NORTHWEST CROPS & SOILS PROGRAM

2023 Soybean Cover Crop Termination X Nitrogen Fertility Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2023 SOYBEAN COVER CROP TERMINATION X NITROGEN FERTILITY TRIAL

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In 2023, the University of Vermont Extension Northwest Crops and Soils Program investigated the impact of 1) a winter rye cover crop and 2) low rates of starter nitrogen fertilizer at Borderview Research Farm on soybean crop yield and quality 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 soybean production expands throughout Vermont, it is important to understand the potential benefits, consequences, and risks associated with growing cover crops in these systems. Low rates of nitrogen applied as starter fertilizer may provide additional nitrogen to meet the needs of the crop and make up for what was tied up by the winter rye cover crop. 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 2022-2023 to investigate the impacts of winter rye termination methods and starter nitrogen fertilizer rates on the yield and quality of the subsequent soybean crop.

MATERIALS AND METHODS

The trial was conducted at Borderview Research Farm in Alburgh, VT in 2022-2023. The experimental design was a complete randomized block design with split plots and four replications (Table 1). The main plots were five spring cover crop termination methods (Table 2) and subplots were four starter nitrogen fertilizer application rates (0, 10, 20, and 30 lbs ac^{-1}). The winter rye was planted on 24-Sep 2022. In the spring prior to cover crop termination, cover crop biomass was measured on 9-May 2023 in the Plow and Spray Early treatments and on 23-May 2023 in the Spray Late, Roll & Plant, and Plant & Roll treatments. A $0.25m^2$ area was harvested using hand clippers and a quadrat from the four replicates of each termination method. Samples were weighed prior to and after drying to determine dry matter content and calculate rye biomass. On 1-Jun 2023, the soybeans were planted using a John Deere no-till planter at a rate of 180,000 seeds ac^{-1} with 30” row spacing and 4 rows per plot. The variety SG 0720XT (maturity group 0.7) soybean was obtained from Seedway, LLC (Hall, NY) for the trial. The starter was applied as liquid nitrogen (UAN; 32-0-0) over the row at planting.

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 to 15% slopes
Previous crop	Dry beans
Plot size (feet)	10 x 20
Row spacing (inches)	30
Replicates	4
Cover crop planting date	24-Sep 2022
Cover crop variety	ND Gardner

Cover crop seeding rate	75 lbs ac^{-1}
Soybean variety	SG 0720XT (maturity group 0.7, Roundup Ready®2Xtend)
Fertilizer	UAN at planting 0, 10, 20, 30 lbs ac^{-1}
Soybean planting date	1-Jun 2023
Soybean seeding rate (seeds ac^{-1})	180,000
Soybean harvest date	4-Oct 2023

Table 2. Cover crop termination treatments, Alburgh, VT, 2023

Treatment	Cover crop termination details
Plow	Rye plowed under 3 weeks before planting soybeans
Spray early	Rye sprayed with herbicide 3 weeks before planting soybeans
Spray Late	Rye sprayed with herbicide 1 week before planting soybeans
Roll & plant	Rye roller crimped just before planting soybeans
Plant then Roll	Soybeans planted and then rye roller crimped after soybean emergence

To determine if there were any differences in soil properties prior to cover crop termination, soil samples were collected from the early termination treatments (Plow and Spray Early) on 9-May and from the late termination treatments (Spray Late, Roll & Plant, and Plant then Roll) on 23-May and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis (Ithaca, NY).

Soils were 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 nitrogen application rate and termination method, soil samples were collected every two weeks beginning on 8-Jun and ending on 2-Aug. Soil temperature was monitored throughout the season using Maxim iButton temperature sensors and data logger from Embedded Data Systems, LLC (Lawrenceburg, KY). The temperature sensors and data loggers provide temperature readings every four hours. Soil moisture was measured using a soil moisture meter at the same time that soil nitrate samples were collected. Soil nitrate-N, temperature, and moisture were measured in select plots only: the control and high N application rates for the Plow, Spray Early, and Plant then Roll treatments.

Plots were monitored for disease pressure throughout the season, and on 17-Aug, plots were assessed for severity of infection with downy mildew (*Peronospora manshurica),* bacterial blight (*Pseudomonas syringae pv. glycinea*), Septoria brown spot (*Septoria glycines*), frogeye leaf spot (*Cercospora sojina*), and anthracnose (*Colletotrichum truncatum*). Assessments were made by inspecting each plot and assigning a rating (0-10), where 0 equated to damage/infection not present and 10 equated to infection or damage present on 100% of leaf area.

On 4-Oct, the soybeans were harvested using an Almaco SPC50 small plot combine and seed was cleaned with a small Clipper M2B cleaner (A.T. Ferrell, Bluffton, IN). Seed was weighed for plot yield and tested for harvest moisture and test weight using a DICKEY-John Mini-GAC Plus moisture and 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 nitrogen application rate and termination treatments were treated as fixed. Sample date for moisture, temperature, 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). Temperatures were cooler than average from June to August. The monthly average temperature in August was only 67°F, 3.73 degrees colder than average. Excessive rainfall occurred throughout most of the season, except for September. From June to October, Alburgh, VT received 31.18 inches of rain, 8.06 inches above the 30-year normal. There was a total of 2409 accumulated Growing Degree Days (GDDs), which is typical for this location.

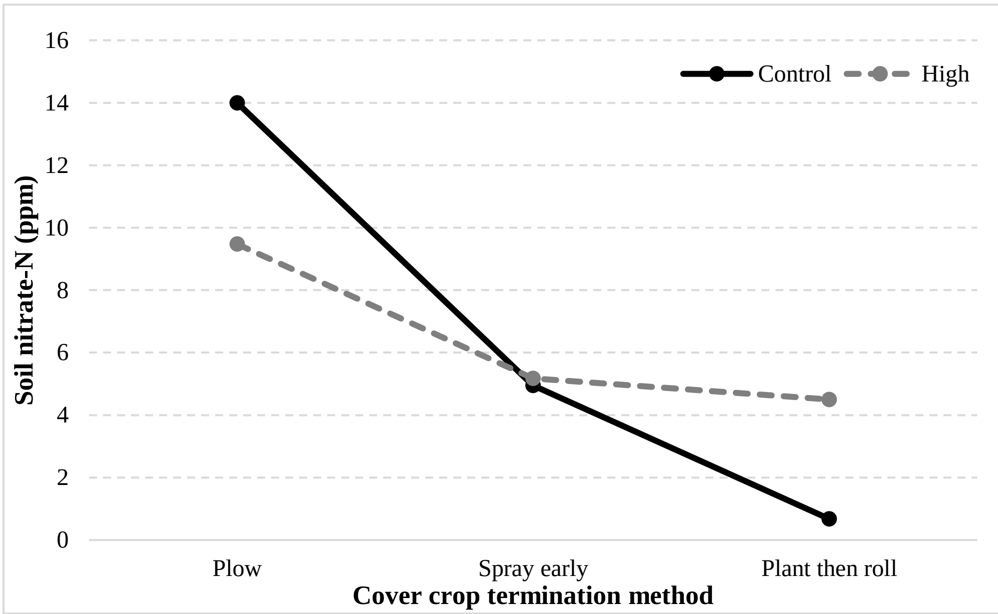
Table 3. Weather data for Alburgh, VT, 2023.

Alburgh, VT	Jun	Jul	Aug	Sep	Oct
Average temperature (°F)	65.7	72.2	67.0	63.7	54.4
Departure from normal	-1.76	-0.24	-3.73	1.03	4.11
Precipitation (inches)	4.40	10.8	6.27	2.40	5.38
Departure from normal	0.14	6.69	2.73	-1.27	1.55
Growing Degree Days (50-86°F)	483	712	540	449	225
Departure from normal	-41.0	17.0	-101	62.0	87.0

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 (winter rye termination method and nitrogen application rate) for soil nitrate-N (NO_3) on 8-Jun (p=0.04) and 21-Jun (p=0.05). On 8-Jun, soil nitrate-N was highest overall in the Plow treatment compared to the Spray Early and Plant then Roll treatments (Figure 1). Within the Plow treatment, soil nitrate-N was greater in the control plots than in the high N application rate. But this was not observed in the Spray Early treatment, where there was almost no difference in the amount of soil nitrate-N. And in the Plant then Roll treatment, soil nitrate-N was higher in the high N application rate than in the control. On 21-Jun, soil nitrate-N levels were greater in the high N application rates than the control for the Spay Early and Plant then Roll treatments, not in the Plow treatment (Figure 2). Within the control plots, the Plow treatment had much higher levels of soil nitrate-N, about 14 ppm more than the Spray Early or Plant then Roll treatments. In the Plant then Roll treatment, soil nitrate-N levels were low in both the control and high N application rate compared to the other termination methods.



(Above) Figure 1. Cover crop termination x nitrogen application rate interaction for soil nitrate-N (NO_3-N) on 8-Jun, Alburgh, VT, 2023.

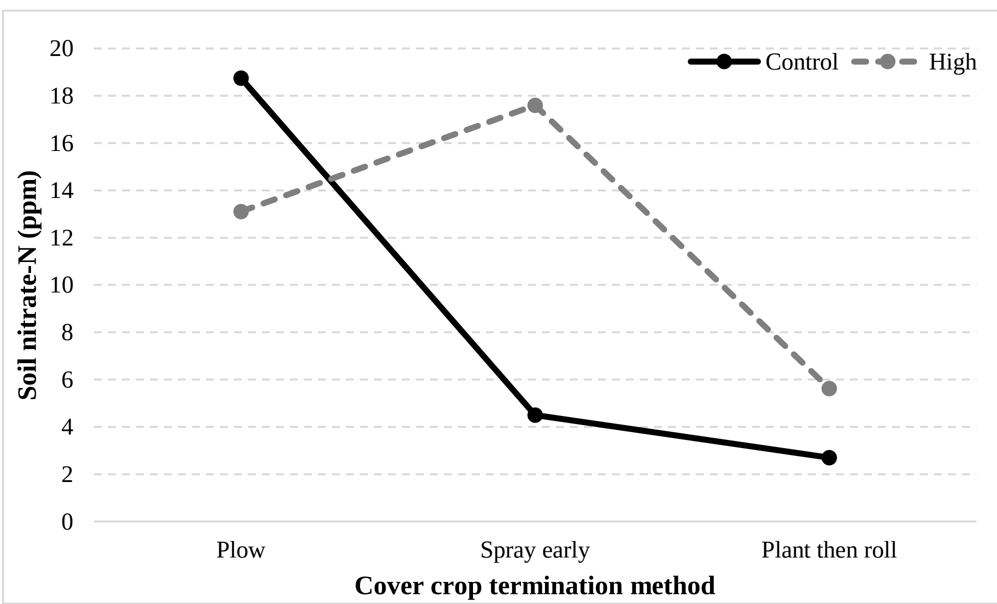


Figure 2. Cover crop termination x nitrogen application rate interaction for soil nitrate-N (NO_3-N) on 21-Jun, Alburgh, VT, 2023.

Impact of Cover Crop Termination Method

To determine if delaying winter rye termination had any impacts on soil health indicators, soil samples were taken just before termination on 9-May in the Plow and Spray Early treatments and on 23-May in the Spray Late, Roll & Plant, and Plant then Roll treatments. Soil health indicators are compared between early and late termination timings in Tables 4 and 5 below since there were no nitrogen application treatments at the time of sampling between early termination methods (Plow and Spray Early) or between late termination methods (Spray Late, Roll & plant, and Roll then plant). Overall, there were few differences in soil health between early and late termination methods. The amount of potassium in the soil was significantly higher in the late termination methods than the early termination methods. This was the only statistical difference between the termination methods. Overall, soil health scores were high for both termination timings indicating high functioning soils for this trial.

Table 4. Organic matter, active carbon, total C, total N, soil organic carbon, and aggregate stability by cover crop termination timing, Alburgh, VT, 2023.

Termination timing	Organic matter	Active carbon	Total carbon	Total nitrogen	Soil organic carbon	Aggregate stability
	%	ppm	%	%	%	%
Early	3.89	653	2.46	0.250	2.43	30.0
Late	3.76	669	2.62	0.299	2.59	32.0
LSD (p=0.10)‡	NS§	NS	NS	NS	NS	NS
Trial mean	3.82	661	2.54	0.275	2.51	31.0

‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Table 5. Predicted water capacity, soil protein, soil respiration, pH, phosphorus, potassium, and overall score by cover crop termination timing, Alburgh, VT, 2023.

Termination timing	Predicted water capacity	Soil proteins	Soil respiration	pH	Phosphorus	Potassium	Overall score
	g H_2O g soil^{-1}	mg protein g soil^{-1}	mg CO_2 g soil^{-1}		ppm	ppm	
Early	0.223	5.93	0.654	6.92	8.08	83.6[b]	77.1
Late	0.223	6.41	0.704	6.87	19.0	**140**[a]†	79.3
LSD (p=0.10)‡	NS	NS	NS	NS	NS	38.4	NS
Trial Mean	0.223	6.17	0.679	6.89	13.5	112	78.2

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

Prior to termination, winter rye biomass was measured to understand the impact of delayed termination on spring biomass production. Winter rye was not sampled in the Plow treatment. Winter rye biomass production was statistically lower in the Spray Early treatment compared to the three late termination methods (Table 6). The rye in the Spray Early treatment was terminated two weeks earlier than the other termination methods and rye biomass more than doubled in those two weeks.

Table 6. Winter rye spring biomass by termination method, Alburgh, VT, 2023.

Termination method	Winter rye DM yield	
	lbs. ac^{-1}	tons ac^{-1}
Spray Early	3315[b]	1.66[b]
Spray Late	**7922[a]**†	**3.96[a]**
Roll & Plant	7625[a]	3.81[a]
Plant then Roll	7383[a]	3.69[a]
LSD (p = 0.10)‡	1431	0.72
Trial mean	6561	3.28

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

Soil moisture, temperature, and nitrate-N were measured starting one week after planting and continuing every other week for a total of five sample dates. Three termination methods were selected to represent no cover crop residue (Plow), low cover crop residue (Spray Early) and high cover crop residue (Plant then Roll). There were no significant differences in soil moisture between termination methods across all sample dates (Table 7). Soil temperature was impacted by termination method (Table 8). On 8-Jun, soil temperature was significantly higher in the Plow and Spray Early treatments than in the Plant then Roll treatment. On 21-Jun, 6-Jul, and 19-Jul soil temperatures were significantly higher in the Plow treatment than the other two treatments and were significantly lower in the Plant then Roll treatment than all other treatments. On 2-Aug there were no statistically significant differences between the termination methods. The Plow treatment had the highest soil nitrate-N on 8-Jun, 21-Jun, 6-Jul, and 19-Jul (Table 9). On 21-Jun there was no statistical difference in soil nitrate-N between the Plow and Spray Early treatments. There were no statistical differences in soil nitrate-N on 2-Aug between the three termination methods. Overall, levels of soil nitrate-N peaked 3 weeks after planting (21-Jun) and decreased through 2-Aug.

Table 7. Soil moisture by cover crop termination method, Alburgh, VT, 2023.

Termination method	Soil moisture				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
			%		
Plow	13.3	15.0	17.8	17.0	14.5
Spray Early	13.7	16.8	20.1	17.3	14.5
Plant then Roll	12.7	15.4	19.2	17.7	14.2
LSD (p = 0.10)‡	NS§	NS	NS	NS	NS
Trial mean	13.2	15.7	19.0	17.3	14.4

‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Table 8. Soil temperature by cover crop termination method, Alburgh, VT, 2023.

Termination method	Soil temperature				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
	°F				
Plow	**63.1**[a]†	**72.0**[a]	**79.7**[a]	**74.5**[a]	65.5
Spray Early	62.6[a]	69.2[b]	77.6[b]	73.7[b]	65.3
Plant then Roll	61.2[b]	65.4[c]	75.0[c]	72.5[c]	65.4
LSD (p = 0.10)‡	0.69	1.24	0.94	0.54	NS§
Trial mean	62.3	68.8	77.4	73.6	65.4

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

Table 9. Soil nitrate-N (NO_3) by cover crop termination method, Alburgh, VT, 2023.

Termination method	Soil nitrate-N (NO_3)				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
	ppm				
Plow	**11.7**[a]†	**15.9**[a]	**14.5**[a]	**6.86**[a]	2.70
Spray Early	5.06[b]	11.1[a]	7.55[b]	4.61[b]	2.70
Plant then Roll	2.59[b]	4.16[b]	5.85[b]	4.39[b]	2.81
LSD (p = 0.10)‡	2.56	5.97	2.81	1.33	NS§
Trial mean	6.46	10.4	9.28	5.29	2.74

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

The cover crop termination method had a statistically significant impact on soybean yield and harvest moisture (Table 10). Soybeans in the Plant then Roll treatment had statistically higher harvest moisture and lower yields than all other treatments. Soybean yields were reduced by about 500 to 600 lbs or 8 to 10 bu ac^{-1} when soybeans were planted into living rye cover crop that was roller crimped after soybeans had emerged. The cover crop termination method did not have a significant impact on test weight.

Table 10. Soybean harvest characteristics by cover crop termination method, Alburgh, VT, 2023.

Termination method	Harvest moisture	Yield at 13% moisture		Test weight
	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
Plow	12.8[a]	2602[a]	43.4[a]	56.0
Spray Early	**12.5[a]**†	**2666[a]**	**44.4[a]**	56.7
Spray Late	12.6[a]	2511[a]	41.8[a]	56.0
Roll & plant	12.9[a]	2533[a]	42.2[a]	56.1
Plant then Roll	13.4[b]	2014[b]	33.6[b]	56.5
LSD (p = 0.10)‡	0.42	249	41.5	NS§
Trial mean	12.8	2465	41.1	56.3

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

Overall, disease ratings were low but there were significant differences in disease ratings between termination treatments (Table 11). Downy mildew and frogeye leaf spot were the most prevalent and had the highest average disease ratings: 1.96 and 1.49 respectively. The Spray Late treatment had the highest disease rating of downy mildew but was not statistically different from the Spray Early treatment. The Plow and Plant then Roll treatments had significantly lower downy mildew damage than the other treatments. Frogeye leaf spot damage was significantly greater in the Spray Early treatment than all other termination methods. The Spray Early treatment also had statistically greater Septoria brown spot damage than all termination methods except the Plant then Roll treatment. There was no significant difference in bacterial blight or anthracnose disease ratings between termination methods.

Table 11. Disease rating by cover crop termination method, Alburgh, VT, 2023.

Termination method	Bacterial blight	Downy mildew	Frogeye leaf spot	Anthracnose	Septoria brown spot
	0-10 scale¥				
Plow	0.19	1.44[c]	1.5[bc]	0.25	0.00[b]
Spray Early	0.06	2.31[ab]	**2.00[a]**	0.38	**0.19[a]**
Spray Late	0.25	**2.75[a]**†	1.63[b]	0.50	0.00[b]
Roll & plant	0.00	2.19[b]	1.25[cd]	0.38	0.00[b]
Plant then Roll	0.06	1.13[c]	1.06[d]	0.25	0.06[ab]
LSD (p = 0.10) ‡	NS§	0.53	0.31	NS	0.13
Trial Mean	0.11	1.96	1.49	0.35	0.05

¥ 0 to 10 scale; rating of 0 = no infection or damage and rating of 10 = 100% infection or damage.
†Within a column, treatments marked with the same letter were statistically similar (p=0.10). The top performer is in **bold**.
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Impact of Nitrogen Application Rate

The high nitrogen application rate was compared to the control to see if a higher nitrogen application rate at planting resulted in difference in soil moisture, temperature, or nitrate-N over the season. There was no significant difference in soil moisture between nitrogen application rates (Table 12). Soil temperature was statistically higher in the high N application rate compared to the control only on 2-Aug (Table 13). Soil nitrate-N was not statistically different between the high application rate and the control on 8-Jun, 21-Jun, 19-Jul, or 2-Aug (Table 14). Only on 6-Jul was soil nitrate-N significantly greater in the high application treatment compared to the control.

Table 12. Soil moisture by nitrogen application rate, Alburgh, VT, 2023.

Nitrogen application rate	Soil moisture				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
	%				
Control	12.9	16.0	19.4	17.1	13.9
High	13.5	15.5	18.6	17.5	14.9
LSD (p = 0.10)‡	NS§	NS	NS	NS	NS
Trial mean	13.2	15.7	19	17.3	14.4

‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Table 13. Soil temperature by nitrogen application rate, Alburgh, VT, 2023.

Nitrogen application rate	Soil temperature				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
	°F				
Control	62.3	68.6	77.2	73.4	65.2[b]
High	62.3	69.1	77.7	73.7	**65.6[a]**†
LSD (p = 0.10)‡	NS§	NS	NS	NS	0.33
Trial mean	62.3	68.8	77.4	73.6	65.4

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

Table 14. Soil nitrate-N (NO_3) by nitrogen application rate, Alburgh, VT, 2023.

Nitrogen application rate	Soil nitrate-N (NO_3)				
	8-Jun	21-Jun	6-Jul	19-Jul	2-Aug
	ppm				
Control	6.54	8.65	7.97[b]	5.10	2.70
High	6.38	12.1	**10.6[a]**†	5.48	2.78
LSD (p = 0.10)‡	NS§	NS	2.30	NS	NS
Trial mean	6.46	10.4	9.28	5.29	2.74

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

Nitrogen applied as starter fertilizer did not have a significant impact on soybean yield, harvest moisture, or test weight (Table 15). There was a significant difference in downy mildew disease rating between nitrogen application rates (Table 16). The low application rate had the highest downy mildew rating, but was not statistically different from the control treatment. The high application rate did have statistically lower downy mildew damage compared to all other treatments. There was no significant difference in disease rating for bacterial blight, frogeye leaf spot, anthracnose, or Septoria brown spot.

Table 15. Soybean harvest characteristics by nitrogen application rate, Alburgh, VT, 2023.

Nitrogen application rate	Harvest moisture	Yield at 13% moisture		Test weight
	%	lbs. ac^{-1}	bu. ac^{-1}	lbs. bu^{-1}
Control	12.8	2594	43.2	56.4
Low	13.0	2387	39.8	56.1
Normal	12.7	2481	41.4	55.9
High	12.9	2399	40.0	56.6
LSD (p = 0.10)‡	NS§	NS	NS	NS
Trial mean	12.8	2465	41.1	56.3

‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

Table 16. Disease rating by nitrogen application rate, Alburgh, VT, 2023.

Nitrogen application rate	Bacterial blight	Downy mildew	Frogeye leaf spot	Anthracnose	Septoria brown spot
	0-10 scale¥				
Control	0.10	2.20[ab]	1.45	0.35	0.05
Low	0.15	**2.40[a]**†	1.65	0.40	0.05
Normal	0.15	1.90[b]	1.45	0.45	0.10
High	0.05	1.35[c]	1.40	0.20	0.00
LSD (p = 0.10) ‡	NS§	0.48	NS	NS	NS
Trial Mean	0.11	1.96	1.49	0.35	0.05

¥ 0 to 10 scale; rating of 0 = no infection or damage and rating of 10 = 100% infection or damage.
†Within a column, treatments marked with the same letter were statistically similar (p=0.10). The top performer is in **bold**.
‡LSD; Least significant difference at the p=0.10.
§NS; No significant difference between treatments.

DISCUSSION

For the 2022-2023 season, the UVM Extension Northwest Crops and Soils Program initiated a trial to investigate the impact of winter rye cover crop termination methods and starter nitrogen fertilizer rates on soybean crop yield and quality in Alburgh, VT. In 2023, excessive rainfall persisted during the soybean growing season, and there was a total of 31.2 inches of rain. Temperatures were quite cool from June to August, but then unseasonably warm in September and October. But there was a total of 2409 accumulated Growing Degree Days, which is typical for this region.

Soil health samples collected prior to cover crop termination indicate that the soil in this trial was high functioning and that there were no limiting factors to crop growth. There was double the amount of biomass in the late terminated rye treatments compared to earlier termination. There were no statistical differences in rye biomass between any of the late termination methods (Spray Late, Roll & plant, and Plant then Roll). This suggests that any difference in soybean yield between the late termination treatments was not due to statistically greater biomass in any of those treatments. There were no differences in soil moisture between treatments and this is likely due to the increased precipitation this season. The soil temperature was lowest in the late terminated cover crop treatments. The soil temperatures did not appear to impact soybean yields, however. The amount of soil nitrate-N was also statistically greater in the Plow treatment in June and July. There was no statistical difference in soil nitrate-N levels between the Spray Early and Plant then Roll treatment on any sample date except for 21-Jun. This was about one week after the winter rye was roller crimped in the Plant then Roll treatment. Soybean yields were not statistically different in the Plow, Spray Early, Spray Late, or Roll & Plant treatments. The Plant then Roll treatment had significantly reduced soybean yields and higher seed moisture at harvest. All soybeans were planted on 1-Jun, but the winter rye was not roller crimped in the Plant then Roll treatment until after the soybeans had emerged, which was approximately 2 weeks after planting. Statistical analysis was not done on soybean emergence, but it was observed that soybean emergence was about 5-7 days later in the Plant then Roll treatment than in other termination methods. Cooler soils, late germination, and possibly lower plant populations may have contributed to the yield reductions.

The nitrogen application rates had less of an impact on soybean yields compared to cover crop termination methods. Despite differences in application rates, soil nitrate-N levels were only significantly higher than the control on 6-Jul. Nitrogen fertilizer rates had no impact on soybean yield in this year's trial. The significant interaction between termination method and nitrogen application rate for soil nitrate-N on 8-Jun and 21-Jun suggest that increased nitrogen application rates at planting could be beneficial for increasing the available nitrogen in the soil when there is high cover crop residue or biomass. More research needs to be done to better understand the impact that nitrogen applications at planting can have on soybean yields.

It is important to remember that these data only represent one year and one trial location. Cover cropping can be a beneficial management strategy, but it is important to understand the potential benefits, consequences, and risks associated with growing cover crops in soybean production systems.

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