
# 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 2021 to investigate the impacts of cover crops, tillage, and manure application in corn silage. The results from the 2020-2021 field season are summarized here.

## 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 2020 at a rate of 6000 gal $ac^{-1}$. The manure was surface applied and immediately incorporated using an aerway 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 22-Sep 2020 into cover crop plots using a Sunflower no-till 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 (https://soilhealth.cals.cornell.edu/). Cover crop ground cover, height, and biomass was measured on 26-Apr 2021. Ground cover was measured by processing photographs using the Canopeo smartphone application (https://canopeoapp.com/#/login). Cover crop height was measured at three randomly selected locations within each plot. Due to poor establishment and growth, there was insufficient biomass to collect for dry matter yield or nutrient content analyses. Manure was surface applied to spring manure plots on 26-Apr 2021 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 1-May 2021 by an application of Roundup Power Max herbicide at a rate of 1 qt $ac^{-1}$.

Corn was planted on 8-May 2021 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 again collected from plots at a 6" depth on 10-Jun 2021 and sent to the AETL to determine pre-side dress nitrate (PSNT) concentration.

**Table 1. No-Till Cover Crop Trial Management, Alburgh, VT, 2020-2021.**

| Location | Borderview Research Farm – Alburgh, VT |
|---|---|
| **Soil type** | Benson rocky silt loam |
| **Previous crop** | Corn silage |
| **Tillage treatments** | Conventional tillage: immediate incorporation with aerway in fall, Pottinger TerraDisc in spring<br>No-Till: manure not incorporated |
| **Manure treatments** | Fall application (21-Sep 2020)<br>Spring application (26-Apr 2021) |
| **Cover crop treatments** | Winter rye<br>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: 21-Sep 2020 (6,000)<br>Spring: 26-Apr 2021 (6000) |
| **Planting dates** | Rye: 22-Sep 2020<br>Corn: 8-May 2021 |
| **Cover crop termination** | Roundup PowerMax 1 qt $ac^{-1}$ applied 1-May 2021<br>incorporated with disc harrow in conventional tillage plots |
| **Harvest date** | 10-Sep 2021 |

No additional N was applied to the plots. Just prior to corn harvest, 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 end of season nitrate content at the Dairy One Forage Laboratory (Ithaca, NY). Corn was harvested on 10-Sep 2021 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 Crops Testing Lab 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 September 2020 through May 2021 there were 3385 Growing Degree Days (GDDs) accumulated for the winter rye, 230 more than the 30-year normal. Precipitation during this time was extremely low with the monthly accumulation being below normal in all months except for April. Overall precipitation was 10.5 inches below normal across this time span. For the corn, there were 2613 GDDs accumulated from May through September, 64 more than normal. Precipitation during this time remained below normal for all months except Sep with a total of 6.27 inches below normal being accumulated. The region was classified as experiencing “abnormally dry” and “moderate drought” conditions throughout the entire season (Drought.gov).

**Table 2. 2020-2021 weather data for Alburgh, VT.**

| | 2020 | | | | 2021 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
| Average temperature (°F) | 59.2 | 48.3 | 42.0 | 29.4 | 21.5 | 19.8 | 33.2 | 48.1 | 58.4 | 70.3 | 68.1 | 74.0 | 62.8 |
| Departure from normal | -3.53 | -2.01 | 2.69 | 1.20 | 0.64 | -3.07 | 0.93 | 2.52 | -0.03 | 2.81 | -4.31 | 3.25 | 0.14 |
| | | | | | | | | | | | | | |
| Precipitation (inches) | 2.75 | 3.56 | 1.41 | 1.40 | 0.39 | 0.47 | 0.97 | 3.52 | 0.66 | 3.06 | 2.92 | 2.29 | 4.09 |
| Departure from normal | -0.92 | -0.27 | -1.29 | -1.10 | -1.74 | -1.30 | -1.27 | 0.45 | -3.10 | -1.20 | -1.14 | -1.25 | 0.42 |
| | | | | | | | | | | | | | |
| Growing Degree Days (base 32°F) | 816 | 521 | 352 | 100 | 8 | 32 | 241 | 497 | 818 | | | | |
| Departure from normal | -107 | -48 | 117 | 52 | 8 | 21 | 103 | 85 | -1 | | | | |
| | | | | | | | | | | | | | |
| Growing Degree Days (base 50°F) | | | | | | | | | 334 | 597 | 561 | 727 | 394 |
| Departure from normal | | | | | | | | | 33 | 73 | -134 | 85 | 7 |

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 (50.0%) in the conventional tillage treatment receiving fall manure. This was statistically similar to only the conventional tillage treatment with winter cover receiving spring 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. Soil health metrics also differed by conservation management system. All significant soil health metrics were statistically higher in the conventionally tilled treatment receiving spring manure with a winter cover crop. For each soil health metric except for overall soil health score, not only did this treatment have the highest level, but it was also statistically higher than all other treatments. For the overall soil health score, the conventional tillage treatment receiving spring manure with a winter cover crop performed statistically similarly to three other treatments that were all no-till treatments. Treatments did not differ in aggregate stability, organic matter content, or respiration.

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

| System treatment | Ground cover | Soil carbon | Soil nitrogen | Active carbon | Predicted water holding capacity | Soil protein | Overall score |
|---|---|---|---|---|---|---|---|
| | | % | | | g $H_2O$ g soil$^{-1}$ | mg protein g soil$^{-1}$ | |
| CT-FM-NoCC† | 1.65c‡ | 2.82bc | 0.262b | 835b | 0.255bc | 8.96b | 82.1bcd |
| CT-FM-WRCC | 50.0a | 2.68bc | 0.240b | 799b | 0.249c | 8.34b | 79.7d |
| CT-SM-NoCC | 0.0850c | 2.55c | 0.240b | 793b | 0.258b | 8.52b | 81.2cd |
| CT-SM-WRCC | 37.0ab | 3.25a | 0.300a | 947a | 0.268a | 11.0a | 86.6a |
| NT-FM-NoCC | 1.75c | 2.77bc | 0.252b | 795b | 0.250bc | 8.41b | 82.3bcd |
| NT-FM-WRCC | 27.3b | 2.78bc | 0.259b | 844b | 0.254bc | 8.89b | 85.0ab |
| NT-SM-NoCC | 0.400c | 2.88b | 0.263b | 852b | 0.253bc | 9.21b | 84.1abc |
| NT-SM-WRCC | 12.6bc | 2.80bc | 0.250b | 818b | 0.254bc | 9.09b | 85.3ab |
| LSD ($p$ = 0.10)¥ | 13.5 | 0.290 | 0.029 | 64.0 | 0.00830 | 1.03 | 3.64 |
| Trial mean | 16.4 | 2.82 | 0.258 | 835 | 0.255 | 9.05 | 83.3 |

†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.

At the beginning of the season, management systems did not differ statistically in soil nitrate content (Table 4). However, by the time the corn was in the V6 growth stage, treatments ranged widely in soil nitrate content (summer). The highest nitrate content was observed in the no-till treatment with spring manure and winter cover crop, which was statistically similar to four other treatments which all also received spring manure. The treatment with the lowest soil nitrate at topdress was the conventionally tilled treatment that received fall manure with no winter cover crop. However, the level of nitrate available even in that treatment would only warrant 17.2 lbs N ac$^{-1}$ to be supplemented (based on a 20 ton ac$^{-1}$ yield goal, Nutrient Recommendations for Field Crops in Vermont). All other treatment would not require additional nitrogen. At the end of the season, nitrate levels were assessed in the basal segments of corn stalks in each plot in order to determine nitrate uptake and therefore availability to the plant. The treatment with the highest corn stalk nitrate content was the no-till treatment that received spring manure with a winter cover crop. This was higher than all other treatments which were statistically similar to one another. However, despite not requiring much if any supplemental nitrogen at the time of topdress, all plots had corn stalk nitrate levels below 250ppm indicating insufficient nitrogen available for adequate yield. This was likely due to the extreme drought conditions that persisted through the duration of the trial which would have limited uptake of nitrogen into the plant despite it being present in the soil.

**Table 4. Soil and corn stalk nitrate content by conservation management system.**

| System treatment | Spring | Summer | End of Season | Supplemental N recommendation |
|---|---|---|---|---|
| | ppm | | | lbs ac$^{-1}$ |
| CT-FM-NoCC† | 4.14 | 28.2d‡ | 36.8b | 17.2 |
| CT-FM-WRCC | 2.69 | 57.7cd | 14.5b | 0 |
| CT-SM-NoCC | 4.36 | 93.1ab | 29.0b | 0 |
| CT-SM-WRCC | 3.35 | 116a | 48.5b | 0 |
| NT-FM-NoCC | 4.01 | 87.5abc | 16.0b | 0 |
| NT-FM-WRCC | 4.00 | 62.5bcd | 17.0b | 0 |
| NT-SM-NoCC | 4.04 | 99.6a | 29.5b | 0 |
| NT-SM-WRCC | 3.53 | 120a | 157a | 0 |
| LSD ($p$ = 0.10) ¥ | NS€ | 35.2 | 76.6 | |
| Trial mean | 3.77 | 83.1 | 43.5 | |

†CT- conventional tillage; NT- no-till; FM- fall manure; SM- spring manure; WRCC- winter rye cover crop; NoCC- no cover crop

‡Treatments that share a letter performed statistically similarly to one another.

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

€NS; Not statistically significant

Treatments did not differ in corn silage yield but did vary in some quality parameters (Table 5). Yields ranged from 13.4 to 19.7 tons ac$^{-1}$ but did not differ statistically.

**Table 5. Corn silage yield and quality by conservation management system.**

| System treatment | Yield at 35% DM | CP | aNDFom | Lignin | Starch | TDN | Nel | 240-hr uNDF | 30-hr NDFD | Milk yield | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | tons ac$^{-1}$ | % of DM | | | | | Mcal lb$^{-1}$ | % of NDF | | lbs ton$^{-1}$ | lbs ac$^{-1}$ |
| CT-FM-NoCC | 16.4 | 7.50 | 51.2 | 3.47bc† | 19.7 | 60.3 | 0.582 | 17.2bc | 52.3bc | 2979 | 17159 |
| CT-FM-WRCC | 16.7 | 7.07 | 49.5 | 3.23abc | 24.7 | 62.0 | 0.606 | 14.8ab | 56.3a | 3142 | 18526 |
| CT-SM-NoCC | 18.9 | 8.10 | 50.6 | 3.90c | 17.8 | 59.0 | 0.567 | 17.4bc | 53.0abc | 2891 | 19510 |
| CT-SM-WRCC | 18.4 | 7.80 | 50.3 | 3.90c | 20.0 | 60.7 | 0.580 | 18.3c | 49.6c | 3037 | 19701 |
| NT-FM-NoCC | 13.4 | 6.77 | 44.1 | 2.43a | 33.5 | 64.7 | 0.656 | 12.6a | 56.5a | 3293 | 15340 |
| NT-FM-WRCC | 15.2 | 7.30 | 49.4 | 3.03ab | 23.7 | 62.3 | 0.614 | 15.2ab | 52.9abc | 3176 | 17129 |
| NT-SM-NoCC | 19.7 | 7.73 | 52.3 | 3.77bc | 18.2 | 60.3 | 0.571 | 17.8bc | 51.0c | 2979 | 20880 |
| NT-SM-WRCC | 14.9 | 8.37 | 48.4 | 3.27bc | 22.3 | 62.3 | 0.615 | 14.9ab | 55.7ab | 3178 | 16613 |
| LSD ($p$ = 0.10)‡ | NS¥ | NS | NS | 0.811 | NS | NS | NS | 3.04 | 3.68 | NS | NS |
| Trial mean | 16.7 | 7.58 | 49.5 | 3.38 | 22.5 | 61.5 | 0.599 | 16.0 | 53.4 | 3084 | 18107 |

†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

Treatments differed in lignin, 240-hr uNDF, and NDF digestibility. The no-till treatment receiving fall manure with no cover crop was the top performer in each of these categories but performed statistically similarly to at least two other management treatments within each category. Individual quality parameter differences did not impact the ultimate predicted milk yield.

### *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 6).

**Table 6.** **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† | **‡ | *** |
| Spring soil nitrate | NS | NS | ** |
| Aggregate stability | NS | ** | NS |
| Organic matter | NS | NS | NS |
| Respiration | NS | NS | NS |
| Soil total carbon | ** | NS | NS |
| Active carbon | NS | NS | * |
| Soil total nitrogen | * | NS | NS |
| Soil protein | * | NS | * |
| Water holding capacity | NS | * | NS |
| Overall score | NS | NS | NS |
| Soil nitrate at topdress | NS | * | NS |
| Corn stalk nitrate | * | NS | NS |
| Corn yield | NS | NS | NS |
| Crude protein (CP) | NS | ** | NS |
| Acid detergent fiber (ADF) | NS | NS | NS |
| Neutral detergent fiber (aNDFom) | NS | NS | NS |
| NDF digestibility (30-hr NDFD) | NS | * | NS |
| Undigestible NDF (240-hr uNDF) | NS | ** | * |
| Lignin | NS | ** | ** |
| Starch | NS | ** | NS |
| Total digestible nutrients (TDN) | NS | NS | NS |
| Net energy for lactation (Nel) | NS | NS | NS |
| Milk yield per ton | NS | NS | NS |
| Milk yield per acre | NS | 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.

### *Impact of Cover Crop*

Treatments that contained cover crops exhibited higher total soil carbon, nitrogen, and protein than plots with no cover crop (Table 7). However, these did not correspond to higher active carbon, respiration, aggregate stability, or overall scores for cover crop plots. It is important to note that this trend is different than was observed across the 2018-2020 seasons and may be due to overall poor establishment of the cover crop impacted by drought conditions through the season and around planting.

**Table 7. Cover crop and soil health metrics by cover crop treatment.**

| Cover crop treatment | Ground cover | Soil carbon | Soil nitrogen | Active carbon | Predicted water holding capacity | Soil protein | Overall score |
|---|---|---|---|---|---|---|---|
| | | % | | mg C kg soil$^{-1}$ | g $H_2O$ g soil$^{-1}$ | mg protein g soil$^{-1}$ | |
| No cover crop | 0.970 | 2.75 | 0.254 | 819 | 0.254 | 8.77 | 82.4 |
| Cover crop | 31.7 | 2.88 | 0.262 | 852 | 0.256 | 9.32 | 84.1 |
| Level of significance | NS‡ | **† | * | NS | NS | * | NS |
| Trial mean | 16.4 | 2.82 | 0.258 | 835 | 0.255 | 9.05 | 83.3 |

†*Significant at the p=0.10 probability level; **Significant at the p=0.05 probability 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. However, plots with cover crops contained similar soil nitrate-N both in the spring and at time of topdress to plots without cover crops (Figure 1). Furthermore, based on the soil nitrate-N contents at the time of topdress, no additional nitrogen was recommended for either treatment. By the end of the season, the nitrate content of the corn stalks did differ statistically (Figure 2), however, levels were higher in plots with cover crops indicating corn in those plots took up more nitrate from the soil than in plots without cover crops. However, this did not translate into higher yields and corn stalk nitrate levels in both treatments indicate insufficient nitrate to support high yields. This was likely due to drought conditions limiting uptake into the plant despite the presence of nitrate in the soil. Most importantly, the presence of a cover crop did not hinder nitrate availability nor corn yield.

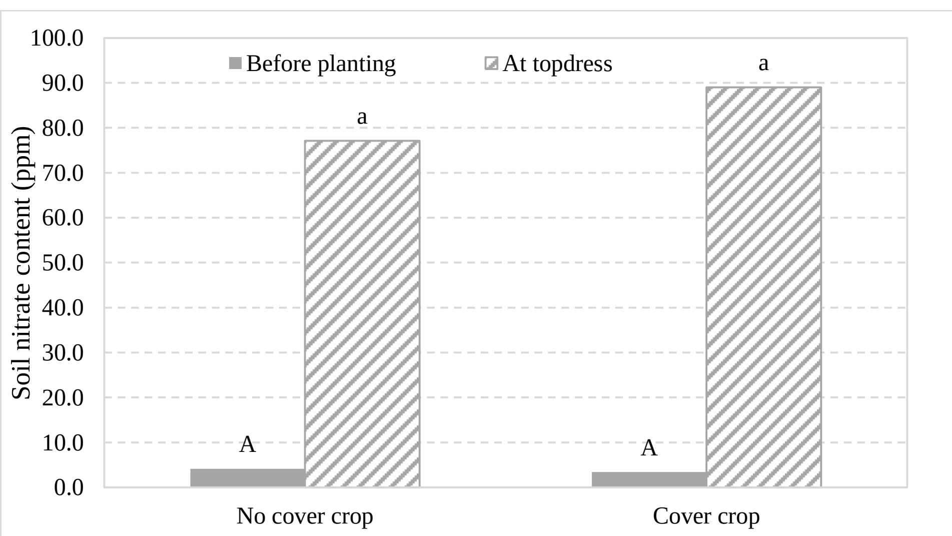


**Figure 1. Soil nitrate content before planting and at the time of topdress.**
Treatments with the same letter performed statistically similarly to one another.

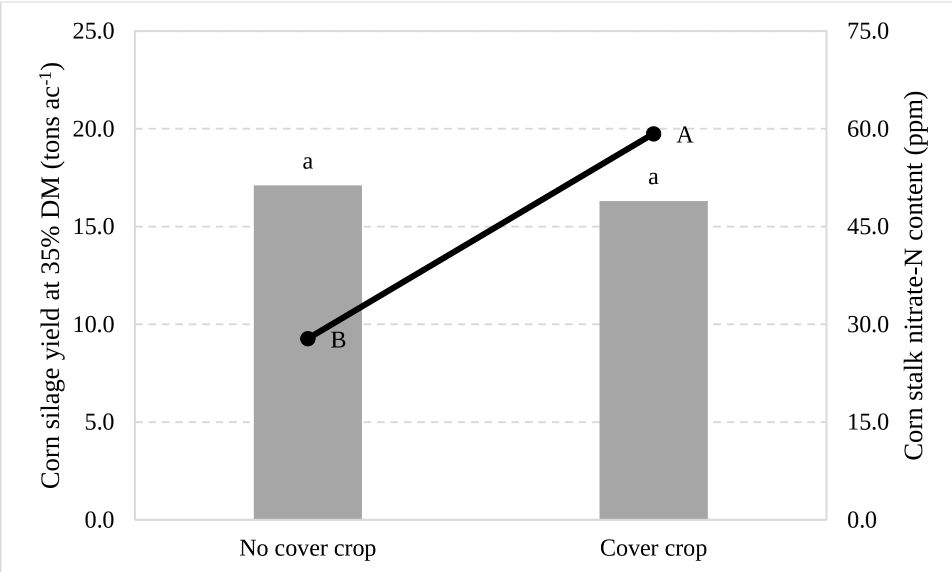


**Figure 2. Corn silage yield and corn stalk nitrate content by cover crop treatment.**
Treatments with the same letter performed statistically similarly to one another.

Despite this higher N uptake in cover crop plots, corn silage quality was similar across cover crop treatments (Table 8).

**Table 8. Corn silage quality characteristics by cover crop treatment.**

| | CP | aNDFom | Lignin | Starch | TDN | NEL | 240-hr uNDF | 30-hr NDFD | Milk yield | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | % of DM | | | Mcal lb$^{-1}$ | % of NDF | | lbs ton$^{-1}$ | lbs ac$^{-1}$ |
| No cover crop | 7.53 | 49.6 | 3.39 | 22.3 | 61.1 | 0.594 | 16.3 | 53.2 | 3035 | 18222 |
| Cover crop | 7.63 | 49.4 | 3.36 | 22.7 | 61.8 | 0.604 | 15.8 | 53.6 | 3133 | 17992 |
| Level of significance | NS† | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Trial mean | 7.58 | 49.5 | 3.38 | 22.5 | 61.5 | 0.599 | 16.0 | 53.4 | 3084 | 18107 |

†NS; Not statistically significant.

### *Impact of Manure Application Timing*

Cover crops established better when manure was applied in the fall at the time of planting (Table 9). This is evidenced by higher spring ground cover in plots receiving fall manure where the cover crop growth was denser and thus provided more ground coverage. However, aggregate stability and water holding capacity were higher in plots receiving spring manure while all other soil health metrics remained statistically similar between manure timing treatments. This was similar to what was observed in the 2018-2020 seasons.

Corn silage yield was not impacted by manure timing (Figure 3). While soil nitrate levels at the time of topdress were significantly higher in plots receiving spring manure, both manure timing treatments provided sufficient nitrate that additional nitrogen supplementation would not be recommended. Furthermore, by harvest both treatments had statistically similar levels of N uptake into the plant as evidence by the corn stalk nitrate analysis.

**Table 9. Cover crop and soil health metrics by manure application timing.**

| Manure application timing | Ground cover | Aggregate stability | Soil carbon | Active carbon | Predicted water holding capacity | Soil protein | Overall score |
|---|---|---|---|---|---|---|---|
| | | % | | mg C kg soil$^{-1}$ | g $H_2O$ g soil$^{-1}$ | mg protein g soil$^{-1}$ | |
| Fall manure | 20.2 | 25.2 | 2.76 | 818 | 0.252 | 8.65 | 82.3 |
| Spring manure | 12.5 | 25.3 | 2.87 | 853 | 0.258 | 9.44 | 84.3 |
| Level of significance | **† | ** | NS‡ | NS | * | NS | NS |
| Trial mean | 16.4 | 25.3 | 2.82 | 835 | 0.255 | 9.05 | 83.3 |

†*Significant at the p=0.10 probability level; **Significant at the p=0.05 probability level.
‡NS; Not statistically significant.

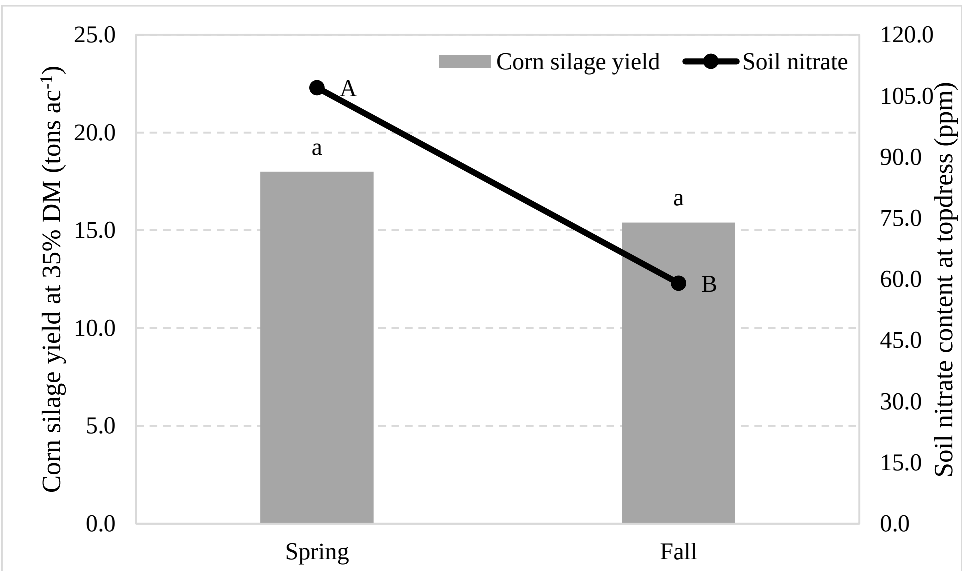


**Figure 3. Corn yield and soil nitrate content at time of topdress by manure application timing treatment.** Treatments that share the same letters performed statistically similarly to one another.

Crude protein levels were higher in corn silage plots that received spring manure (Table 10). Conversely, fall manure application led to lower lignin, 240-hr uNDF, and higher 30-hr NDF digestibility. However, when multiple quality parameters were considered, predicted milk yields did not differ between treatments.

**Table 10. Corn silage yield and quality characteristics by manure application timing.**

| Manure application timing | CP | aNDFom | Lignin | Starch | TDN | NEL | 240-hr uNDF | 30-hr NDFD | Milk yield | |
|---|---|---|---|---|---|---|---|---|---|---|
| | % of DM | | | | | Mcal lb$^{-1}$ | % of NDF | | lbs ton$^{-1}$ | lbs ac$^{-1}$ |
| Fall manure | 7.16 | 48.6 | 3.04 | 25.4 | 62.3 | 0.614 | 15.0 | 54.5 | 3147 | 17038 |
| Spring manure | 8.00 | 50.4 | 3.71 | 19.6 | 60.6 | 0.583 | 17.1 | 52.3 | 3021 | 19176 |
| Level of significance† | ** | NS‡ | ** | ** | NS | NS | ** | * | NS | NS |
| Trial mean | 7.58 | 49.5 | 3.38 | 22.5 | 61.5 | 0.599 | 16.0 | 53.4 | 3084 | 18107 |

†*Significant at the p=0.10 probability level; **Significant at the p=0.05 probability level.
‡NS; Not statistically significant.

### *Impact of Tillage Method*

Ground cover differed statistically between tillage treatments (Table 11) as cover crops established more consistently in conventionally tilled plots (Images 1 and 2). Active carbon and soil protein were 17 mg kg$^{-1}$ and 0.290 mg g$^{-1}$ higher respectively in conventionally tilled plots. This is likely related to the better establishment of cover crops in these plots as cover crops were shown to increase active carbon and protein in the soil. Despite some differences in soil health metrics, overall soil health scores did not differ significantly by tillage treatment.

**Table 11. Cover crop and soil health metrics by tillage treatment.**

| Tillage treatment | Ground cover | Aggregate stability | Soil carbon | Active carbon | Predicted water holding capacity | Soil protein | Overall score |
|---|---|---|---|---|---|---|---|
| | | % | | mg C kg soil$^{-1}$ | g $H_2O$ g soil$^{-1}$ | mg protein g soil$^{-1}$ | |
| Conventional | 22.2 | 22.8 | 2.82 | 844 | 0.258 | 9.19 | 82.4 |
| No-till | 10.5 | 27.8 | 2.81 | 827 | 0.253 | 8.90 | 84.2 |
| Level of significance | ***† | NS‡ | NS | * | NS | * | NS |
| Trial Mean | 16.4 | 25.3 | 2.82 | 835 | 0.255 | 9.05 | 83.3 |

†*Significant at the P=0.1 probability level; ***Significant at the P<.0001 probability level.
‡NS; not statistically significant.

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

Corn silage yields did not differ between tillage treatments (Table 12). In terms of quality, tillage treatments only differed in lignin and 240-uNDF content. In both cases the no-till plots produced corn silage with lower lignin and 240-uNDF content. Overall, however, predicted milk yields were similar between tillage treatments.

**Table 12. Corn silage yield and quality by tillage treatment.**

| Tillage treatment | Yield at 35% DM | CP | aNDFom | Lignin | Starch | TDN | NEL | 240-hr uNDF | 30-hr NDFD | Milk yield | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | tons ac$^{-1}$ | % of DM | | | | | Mcal lb$^{-1}$ | % of NDF | | lbs ton$^{-1}$ | lbs ac$^{-1}$ |
| Conventional | 17.6 | 7.62 | 50.4 | 3.63 | 20.5 | 60.5 | 0.584 | 16.9 | 52.8 | 3012 | 18724 |
| No-till | 15.8 | 7.54 | 48.6 | 3.13 | 24.4 | 62.4 | 0.614 | 15.1 | 54.0 | 3156 | 17491 |
| Level of significance | NS‡ | NS | NS | **† | NS | NS | NS | * | NS | NS | NS |
| Trial mean | 16.7 | 7.58 | 49.5 | 3.38 | 22.5 | 61.5 | 0.599 | 16.0 | 53.4 | 3084 | 18107 |

†*Significant at the P=0.1 probability level; ***Significant at the P<.0001 probability 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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