Integrating Cover Crops and Manure into Corn Silage Cropping Systems

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THE UNIVERSITY OF VERMONT EXTENSION

INTEGRATING COVER CROPS AND MANURE INTO CORN SILAGE CROPPING SYSTEMS

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With increasing focus on managing environmental impacts from agriculture, farmers are looking for ways to manage nutrients efficiently on their farms without sacrificing crop productivity. Cover cropping and no-till crop production are strategies that have been promoted as methods that help retain nutrients on farms and minimize losses to the environment. However, integrating these practices into the cropping system requires changes to other aspects of the system. For instance, manure management becomes more difficult when using no-till production methods as the timing or method of application may need to be altered to fit appropriately into the new production system. Farmers are curious what benefits to the soil, nutrient cycling, or crop production, may be realized from the additions of cover crops or transition to no-till methods within a corn silage cropping system. To help answer these questions, University of Vermont Extension's Northwest Crops and Soils Program conducted a field experiment between the fall of 2017 and the fall of 2019 to investigate the impacts of cover crops, tillage, and manure application in corn silage.

MATERIALS AND METHODS

The field trial was conducted at Borderview Research Farm in Alburgh, VT (Table 1). Treatments included tillage methods (conventional vs. no-till), manure application timing (fall vs spring), and cover crop integration (cover crop vs. no cover crop). Plots were 10' x 40' and replicated four times. Manure was applied to fall manure plots on 21-Sep 2017 and 24-Sep 2018 at a rate of 6200 gal ac^{-1}. The manure was surface applied and immediately incorporated using an aerway in conventional tillage plots, and just surface applied in no-till plots. A manure sample was collected at the time of application and sent to the University of Vermont Agricultural and Environmental Testing Lab (AETL) for nutrient analysis. Winter rye was planted on 25-Sep 2017 and 24-Sep 2018 into cover crop plots using a Sunflower grain drill. The following spring, soils were sampled by collecting approximately 10 soil cores at a 6" depth within each plot using a soil probe. These samples were immediately dried and transported to the AETL to be analyzed for soil nitrate (NO_3) nitrogen (N) content. An additional sample was collected according to the Cornell Soil Health sampling protocol and sent to the Cornell Soil Health Laboratory to be analyzed. Cover crop ground cover, height, and biomass was measured on 8-May 2018 and 6-May 2019. Ground cover was measured by processing photographs using the Canopeo smartphone application. Cover crop height was measured at three randomly selected locations within each plot. Cover crop biomass was collected from two $0.25m^2$ areas within each plot. The material from the area was cut at ground height, collected, weighed, and dried to determine dry matter content and calculate dry matter yield. Cover crop biomass was terminated on 14-May 2018 by an application of Roundup at a rate of 1 qt ac^{-1} and on 7-Jun 2019 by an application of Lumax EZ herbicide at a rate of 3 pints ac^{-1}. The biomass was then incorporated into the soil using disc harrows in the conventional tillage plots to prepare the seedbed for corn planting. Manure was surface applied to spring manure plots on 11-May 2018 and 8-May 2019 at a rate of 5800 gal ac^{-1}.

Table 1. No-Till Cover Crop Trial Management, Alburgh, VT, 2017-2019.

Location	Borderview Research Farm – Alburgh, VT	
Year	2018	2019
Soil type	Benson rocky silt loam	Benson rocky silt loam
Previous crop	Spring barley	Corn silage
Tillage treatments	Conventional tillage: immediate incorporation with aerway No-Till: manure not incorporated	Conventional tillage: immediate incorporation with aerway No-Till: manure not incorporated
Manure treatments	Fall application Spring application	Fall application Spring application
Cover crop treatments	Winter rye No cover crop	Winter rye No cover crop
Seeding rates (rye/corn)	100 lbs ac^{-1}/34,000 seeds ac^{-1}	100 lbs ac^{-1}/34,000 seeds ac^{-1}
Corn variety	Syngenta NK8618, 86 RM	Syngenta NK8618, 86 RM
Replications	4	4
Plot size (ft)	10’ x 40’	10’ x 40’
Manure application dates	21-Sep 2017 11-May 2018	24-Sep 2018 8-May 2019
Planting dates (rye/corn)	25-Sep 2017 / 8-Jun 2018	24-Sep 2018 / 13-May 2019
Cover crop termination	Roundup 1 qt ac^{-1} applied 14-May 2018 incorporated with disc harrow in conventional tillage plots	Lumax EZ 3 pints ac^{-1} applied 7-Jun 2019 incorporated with disc harrow in conventional tillage plots
Harvest date	17-Sep 2018	19-Sep 2019

Corn was planted on 17-May 2018 at a rate of 34,000 seeds ac^{-1} with 250 lbs ac^{-1} 15-15-15 corn starter fertilizer using a John Deere 7500 no-till corn planter. Due to complications with the planter and bird pressure, corn was replanted on 8-Jun 2018. In 2019, corn was planted on 13-May 2019 at a rate of 34,000 seeds ac^{-1} with 245 lbs ac^{-1} 10-20-20 corn starter fertilizer using a John Deere 7500 no-till corn planter. Soil was again collected from plots at a 6” depth on 22-Jun 2018 and 1-Jul 2019 and sent to the AETL to determine pre-side dress nitrate concentration. No additional N was applied to the plots. Just prior to corn harvest, corn populations were counted and 8” basal corn stalk segments from 6” above ground level were collected from three randomly selected corn plants in each plot. The stalk samples were dried, ground to 1mm particle size, and analyzed for nitrate content at the AETL. Corn was harvested on 17-Sep 2018 and 19-Sep 2019 using a John Deere 2-row chopper and a wagon fitted with scales. The yield of each plot was recorded and an approximate 1 lb subsample was collected and dried to determine dry matter content and calculate yield. The samples were then ground and analyzed for forage quality at the UVM Cereal Grain Testing Lab via NIR techniques as described for the cover crop biomass.

Data was analyzed using the PROC MIXED procedure SAS (SAS Institute, 1999). Year and replications were treated as random effects, and manure, cover crop, and tillage treatments were treated as fixed. Treatment mean pairwise comparisons were made using the Tukey-Kramer adjustment. Treatments were considered different at the 0.10 level of significance. Due to minimal year by treatment interactions, data were combined across trial years prior to statistical analysis.

Variations in yield and quality can occur because of variations in genetics, soil, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among hybrids 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. Where the difference between two hybrids 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 hybrids. Hybrids that were not significantly lower in performance than the highest hybrid in a particular column are indicated with an asterisk. In this example, hybrid C is significantly different from hybrid A but not from hybrid 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 hybrids 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 hybrids were significantly different from one another. The asterisk indicates that hybrid B was not significantly lower than the top yielding hybrid C, indicated in bold.

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

RESULTS

Weather data was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Tables 2 and 3). From September 2017 through May 2018 there were 3376 Growing Degree Days (GDDs) accumulated for the winter rye, 235 more than the 30-year normal. Precipitation during this time was below normal for all months except for April with a total of 6.81 inches below normal being accumulated. For the corn there were 2298 GDDs accumulated from June through September, 245 more than normal. Precipitation during this time was below normal for all months with a total of 2.81 inches below normal being accumulated.

Table 2. 2017-2018 weather data for Alburgh, VT.

	2017				2018								
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average temperature (°F)	64.4	57.4	35.2	18.5	17.1	27.3	30.4	39.2	59.5	64.4	74.1	72.8	63.4
Departure from normal	3.90	9.30	-2.80	-7.00	-1.80	5.90	-0.70	-5.60	3.00	-1.40	3.50	4.00	2.90
Precipitation (inches)	1.84	3.29	2.28	0.78	0.79	1.16	1.51	4.43	1.94	3.74	2.43	2.96	3.48
Departure from normal	-1.82	-0.27	-0.84	-1.57	-1.21	-0.56	-0.71	1.62	-1.45	0.11	-1.79	-0.95	-0.18
Growing Degree Days (base 32°F)	971	786	202	56	53	93	90	272	853				
Departure from normal	116	273	-49	-24	4	37	-76	-142	94				
Growing Degree Days (base 50°F)										447	728	696	427
Departure from normal										-34	98	114	67

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Table 3. 2018-2019 weather data for Alburgh, VT.

	2018				2019								
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average temperature (°F)	63.4	45.8	32.2	25.4	15.0	18.9	28.3	42.7	53.3	64.3	73.5	68.3	60.0
Departure from normal	2.86	-2.26	-5.79	-0.15	-3.87	-2.48	-2.79	-2.11	-3.21	-1.46	2.87	-0.51	-0.52
Precipitation (inches)	3.48	3.53	4.50	2.96	1.53	1.70	1.36	3.65	4.90	3.06	2.34	3.50	3.87
Departure from normal	-0.18	-0.03	1.38	0.61	-0.47	-0.02	-0.86	0.84	1.51	-0.57	-1.88	-0.41	0.21
Growing Degree Days (base 32°F)	941	435	136	72	23	38	108	346	660				
Departure from normal	86	-78	-115	-8	-26	-18	-58	-68	-99				
Growing Degree Days (base 50°F)										446	716	568	335
Departure from normal										-36	86	-14	-25

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger.
Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

From September 2018 through May 2019, there were 2759 GDDs accumulated for the winter rye, 384 fewer than the 30-year normal. Precipitation during this time was below normal for most months except for November and December 2018 and April and May 2019 resulting in a total of 2.78 inches above normal being accumulated. For the corn there were 2065 GDDs accumulated from June through September, 11 more than normal. Precipitation during this time was below normal for all months except September with a total of 2.65 inches below normal being accumulated.

Interactions Amongst Main Effects

Cover crop x manure timing

A significant interaction between cover crop treatment and manure application timing was observed for wet aggregate stability (Figure 1). Wet aggregate stability refers to the percentage of soil aggregates that resist degradation from the impact of water. Soil aggregates are formed when groups of soil particles are stuck together by fungal hyphae, organic matter particles, and exudates from plant roots or soil microbes. In this trial we observed an interaction between cover crop treatment and manure application timing, in which the combination of spring manure application and a cover crop being present resulted in a significantly higher aggregate stability. Since the soil health samples were taken at the beginning of the spring, prior to spring manure application, we'd expect less cover crop growth, soil microbial activity, and therefore less soil aggregation. However, this was not the observed trend.

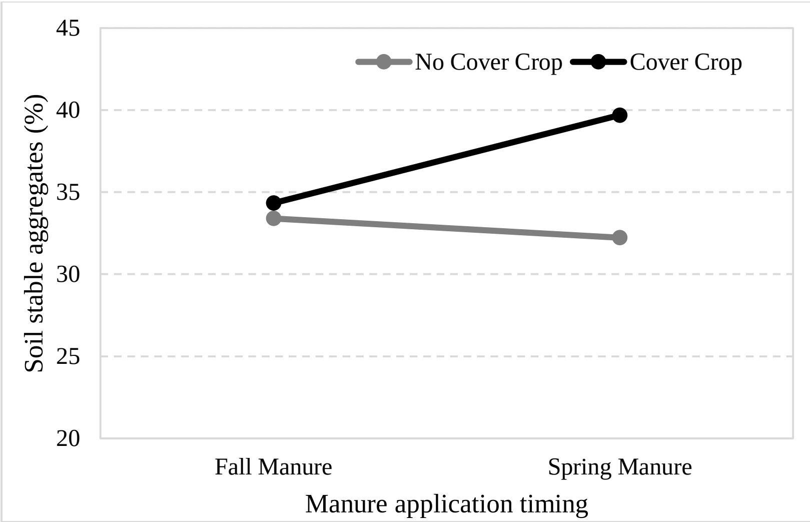


Figure 1. Interaction between cover crop treatment and manure application timing for aggregate stability.

There was also a significant interaction between cover crop treatment and manure application timing observed for soil organic matter content (Figure 2).

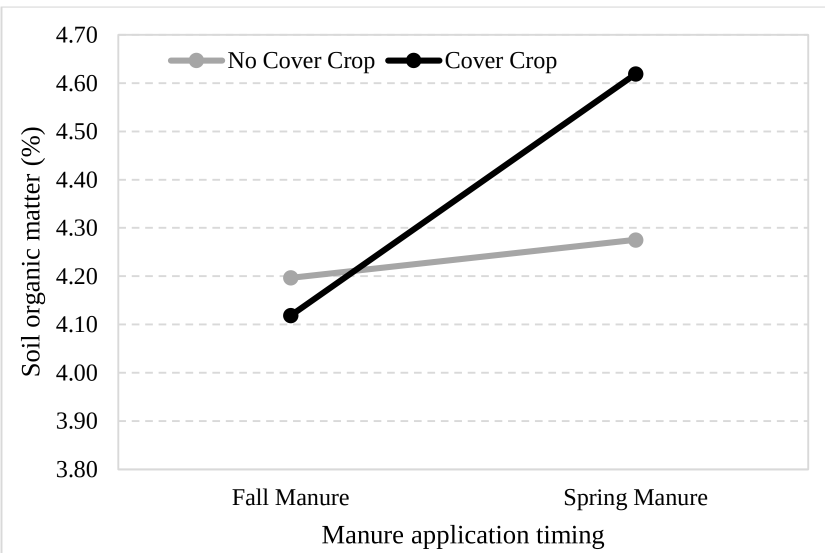


Figure 2. Interaction between cover crop treatment and manure application timing for soil organic matter.

These samples were also taken prior to manure application and exhibit the same trend with increased soil organic matter being observed in plots with spring manure application and a cover crop present. These interactions suggest that the combination of applying manure in the spring and using a cover crop can increase soil organic matter levels thus increasing soil aggregate stability.

Soil respiration also exhibited a significant interaction between cover crop treatment and manure application timing (Figure 3). Soil respiration is a reflection of the soil microbial activity of the soil. Soils that contain living plant roots or have readily degradable materials added tend to demonstrate higher soil respiration. In this trial we observed similar soil respiration between manure application timings when a cover crop was present, but lower respiration in spring applied plots when cover crops were not present.

Since the spring manure application had not yet been made at the time these samples were collected, this trend seems to suggest that soil respiration levels are increased by the addition of either a cover crop or manure, but that having both does not significantly increase respiration.

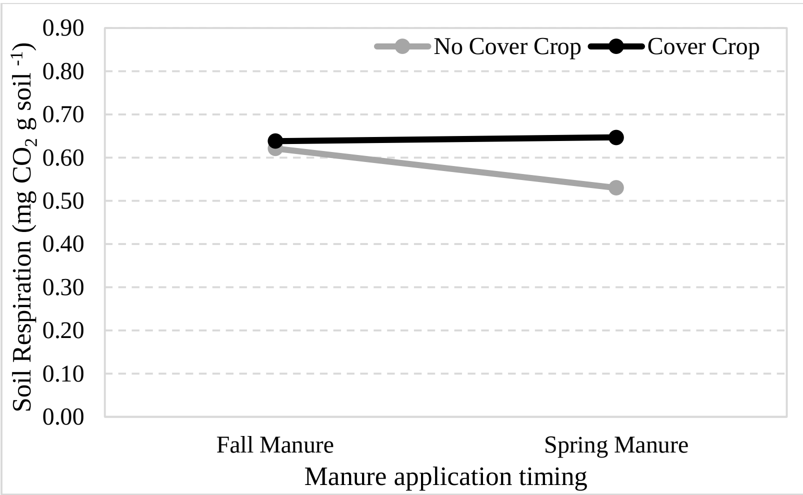


Figure 3. Interaction between cover crop treatment and manure application timing for soil respiration.

Manure application timing x tillage method

A significant interaction between manure application timing and tillage method was observed for corn population (Figure 4). Here we see opposite trends between the two manure application timings and tillage methods in which fall manure application produced better corn establishment in a conventionally tilled system, but spring manure application produced better corn establishment in a no till system. These differences suggest that the suitable manure application timing for a corn silage cropping system is dependent on the tillage method used.

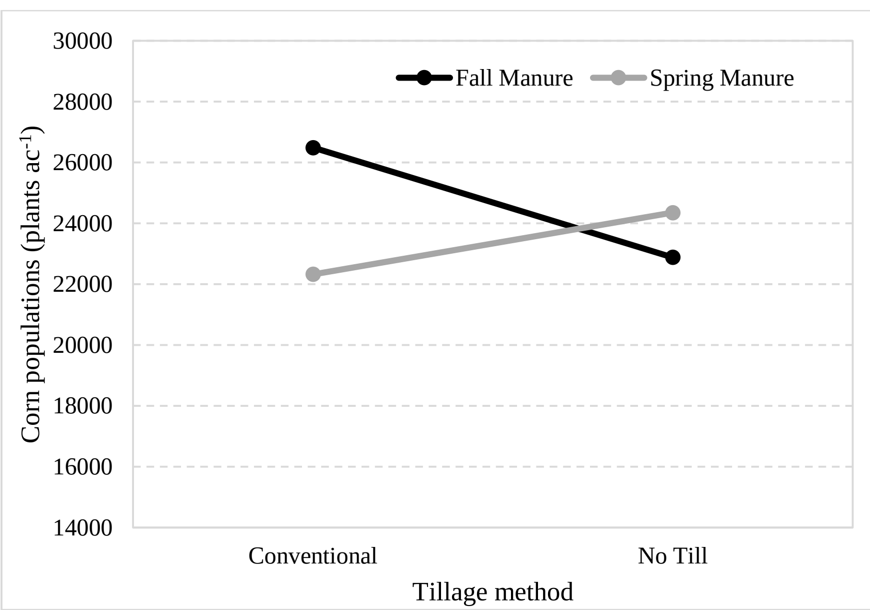


Figure 4. Interaction between manure application timing and tillage method for corn population.

Cover crop treatment x manure application timing x tillage method

There was a significant interaction between cover crop treatment, manure application timing, and tillage method for soil nitrate-N content at the time of corn topdress (Figure 5). This interaction suggests that combining spring manure application with conventional tillage and a cover crop provided the highest nitrate-N content at topdress. When a cover crop is present, the combination of fall manure with conventional tillage treatment exhibits a reduction in soil nitrate-N available at this time likely due to the increased cover crop biomass incorporated into the soil. The fact that this is not observed with the spring manure conventional tillage treatment may be due to two reasons: 1) additional N is supplied by the manure that can then be used to break down the incorporated cover crop biomass leaving more N available in the soil at topdress, and 2) less cover crop biomass is produced when spring manure is applied with a cover crop thereby reducing the amount of biomass to be broken down and the N needed to do so. The reduction observed in the spring manure no till treatment when a cover crop is present seems to indicate that when manure is not incorporated into the soil, the addition of a cover crop reduces the soil nitrate-N available at the time of topdress.

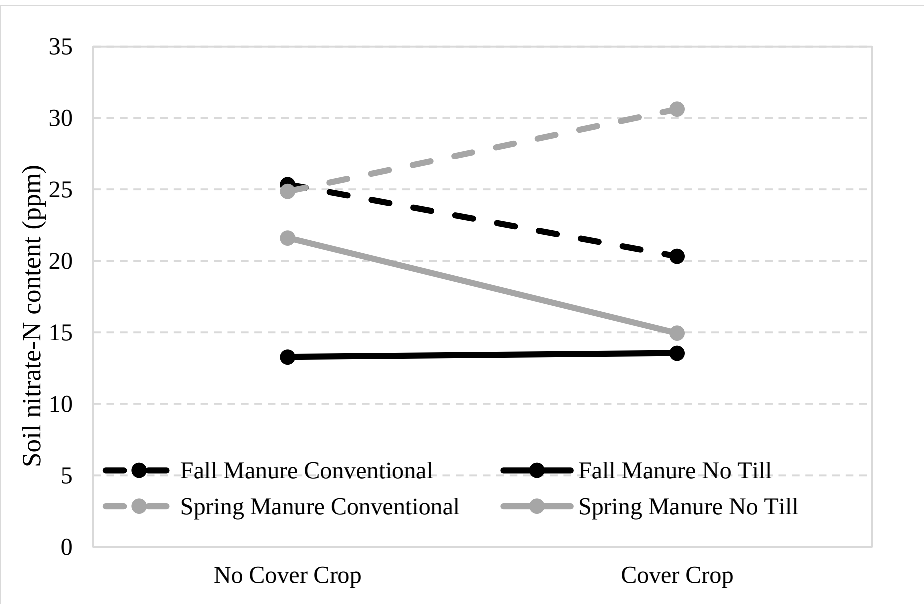


Figure 5. Interaction between cover crop treatment, manure application timing and tillage method for soil nitrate content.

Impact of Year

Soil health characteristics differed significantly across the two trial years (Table 4). Soil aggregate stability, respiration, and organic matter content were higher in 2019 compared to 2018 (Figure 6). This is to be expected as animal manure and cover crop biomass are being added to the soil stimulating microbial activity and changes in soil condition.

Table 4. Cover crop and soil health metrics by year.

Year	Ground cover	Cover crop biomass	Soil aggregate stability	Soil respiration	Soil organic matter	Overall soil health score	Spring soil nitrate-N
	%	tons ac^{-1}			%	0-100	ppm
2018	**36.7**	**0.718**	32.1	0.570	4.21	78.8	4.36
2019	35.7	0.200	**37.7**	**0.649**	**4.39**	**80.2**	**4.54**
LSD (p = 0.10)	NS†	0.113	2.33	0.041	0.173	NS	NS
Trial Mean	36.2	0.459	34.9	0.609	4.30	79.5	4.45

Top performing treatment indicated in **bold**.

†NS; Not statistically significant.

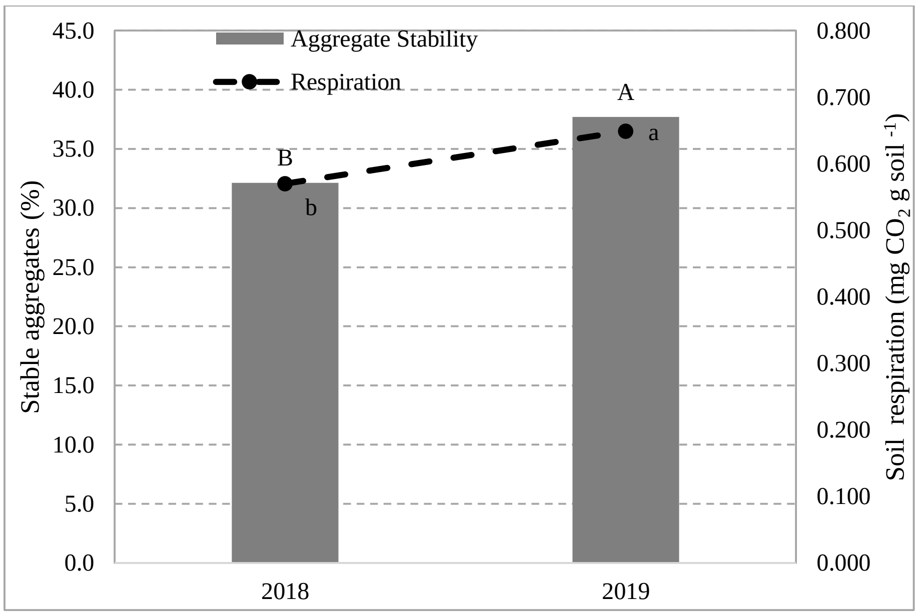


Figure 6. Soil health characteristics by year.

Treatments that share letters performed statistically similarly to one another.

Additionally, the weather conditions in 2018 presented challenges for both establishment and growth and development of quality corn silage. This was exhibited in severely reduced populations and corn quality differences that were likely influenced by these weather conditions (Table 5).

Table 5. Corn silage quality characteristics by year.

Year	Dry matter content	Crude protein	ADF	NDF	Ash	Fat	Starch	TDN	Ne_L	Milk yield	
	%	% of DM							Mcal lb^{-1}	lbs ton^{-1}	lbs ac^{-1}
2018	44.5	**9.97**	24.8	41.7	**3.00**	**4.56**	30.5	**69.3**	0.674	3128	20393
2019	**42.0**	8.47	**20.1**	**36.5**	4.05	3.15	**38.6**	65.5	**0.692**	**3498**	**24169**
LSD (p = 0.10)	1.29	0.295	0.881	1.43	0.29	0.34	1.93	0.938	0.012	72.8	2067
Trial Mean	43.2	9.22	22.4	39.1	3.52	3.85	34.5	67.4	0.683	3313	22281

Top performing treatment indicated in **bold**.

The significantly higher crude protein level in 2018 may be related to soil nitrate-N content which was also substantially higher at the time of topdress in 2018 compared to 2019 (Figure 7). On average, the corn silage crop required 40 more lbs N ac^{-1} at topdress in 2019 compared to 2018.

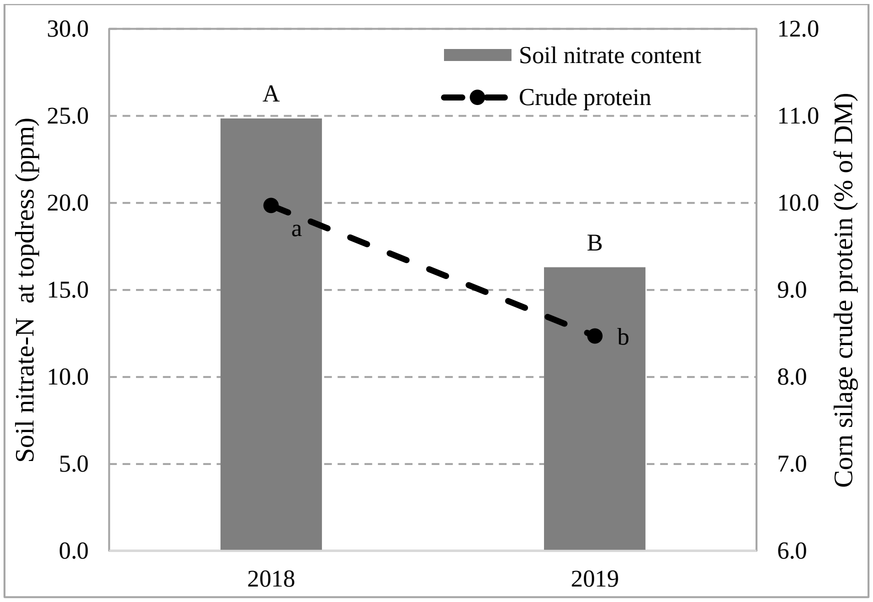


Figure 7. Soil nitrate and corn silage crude protein content by year.
Treatments that share a letter performed statistically similarly to one another.

Impact of Cover Crop

Treatments that contained cover crops had higher soil aggregate stability, soil respiration, and overall soil health scores than plots with no cover crop (Table 6). In this trial, having a cover crop increased aggregate stability by 4.2%. This was likely due to increased microbial activity which helps create stable soil aggregates through microbial exudates. This was supported by higher soil respiration, a measure of microbial activity, in cover crop plots compared to plots with no cover crop (Figure 8).

Table 6. Cover crop and soil health metrics by cover crop treatment.

Year	Ground cover	Cover crop biomass	Soil aggregate stability	Soil respiration	Soil organic matter	Overall soil health score	Spring soil nitrate-N
	%	tons ac^{-1}	%	mg CO_2 g $soil^{-1}$	%	0-100	ppm
Cover Crop	**68.5**	**0.459**	37.0	0.643	4.37	80.5	4.20
No Cover Crop	3.98	0.000	**32.8**	**0.576**	**4.24**	**78.6**	**4.71**
LSD (p = 0.10)	5.66	N/A‡	2.33	0.041	NS†	1.45	NS
Trial Mean	36.2	0.459	34.9	0.609	4.30	79.5	4.45

Top performing treatment indicated in **bold.**
‡N/A; statistical analysis not performed.
†NS; not statistically significant.

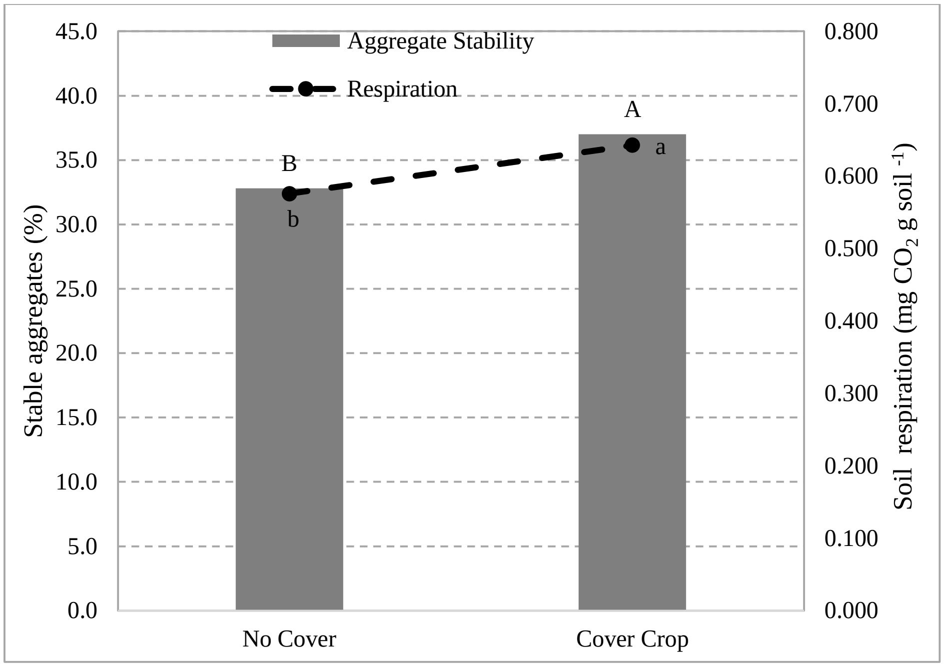


Figure 8. Soil aggregate stability and respiration by cover crop treatment.
Treatments that share letters performed statistically similarly to one another.

One reason farmers are often hesitant to adopt cover cropping is because they believe that the biomass produced by the cover crop will immobilize nitrogen, thereby, requiring more additional nitrogen or negatively impact the corn silage yield. However, despite higher soil health and activity, plots containing cover crops had similar soil nitrate levels at both the beginning of the spring and by the time of topdress compared to plots without cover crops (Figure 9) and produced similar corn silage yields (Figure 10).

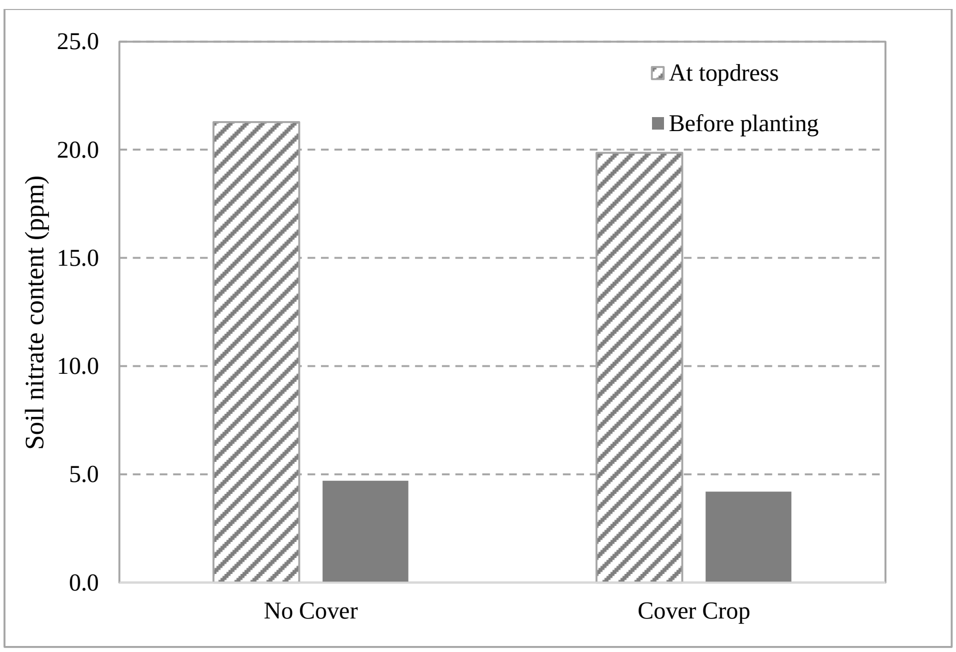


Figure 9. Soil nitrate content before planting and at the time of topdress.
Treatments performed statistically similarly to one another.

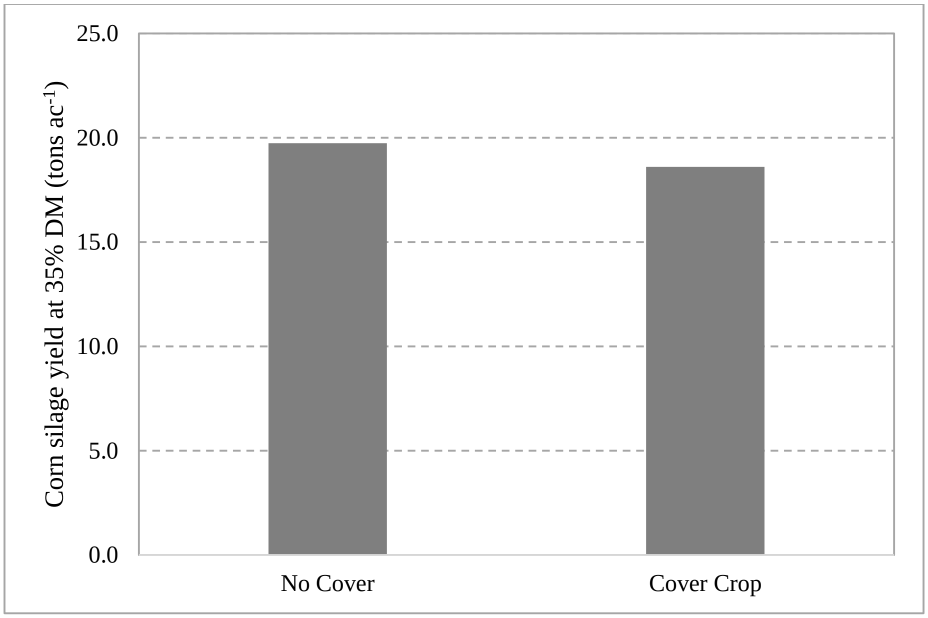


Figure 10. Corn silage yield by cover crop treatment.
Cover crop treatments performed statistically similarly to one another.

Corn silage quality characteristics were also not significantly impacted by the presence of cover crops in the cropping system (Table 7).

Table 7. Corn silage quality characteristics by cover crop treatment.

Treatment	Dry matter content	Crude protein	ADF	NDF	Ash	Fat	Starch	TDN	Ne_L	Milk yield	
	%	% of DM							Mcal lb^{-1}	lbs ton^{-1}	lbs ac^{-1}
Cover Crop	43.2	9.32	22.7	39.5	3.65	3.69	33.4	67.2	0.679	3285	22747
Control	43.3	9.12	22.2	38.7	3.40	4.02	35.7	67.7	0.688	3341	21815
LSD (p = 0.10)	NS†	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trial Mean	43.2	9.22	22.4	39.1	3.52	3.85	34.5	67.4	0.683	3313	22281

†NS; Not statistically significant.

Impact of Manure Application Timing

Applying manure in the fall significantly increased spring cover crop biomass and ground cover compared to applying manure in the spring (Figure 11). Furthermore, plots receiving fall manure produced 2.14 tons ac^{-1} less corn silage than plots receiving spring manure (Figure 12). As described in the previous section, there was no significant impact from cover crop treatment on corn silage yield. Therefore, this decreased yield is likely a result of less nitrogen availability in the fall versus spring applied manure (Table 8). Manure applied in the fall provided approximately 46 lbs N ac^{-1} while spring applied manure supplied 63 lbs N ac^{-1}. This is further supported by higher observed soil nitrate-N concentrations in spring manure plots at the time of corn topdress compared to fall manure plots (Figure 13). Based on soil nitrate-N concentrations at this time, spring manure plots would require an additional 40 lbs ac^{-1} N while fall manure plots would require an additional 70 lbs ac^{-1} N.

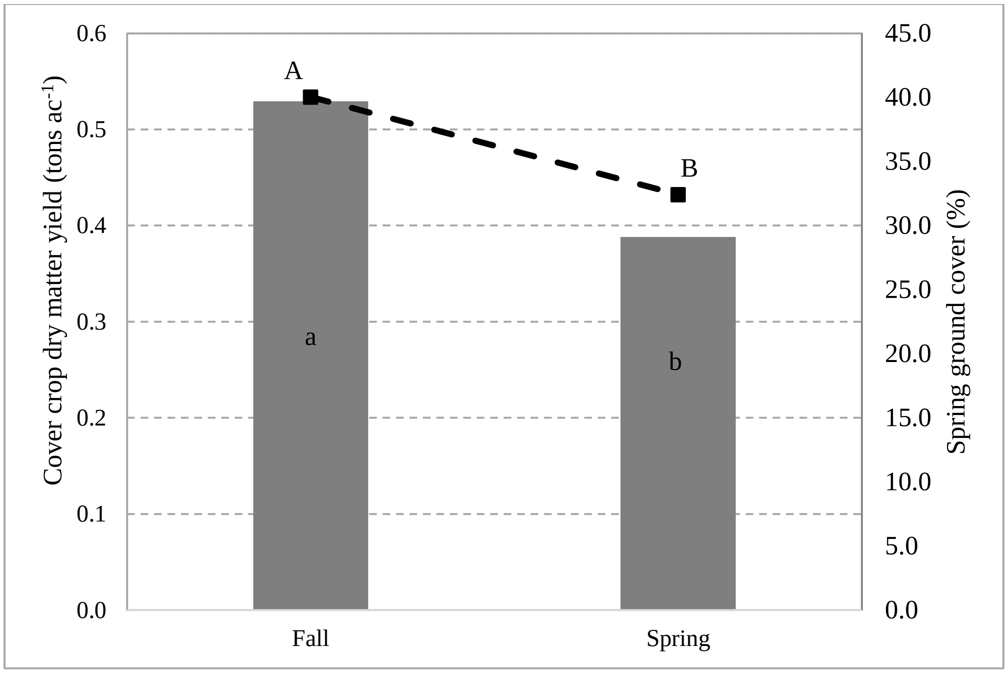


Figure 11. Cover crop biomass and ground cover by manure application timing.
Treatments that share letters performed statistically similarly to one another.

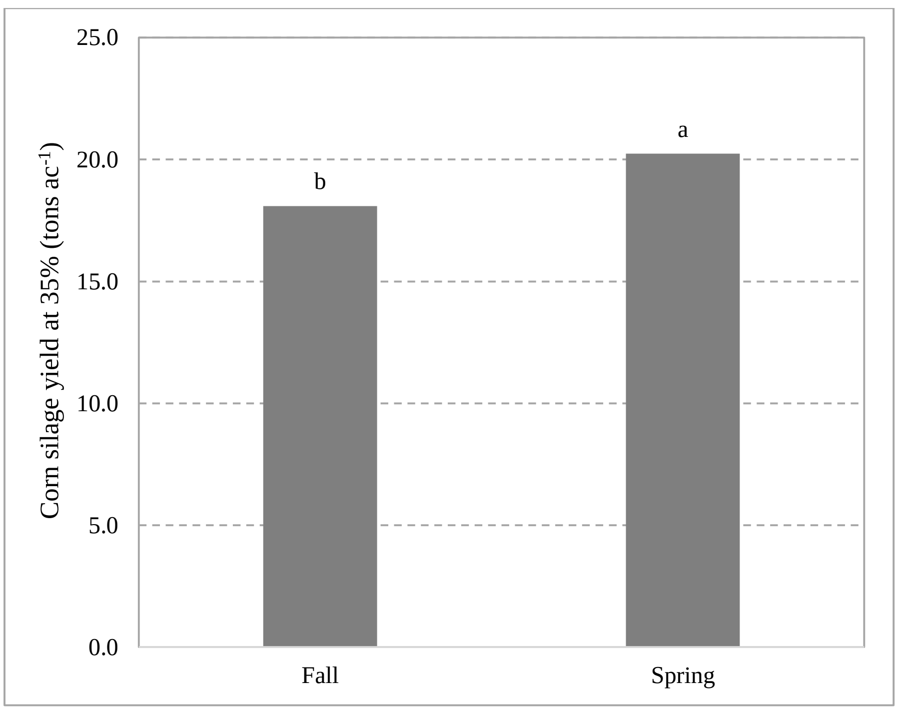
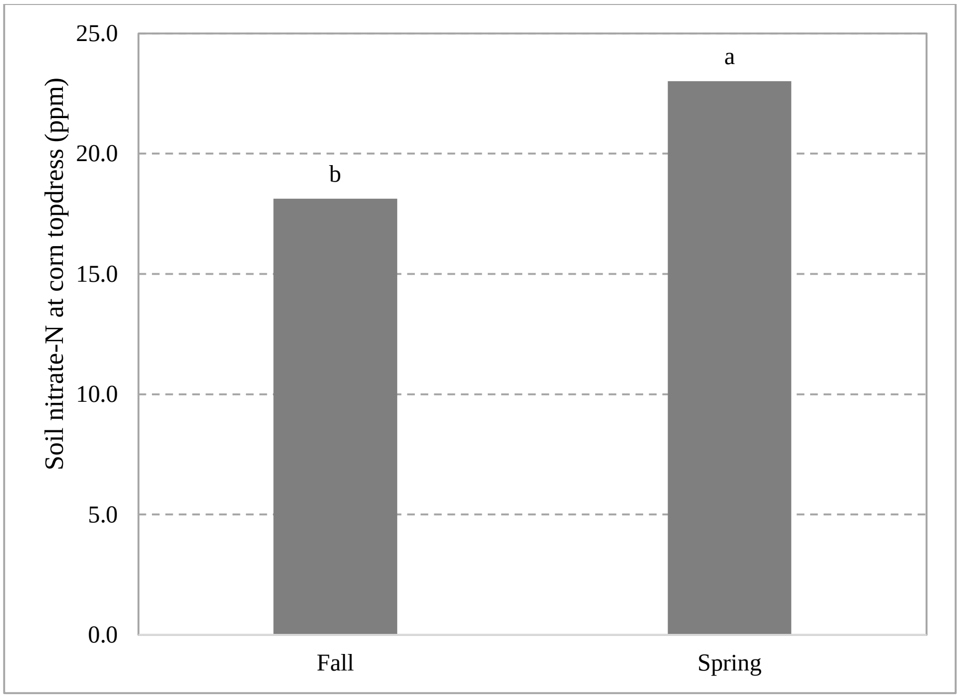


Figure 12. Corn silage yield by manure application timing.
Treatments that share letters performed statistically similarly to one another.

Table 8. Nitrogen supplied by manure*.

Manure Treatment	Available N lbs ac^{-1}
Spring	63
Fall	46

*Estimated from Nutrient Recommendations for Field Crops in Vermont.



Given these nitrate levels at the time of topdress, plots that received fall manure would require **almost twice as much** additional N as plots that received spring manure to produce the same target yield.

Figure 13. Soil nitrate content at corn topdress by manure application timing.
Treatments that share letters performed statistically similarly to one another.

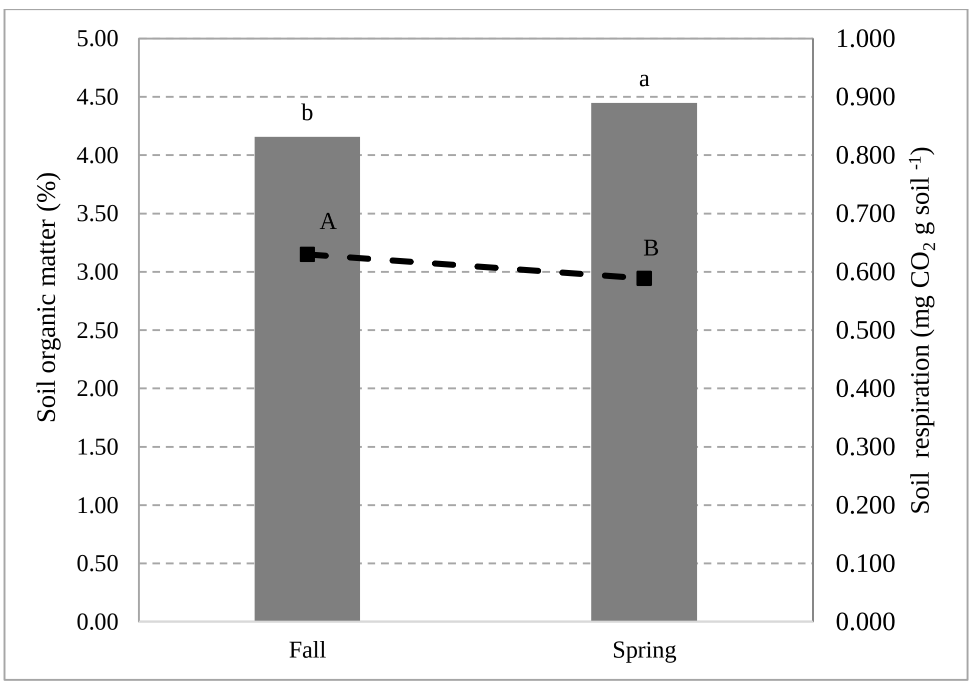


Figure 14. Soil organic matter and respiration by manure application timing.
Treatments that share letters performed statistically similarly to one another.

Soil health characteristics also varied by manure application timing (Figure 14). Soil organic matter was higher in plots that received spring manure whereas soil respiration was higher in plots that received fall manure.

Table 9. Corn silage quality characteristics by manure application timing.

Manure Application Timing	Dry matter content	Crude protein	ADF	NDF	Ash	Fat	Starch	TDN	Ne_L	Milk yield	
	%	% of DM							Mcal lb^{-1}	lbs ton^{-1}	lbs ac^{-1}
Fall	**43.2**	9.09	**22.4**	**39.0**	**3.41**	**3.96**	**35.1**	**67.9**	**0.689**	**3340**	21194
Spring	43.3	**9.35**	22.5	39.1	3.63	3.75	33.9	67.0	0.677	3286	**23368**
LSD (p = 0.10)	NS†	NS	NS	NS	NS	NS	NS	NS	NS	NS	2067
Trial Mean	43.2	9.22	22.4	39.1	3.52	3.85	34.5	67.4	0.683	3313	22281

Top performing treatment indicated in **bold**.
†NS; Not statistically significant.

Corn silage quality characteristics were not significantly impacted by manure application timing except for milk yield per acre (Table 9). This is due to the significant impact of manure application timing on corn silage yield, not on corn silage quality.

Impact of Tillage Method

Ground cover differed statistically between tillage treatments (Table 10) as cover crops established better in conventionally tilled plots (Images 1 and 2). However, this did not translate into a significant increase in biomass or height.

Table 10. Cover crop and soil health metrics by tillage method.

Year	Ground cover	Cover crop biomass	Soil aggregate stability	Soil respiration	Soil organic matter	Overall soil health score	Spring soil nitrate-N
	%	tons ac-1	%	mg CO_2 g soil $^{-1}$	%	0-100	ppm
Conventional	**39.5**	**0.496**	33.6	0.595	4.29	78.5	4.63
No-Till	32.93	0.422	**36.3**	**0.623**	**4.32**	**80.5**	**4.27**
LSD (p = 0.10)	5.66	NS†	2.33	NS	NS	1.45	NS
Trial Mean	36.2	0.459	34.9	0.609	4.30	79.5	4.45

Top performing treatment indicated in **bold.**
†NS; not statistically significant.

Image 1 - 2. Cover in conventionally tilled (left) and no-till (right) plots.

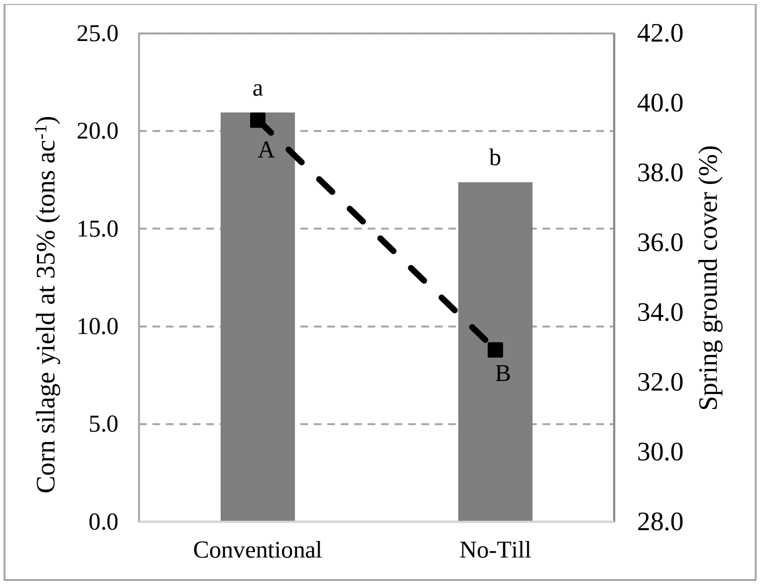


Figure 15. Ground cover and corn silage yield by tillage.
Treatments that share a letter performed statistically similarly.

Corn silage yields were 3.56 tons ac^{-1} higher in conventionally tilled plots compared to no-till plots (Figure 15). This may have been related to nitrogen availability in conventionally tilled plots as exhibited by soil nitrate content at the time of topdress (Figure 9). Based on the soil nitrate concentrations at this time, conventionally tilled plots would have required an additional 30 lbs N ac^{-1} (approximately 65 lbs ac^{-1} urea), while the no-till plots would have required an additional 80 lbs N ac^{-1} (approximately 174 lbs ac^{-1} urea). Since additional nitrogen beyond manure was not applied, corn silage protein levels were lower in no-till plots compared to conventionally tilled plots (Figure 16).

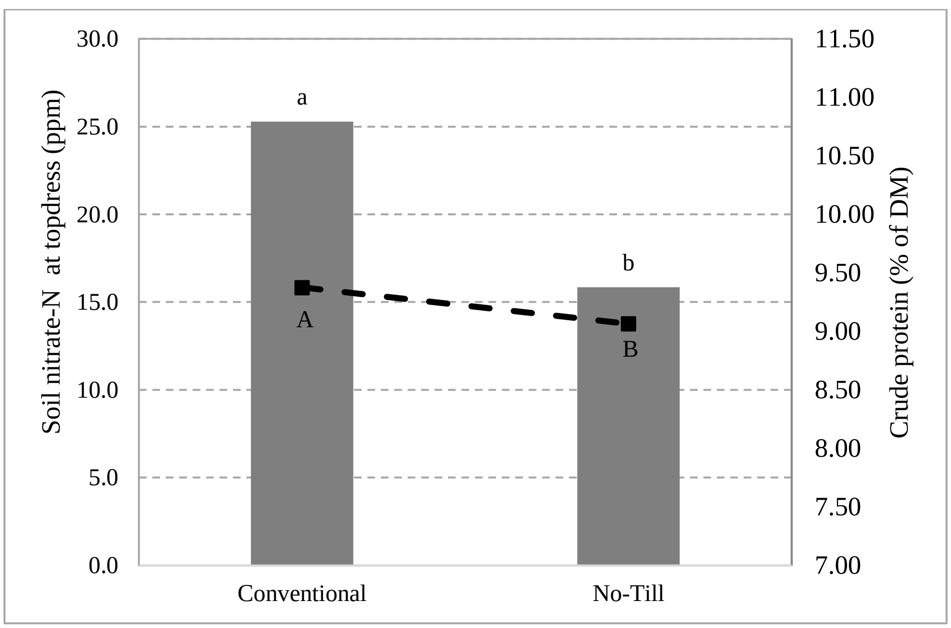


Figure 16. Soil nitrate content and corn silage crude protein content by tillage.
Treatments that share a letter performed statistically similarly to one another.

Despite lower soil N availability and corn silage yields, no-till plots had statistically higher soil aggregate stability (Figure 17). These differences, and potentially other soil health parameters, may have been more considerable if the research site had been managed under conventional and no-till management for a longer period of time.

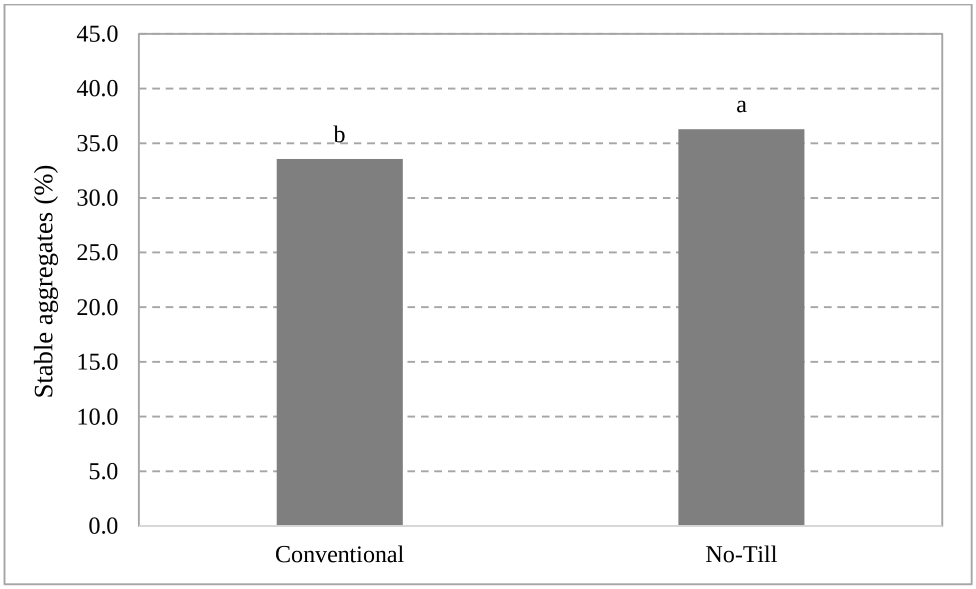


Figure 17. Soil aggregate stability by tillage method.
Treatments that share a letter performed statistically similarly to one another.

Corn silage quality characteristics were not significantly impacted by manure application timing except for milk yield per acre (Table 11). This is due to the significant impact of manure application timing on corn silage yield, not on corn silage quality.

Table 11. Corn quality characteristics by tillage method.

Tillage Treatment	DM content	Crude protein	ADF	NDF	Ash	Fat	Starch	TDN	Ne_L	Milk yield	
	%	% of DM							Mcal lb^{-1}	lbs ton^{-1}	lbs ac^{-1}
Conventional	**42.9**	**9.37**	22.6	39.2	3.60	**3.91**	34.5	**67.5**	**0.684**	**3321**	**24489**
No-Till	43.6	9.06	**22.3**	**39.0**	**3.44**	3.80	**34.6**	67.3	0.682	3306	20073
LSD (p = 0.10)	NS†	0.295	NS	NS	NS	NS	NS	NS	NS	NS	2067
Trial Mean	43.2	9.22	22.4	39.1	3.52	3.85	34.5	67.4	0.683	3313	22281

Top performing treatment indicated in **bold**.
†NS; Not statistically significant.

DISCUSSION

Integrating no-tillage into corn silage systems can pose challenges with other aspects of the cropping system, especially regarding the method and timing of manure application, and cover crops. Managing cover crop biomass in the spring to adequately prepare the soil for planting can be a challenge. In a conventional tillage system, incorporating the biomass into the soil can tie up nitrogen that otherwise would be utilized by the crop. Pairing cover crop incorporation with manure application can help provide more available nitrogen to the subsequent crop (Table 12). However, in a no-till system, manure is left unincorporated and much of the N is lost through volatilization. Cover crops can help build soil health and aide with the transition to no-till. However, the additional cover crop biomass may further exacerbate the lack of N in these systems, especially in fields transitioning to no-till systems (such as the one in this study). Additional fertility may be needed in a no-till system to support the corn crop yield goals. It should be noted that these data represent only one year and should not be used alone to make management decisions.

Table 12. Available N supplied to the corn crop*.

Manure Treatment	Tillage Treatment	Available N lbs ac^{-1}
Spring	Conventional	79
	No-Till	48
Fall	Conventional	60
	No-Till	32

*Available N was estimated from Nutrient Recommendations for Field Crops in Vermont.

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