Integrating Cover Crops and Manure into Corn Silage Cropping Systems

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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 2021 and the fall of 2022 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 16-Sep 2021 at a rate of 6200 gal ac^{-1}. The manure was surface applied and immediately incorporated using a Pottinger TerraDisc in conventional tillage plots, and 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 21-Sep 2021 into cover crop plots using a Sunflower no-till grain drill. Soil samples were collected according to the Cornell Soil Health sampling protocol and sent to the Cornell Soil Health Laboratory to be analyzed (https://soilhealth.cals.cornell.edu/). Cover crop ground cover and biomass were measured on 2-May 2022. Ground cover was measured by processing photographs using the Canopeo smartphone application (https://canopeoapp.com/#/login). Cover crop biomass was measured by harvesting the material within a 0.25 m^2 quadrat in each plot. The samples were weighed and dried to determine dry matter content and yield. The dried samples were then ground and sent to Dairy One for total nitrogen and carbon analysis. Manure was surface applied to spring manure plots on 5-May 2022 at a rate of 6000 gal ac^{-1}. Conventional tillage plots were tilled using a Pottinger TerraDisc to incorporate manure and/or cover crop biomass. All remaining cover crop plots were terminated on 6-May 2022 by an application of Roundup Power Max herbicide at a rate of 1 qt ac^{-1}.

Corn was planted on 10-May 2022 at a rate of 34,000 seeds ac^{-1} with 250 lbs ac^{-1} 19-19-19 corn starter fertilizer using a John Deere 7500 no-till corn planter. Soil was collected from plots at a 6" depth on 13-Jun 2022 and sent to the AETL to determine pre-side dress nitrate (PSNT) concentration.

Table 1. No-Till Cover Crop Trial Management, Alburgh, VT, 2021-2022.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Corn silage
Tillage treatments	Conventional tillage: immediate incorporation with PottingerTerraDisc No-Till: manure not incorporated
Manure treatments	Fall application (16-Sep 2021) Spring application (5-May 2022)
Cover crop treatments	Winter rye No cover crop
Seeding rates (rye/corn)	100 lbs ac^{-1}/34,000 seeds ac^{-1}
Corn variety	Syngenta NK8618, 86 RM
Replications	4
Plot size (ft)	10' x 40'
Manure application dates (rate, gal ac^{-1})	Fall: 16-Sep 2021 (6200) Spring: 5-May 2022 (6000)
Planting dates	Rye: 21-Sep 2021 Corn: 10-May 2022
Cover crop termination	Roundup PowerMax 1 qt ac^{-1} applied 6-May 2022 incorporated with Pottinger TerraDisc in conventional tillage plots
Harvest date	7-Sep 2022

No additional fertility was added. Corn was harvested on 7-Sep 2022 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 E. E. Cummings Crop Testing Laboratory at the University of Vermont via near-infrared reflectance spectroscopy (NIR) procedures using a FOSS DS2500 NIRS.

Data were analyzed using the general linear model procedure in SAS (SAS Institute, 1999). Replications were treated as a random effect and manure, cover crop, and tillage treatments were treated as fixed. Treatments were considered different at the 0.10 level of significance. Orthogonal contrasts were conducted to determine mean differences cover crop versus no cover crop, tillage versus no-tillage, and spring versus fall manure applications. 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 were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 2). From October 2021 through April 2022 there were 1672 Growing Degree Days (GDDs) accumulated for the winter rye, 261 more than the 30-year normal. Precipitation monthly accumulations were above normal in all months except for October, March, and April. Overall precipitation was 1.18 inches above normal across this time span. For the corn there were 2157 GDDs accumulated from May through August, just 2 fewer than normal. Precipitation during this time was above normal for June and August and slightly below normal for May and July. A total of 19.5 inches of precipitation accumulated during the corn growing season, 3.87 above normal.

Table 2. 2021-2022 weather data for Alburgh, VT.

	2021			2022							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Average temperature (°F)	54.6	37.6	28.6	10.7	20.0	32.3	44.8	60.5	65.3	71.9	70.5
Departure from normal	4.31	-1.68	0.36	-10.20	-2.93	-0.03	-0.81	2.09	-2.18	-0.54	-0.20
Precipitation (inches)	6.23	2.26	1.42	0.28	1.14	2.52	5.57	3.36	8.19	3.00	4.94
Departure from normal	2.40	-0.44	-1.08	-1.85	-0.63	0.28	2.50	-0.40	3.93	-1.06	1.40
Growing Degree Days (base 32°F)	701	232	107	13	58	170	391				
Departure from normal	133	-3	59	13	47	32	-20				
Growing Degree Days (base 50°F)								394	459	674	630
Departure from normal								93	-64	-20	-11

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.

Effects of Conservation Management Systems

Conservation management systems differed statistically in spring ground cover and soil health metrics (Table 3). Spring winter rye ground cover was highest (73.9%) in the conventional tillage treatment receiving fall manure. While we would expect significantly lower ground cover from treatments without a winter cover crop, both no-till treatments with cover crops receiving either spring or fall manure were significantly lower than the conventionally tilled treatments with cover crops. As little to no weeds were growing at this time, increased ground cover can be attributed to increased cover crop establishment. These trends were also seen in previous years. Soil health metrics also differed by conservation management system. With the exception of aggregate stability, all soil health metrics were statistically higher in the conventionally tilled treatment receiving spring manure with a winter cover crop. For many of these metrics, not only did this treatment have the highest level, but it was also statistically higher than all other treatments. Treatments did not differ in soil total carbon or nitrogen content or corn yield. Soil aggregate stability was significantly highest in the NT-SM-WRCC and NT-FM-WRCC treatments.

Table 3. Ground cover and soil health metrics by conservation management systems.

System treatment	Ground cover	Aggregate stability	Predicted water holding capacity	Active carbon	Soil protein	Respiration	Soil nitrate at topdress
	%		g H_2O g soil^{-1}	mg C kg soil^{-1}	mg protein g soil^{-1}	mg CO_2 g soil^{-1}	ppm
CT-FM-NoCC†	0.263d‡	20.7c	0.248bc	739bcd	7.50b	0.476c	14.0abc
CT-FM-WRCC	60.1b	23.2c	0.242c	673d	6.51c	0.602a	8.90d
CT-SM-NoCC	0.398d	20.5c	0.257ab	753bc	7.56b	0.500c	**17.1a**
CT-SM-WRCC	**73.9a**	20.2c	**0.262a**	**861a**	**8.73a**	**0.613a**	15.5ab
NT-FM-NoCC	1.41d	26.1bc	0.245c	694cd	7.29bc	0.528bc	12.8bc
NT-FM-WRCC	49.4c	31.3ab	0.241c	726bcd	7.45b	0.579ab	7.84d
NT-SM-NoCC	0.258d	26.2bc	0.245c	797ab	7.56b	0.578ab	13.9abc
NT-SM-WRCC	49.2c	**36.2a**	0.246bc	748bc	7.62b	0.605a	11.0cd
LSD (p = 0.10)¥	8.20	6.68	0.012	74.7	0.856	0.069	3.46
Trial mean	29.4	25.6	0.248	749	7.53	0.560	12.6

†CT- conventional tillage; NT- no-till; FM- fall manure; SM- spring manure; WRCC- winter rye cover crop; NoCC- no cover crop
‡Treatments that share letters performed statistically similarly to one another. The top performer is indicated in **bold.**
¥Least significant difference (LSD) at the 0.10 level.

By the time the corn was in the V6 growth stage, soil nitrate levels ranged from 7.64 to 17.1 ppm. These levels resulted in nitrogen topdress recommendations ranging from 62 to 99 lbs N ac^{-1} (based on a 20 ton ac^{-1} yield goal, Nutrient Recommendations for Field Crops in Vermont). By the end of the season, no differences were observed in corn silage yield with all treatments producing over 22 tons ac^{-1}.

Treatments did not differ in corn silage yield but did vary in some quality parameters (Table 4). Yields ranged from 22.9 to 25.4 tons ac^{-1} but did not differ statistically. Treatments did, however, vary in protein, fiber, starch, and NFC content. Low fiber, protein, and NFC content paired with high starch content suggests that the CT-FM-WRCC treatment produced biomass with more ears than its non-cover cropped counterpart. Generally, treatments with higher available soil nitrate at the time of topdress had higher protein concentrations. However, with no statistical differences in yields, these slight quality differences did not ultimately translate into statistically different predicted milk yields.

Table 4. Corn silage yield and quality by conservation management system.

System treatment†	Yield at 35% DM	CP	aNDFom	Starch	NFC	240-hr uNDF	30-hr NDFD	Milk yield	
	tons ac^{-1}	% of DM				% of NDF		lbs ton^{-1}	lbs ac^{-1}
CT-FM-NoCC	22.9	**10.0a**‡	42.8bcd	25.3c	36.8c	13.0	56.6	3229	26377
CT-FM-WRCC	24.7	8.78c	**37.9a**	**35.6a**	**45.6a**	10.9	56.9	3380	29136
CT-SM-NoCC	25.4	9.25bc	41.7bc	27.9bc	38.8bc	13.2	55.9	3237	28962
CT-SM-WRCC	23.5	9.60ab	42.4bcd	28.6bc	38.5bc	12.4	58.9	3256	26829
NT-FM-NoCC	23.4	9.53ab	39.3ab	33.5ab	43.4a	10.9	59.7	3399	27772
NT-FM-WRCC	25.4	9.15bc	40.5abc	31.7ab	41.6ab	12.2	54.9	3271	29548
NT-SM-NoCC	24.7	9.18bc	43.1cd	28.5bc	37.8bc	12.9	56.2	3235	27953
NT-SM-WRCC	22.8	8.88c	45.6d	28.1bc	37.3bc	14.0	53.6	3175	25566
LSD (p = 0.10) ¥	NS€	0.575	3.81	5.71	4.52	NS	NS	NS	NS
Trial mean	24.1	9.30	41.7	29.9	40.0	12.4	56.6	3273	27768

†CT- conventional tillage; NT- no-till; FM- fall manure; SM- spring manure; WRCC- winter rye cover crop; NoCC- no cover
‡Treatments that share a letter performed statistically similarly to one another.
¥Least significant difference (LSD) at the 0.10 level.
€NS; Not statistically significant

Effects of Individual Conservation Practices

Contrasts between the manure timing, tillage, and cover crop treatments were analyzed to determine the impact of each of these individual components within these system treatments (Table 5).

Table 5. Cover, manure, and tillage treatment contrast effects (*p*-values) on soil and crop parameters.

	Cover treatment	Manure timing treatment	Tillage treatment
	Level of significance		
Ground cover	***†	NS‡	***
Aggregate stability	**	NS	**
Organic matter	NS	**	NS
Respiration	**	NS	NS
Soil total carbon	NS	NS	NS
Soil organic carbon	NS	NS	NS
Active carbon	NS	**	NS
Soil total nitrogen	NS	NS	NS
Soil protein	NS	**	NS
Water holding capacity	NS	**	**
Soil nitrate at topdress	**	**	**
Corn yield	NS	NS	NS
Crude protein (CP)	N/A¥	NS	NS
aNDFom	N/A	**	NS
NFC	N/A	**	NS
Starch	N/A	*	NS
240-hr uNDF	N/A	*	NS

30-hr NDFD	N/A	NS	NS
Milk yield per ton	N/A	**	NS
Milk yield per acre	N/A	NS	NS

‡NS; Not statistically significant at the *p*=0.10 probability level

†*Significant at the *p*=0.10 probability level; **Significant at the *p*=0.05 probability level; ***Significant at the *p*=0.0001 probability level.

¥N/A; statistical analysis not performed

Impact of Cover Crop

Treatments that contained cover crops exhibited higher aggregate stability, soil respiration, and soil nitrate at topdress than plots with no cover crop (Table 6).

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

Cover crop treatment	Ground cover	Aggregate stability	Predicted water holding capacity	Active carbon	Soil protein	Respiration	Soil nitrate at topdress
	%		g H_2O g soil^{-1}	mg C kg soil^{-1}	mg protein g soil^{-1}	mg CO_2 g soil^{-1}	ppm
No cover crop	0.581	23.4	0.249	746	7.48	0.520	**14.4**
Cover crop	**58.1**	27.7	0.248	752	7.58	**0.599**	10.8
LSD (p = 0.10) ¥	4.10	3.34	NS‡	NS	NS	0.034	1.73
Trial mean	29.4	25.6	0.248	749	7.53	0.560	12.6

The top performer is indicated in **bold.**

¥Least significant difference (LSD) at the 0.10 level.

‡NS; Not statistically significant.

Farmers can be hesitant to adopt cover cropping because they believe that the cover crop will immobilize nitrogen, thereby, requiring more additional nitrogen or negatively impacting the corn silage yield. In this trial, plots with no cover crop had slightly higher soil nitrate content at the time of topdress compared to plots with a cover crop (Figure 1). However, the difference in nitrate content would only increase the recommendation for supplemental nitrogen by 15 lbs N ac^{-1}. Outside of manure, the plots were not supplemented with nitrogen and ultimately yielded similarly whether a cover crop had been used or not.

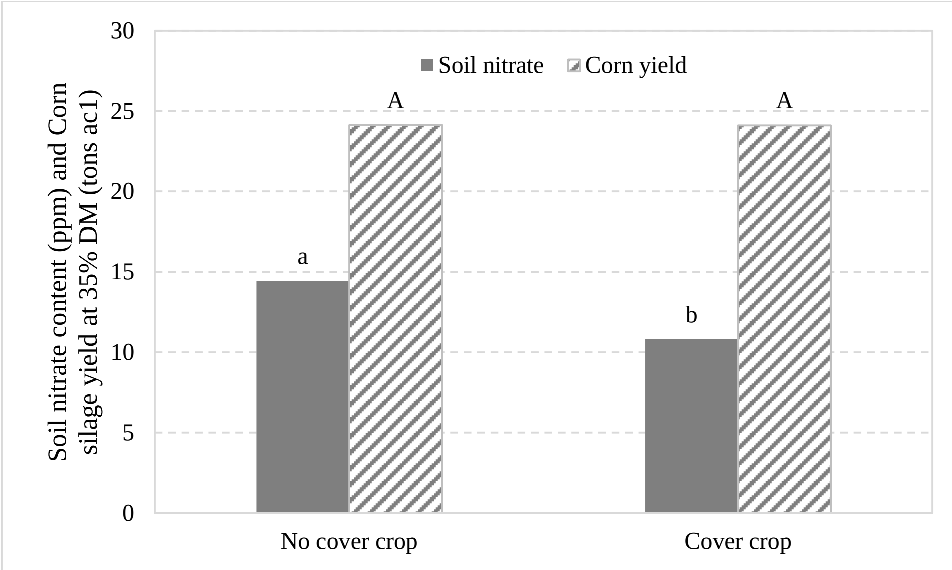

Figure 1. Soil nitrate content at the time of topdress and corn silage yield.
Treatments with the same letter performed statistically similarly to one another.

Impact of Manure Application Timing

All soil health metrics were higher in the plots that received spring manure, however, not all were statistically higher (Table 7). Manure application did not influence cover crop establishment and resulting ground cover, cover crop biomass, or soil aggregate stability. Soil organic matter content was 0.22% higher in plots that received manure in the spring. Similarly, water holding capacity was also higher in these plots. Interestingly, soil respiration was similar between manure application timing treatments, but soil protein was higher in spring applied plots. As expected, spring manure application led to higher soil nitrate content at the time of topdress, however, the higher levels would only decrease supplemental nitrogen recommendations by 15 lbs ac^{-1}. This may have been due to the ample moisture experienced throughout the season, which would have aided in the mineralization additional nitrogen in the soil from the fall applied manure. Plots were supplemented with the same amount of nitrogen and ultimately produced similar yields.

Table 7. Cover crop and soil health metrics by manure application timing.

Manure application timing	Ground cover	Aggregate stability	Organic matter	Predicted water holding capacity	Active carbon	Soil protein	Soil nitrate at topdress
		%		g H_2O g soil^{-1}	mg C kg soil^{-1}	mg protein g soil^{-1}	ppm
Fall manure	27.8	25.3	3.97	0.244	708	7.19	10.9
Spring manure	30.9	25.8	**4.19**	**0.253**	**790**	**7.87**	**14.4**
LSD (p = 0.10)¥	NS‡	NS	0.161	0.006	37.4	0.428	1.73
Trial mean	29.4	25.6	4.08	0.248	749	7.53	12.6

The top performer is indicated in **bold.**
¥Least significant difference (LSD) at the 0.10 level.
‡NS; Not statistically significant.

Yields, protein content, and fiber digestibility were not impacted by manure application timing (Table 8). The fall manure application treatment, however, did provide slightly lower NDF and uNDF, and higher starch, NFC, and milk yield per ton. Ultimately, however, since the yields were similar these small differences in quality did not equate to differences in predicted milk yield on a per acre basis.

Table 8. Corn silage yield and quality characteristics by manure application timing.

Manure application timing	Yield at 35% DM	CP	aNDFom	Starch	NFC	240-hr uNDF	30-hr NDFD	Milk yield	
	tons ac^{-1}	% of DM				% of NDF		lbs ton^{-1}	lbs ac^{-1}
Fall manure	24.1	9.37	**40.1**	**31.5**	**41.8**	**11.7**	57.0	**3320**	28208
Spring manure	24.1	9.23	43.2	28.3	38.1	13.1	56.1	3226	27328
LSD (p = 0.10) ¥	NS‡	NS	1.99	3.15	2.56	1.14	NS	70.3	NS
Trial mean	24.1	9.30	41.7	29.9	40.0	12.4	56.6	3273	27768

The top performer is indicated in **bold.**
¥Least significant difference (LSD) at the 0.10 level.
‡NS; Not statistically significant.

Impact of Tillage Method

Cover crops established better producing higher ground cover and more dry matter yield under conventional tillage compared to no-till (Figure 2). Cover crop biomass was 0.33 tons ac^{-1} higher in conventional tillage plots and had almost 20% more ground cover. The trend that cover crops establish more consistently in conventionally tilled plots has also been seen in previous years in this trial (Images 1 and 2).

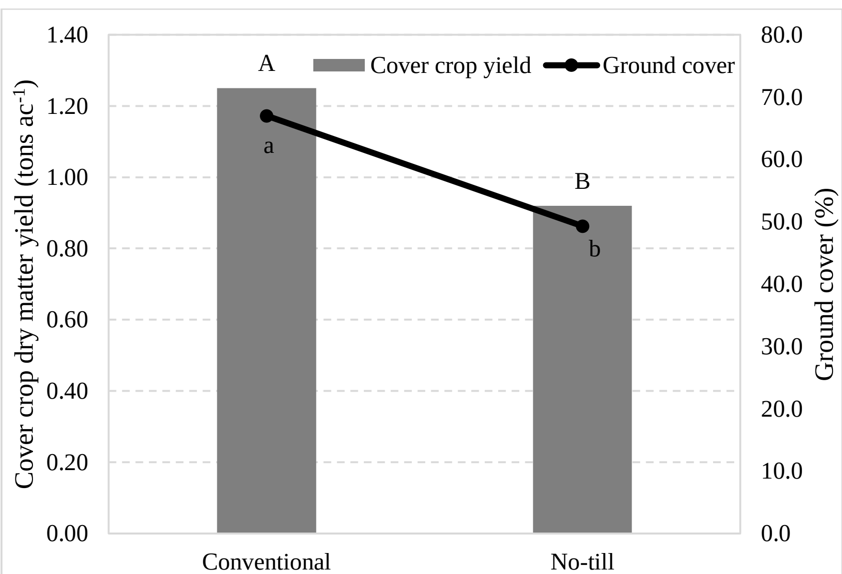

Figure 2. Cover crop ground cover and biomass by tillage treatment.

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

Tillage also impacted soil health metrics (Table 9). While no-till plots had higher aggregate stability, they were lower in all other soil health metrics. However, ultimately tillage treatment did not impact corn silage yields as both treatments yielded approximately 24 tons ac^{-1}. Tillage treatment also did not impact corn quality (Table 10).

Table 9. Cover crop and soil health metrics by tillage treatment.

Tillage treatment	Ground cover	Aggregate stability	Predicted water holding capacity	Active carbon	Soil protein	Soil nitrate at topdress	Cover crop yield
	%		g H_2O g soil^{-1}	mg C kg soil^{-1}	mg protein g soil^{-1}	ppm	tons ac^{-1}
Conventional	**67.0**	21.1	**0.252**	**756**	**7.58**	**13.9**	**1.25**
No-till	49.3	**30.0**	0.244	741	7.48	11.4	0.92
LSD (p = 0.10)¥	7.7	3.34	0.006	NS‡	NS	1.73	0.258
Trial mean	29.4	25.6	0.248	749	7.53	12.6	1.1

The top performer is indicated in **bold.**
¥Least significant difference (LSD) at the 0.10 level.
‡NS; Not statistically significant.

Table 10. Corn silage yield and quality by tillage treatment.

Tillage treatment	Yield at 35% DM	CP	aNDFom	Starch	NFC	240-hr uNDF	30-hr NDFD	Milk yield	
	tons ac^{-1}	% of DM				% of NDF		lbs ton^{-1}	lbs ac^{-1}
Conventional	24.1	9.41	41.2	29.4	39.9	12.3	57.1	3275	27826
No-till	24.1	9.18	42.1	30.4	40.0	12.5	56.1	3270	27710
LSD (p = 0.10)¥	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trial mean	24.1	9.30	41.7	29.9	40.0	12.4	56.6	3273	27768

The top performer is indicated in **bold.**
¥Least significant difference (LSD) at the 0.10 level.
‡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. However, in a no-till system, manure is left unincorporated and much of the ammonium-N may be 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.

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