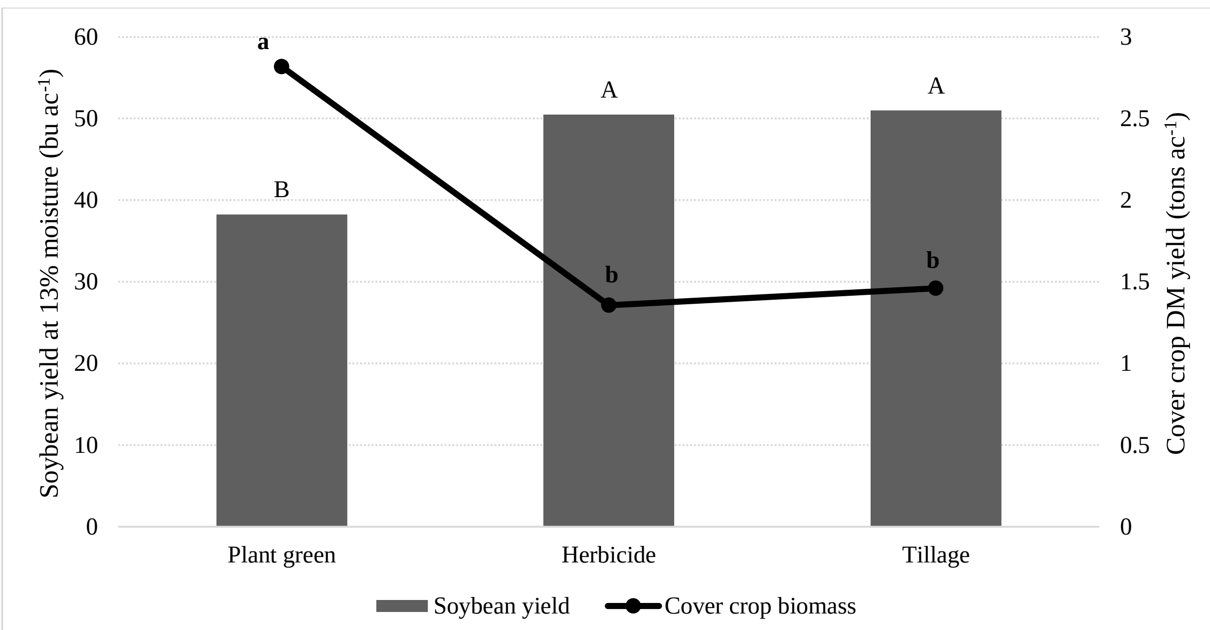

Figure 2. Soybean yield and spring cover crop biomass by cover crop termination method, Alburgh, VT, 2021. Different letters indicate a statistically significant difference between treatments (p=0.10).

The termination method had a significant impact on the carbon (C) and nitrogen (N) content of the winter rye cover crop in the spring (Table 8). The plant green treatment had statistically greater total C content than the other two treatments. The herbicide treatment had the greatest total N content, 0.46%, but was not statistically different from the tillage treatment, 0.42%. All three termination methods had high C:N ratios, which is characteristic of winter rye, especially if allowed to grow to maturity. The C:N ratios for the herbicide, tillage, and plant green treatments were 102, 116, and 125 respectively. This makes sense because the winter rye in the plant green treatment had an additional week to mature and produce more biomass before it was terminated. The high C:N ratio results in slow decomposition of the winter rye which ties up nitrogen, making it unavailable in the soil for the subsequent crop. This may have contributed to lower soybean yields in the plant green treatment compared to the other two treatments.

Table 8. Cover crop carbon and nitrogen content by termination method, Alburgh, VT, 2021.

Termination method	Total nitrogen	Total carbon	C:N ratio
		%	
Tillage	0.42[ab]†	47.0[b]	116[ab]
Herbicide	0.46[a]	47.0[b]	102[b]
Plant green	0.38[b]	47.7[a]	125[a]
Level of significance	*¥	*	*
Trial mean	0.42	47.2	114

†Within a column, treatments marked with the same letter performed statistically similar.
¥Treatments were significantly different at the following p values *0.1< p >0.05; ** 0.05 < p > 0.01; ***p < 0.01.

Soil nitrate-N was significantly higher in the tillage treatment than in the herbicide or plant green treatments, with soil nitrate-N values of 17.5, 10.5, and 10.5 ppm respectively (Table 9). This makes sense because the winter rye in the tillage treatment was plowed down and incorporated, which released more nitrogen into the soil than winter rye that had been sprayed. Soil temperature was statistically higher in the herbicide treatment (67.0° F) than the other two treatments. Soil moisture was greatest in the tillage treatment (16.5%) but was statistically similar to the herbicide treatment (16.4%). Soil moisture was the lowest in the planting green treatment indicating that allowing the winter rye to grow longer in the spring may have depleted soil moisture and caused season long stress on the soybean crop.

Table 9. Soil nitrate-N (NO_3), temperature, and moisture by termination method, Alburgh, VT, 2021.

Termination method	Soil nitrate-N (NO_3)	Soil temperature	Soil moisture
	ppm	°F	%
Tillage	17.5[a]†	66.5[b]	16.5[a]
Herbicide	10.5[b]	67.0[a]	16.4[a]
Plant green	10.5[b]	66.4[b]	13.7[b]
Level of significance	***¥	**	***
Trial mean	12.8	66.6	15.5

†Within a column, treatments marked with the same letter performed statistically similar.
¥Treatments were significantly different at the following p values *0.1< p >0.05; ** 0.05 < p > 0.01; ***p < 0.01.

DISCUSSION

In 2021, the lack of precipitation through most of the growing season was a challenge for the region. Total accumulated precipitation from May to September was 6.27 inches less than normal. But in October, around time of soybean harvest, there was unusually high precipitation, 2.4 inches above the 30-yr average for that month. The seeding rate of the winter rye had minimal impact on soil health in the spring. This is not surprising because changes in soil health may take longer than one cover crop cycle. This is important because differences in other metrics, such as cover crop biomass or soybean yields is likely due to those variables rather than differences in soil health.

Spring soil coverage was positively correlated with seeding rate. Interestingly, there was no impact of seeding rate on cover crop dry mater yield. The cover crop termination method had a greater impact on cover crop biomass production and subsequent soybean harvest. Prior to treatment implementation, spring soil cover was comparable in the herbicide and plant green blocks, but was significantly lower in the tillage block. This is likely due to germination issues in the tillage block in the fall. Regardless of the differences in spring ground cover, the tillage and herbicide treatments produced statistically similar cover crop biomass. The plant green treatment produced twice as much dry matter as the other two treatments as to be expected due to the later termination date. Soybean yield was negatively correlated with cover crop biomass. The plant green treatment had soybean yields that were 1.3X less than the tillage and herbicide treatments. The winter rye in the tillage and herbicide treatments was terminated about a week earlier than in the plant green treatment. This allowed the winter rye to continue to mature and produce more biomass, which resulted in a much higher C:N ratio. The winter rye in the plant green treatment tied up much of the soil nitrogen, making it unavailable to the soybeans. This may have contributed to lower yields in the planting green treatment. In addition, the planting green treatment had a significant impact on soil moisture. As noted, 2021 was an exceptionally dry growing season until harvest. The winter rye cover crop, like other crops, needs moisture to grow. Allowing the cover crop to grow longer means the need for more moisture. Unfortunately, the depleted soil moisture in this treatment was constant across the season because of below average precipitation. This likely had a significant impact on the soybean yields.

Overall, soybean yields in this year’s trial (2795 lbs. ac^{-1}) were lower than in previous years. The trial average in 2020 was 3597 lbs. ac^{-1} and 4575 lbs. ac^{-1} in 2019. It is important to note that in past years of this trial, a mix of over-wintering and winter-killed cover crop species were used. Other conventional soybean trials in 2021 had an average yield of 3357 lbs. ac^{-1}, which is much higher than the average for this trial. The time of cover crop termination in the spring has a strong impact on both cover crop biomass production and soybean yields, so we will continue to investigate cover cropping practices in soybeans in this region to gain a better understanding of successful cover cropping practices and their impacts on soybean performances. UVM Extension Northwest Crops and Soils Program plans to repeat this trial in 2022.

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