
# 2023 Corn Cropping Systems to Improve Economic and Environmental Health

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THE UNIVERSITY OF VERMONT EXTENSION

**2023 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH**

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In 2023, UVM Extension's Northwest Crops & Soils Program continued a multi-year trial at Borderview Research Farm in Alburgh, VT to assess the impact of corn cropping systems on overall health and productivity of the crop and soil. Management choices involving crop rotation, tillage, nutrient management, and cover crops also make differences in the long term. Yields are important and they affect the bottom line immediately and obviously. Growing corn with practices that enhance soil quality and crop yields improves farm resiliency to both economics and the environment. This project evaluated yield and soil health effects of six different corn rotations: continuous corn, no-till, no-till with cover crop, corn planted in a rotation with perennial forage, corn planted after a cover crop of winter rye, and a perennial forage fescue planted after continue corn.

# MATERIALS AND METHODS

The corn cropping system trial was established at Borderview Research Farm in Alburgh, VT in 2014. The experimental design was a randomized complete block with replicated treatments of corn grown in various cropping systems (Table 1).

**Table 1. Corn cropping system specifics for corn yield and soil health, Alburgh, VT, 2023.**

| Crop | Management method | Treatment abbreviation |
|---|---|---|
| Corn silage | Continuous corn, tilled | CC |
| Corn silage | Fourth year in corn silage in 5-year corn/5-year hay rotation | RotYr4 (corn) |
| Corn silage | No-till corn | NT |
| Corn Silage | No-Till with winter cover crop | NTCC |
| Corn silage | Winter cover crop, tilled | WCCC |
| Perennial Forage | Fourth year in perennial forage in 5-year corn/5-year hay rotation | RotYr9 (forage) |

The soil type at the research site was an Amenia silt loam with 0-2% slopes (Table 2). Each cropping system was replicated 4 times in 20' x 50' plots, except the NT plots which were split in half (10' x 50') to study effects of cover crops in a long-term no-till corn system. Soil samples were collected on 14-Apr and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis (Ithaca, NY). Ten soil samples from five locations within each plot were collected six inches in depth with a trowel, thoroughly mixed, put in a labeled gallon bag, and mailed.

Percent aggregate stability was measured by Cornell Sprinkle Infiltrometer and indicates ability of soil to resist erosion. Predicted percent available water capacity and predicted soil protein (N mg/soil g) was calculated with a Random Forest model from a suite of measured parameters and soil texture (Cornell Soil Health Manual Series, Fact Sheet Number 19-05b). Predicted soil protein is used to quantify organically bound nitrogen (N) that microbial activity can mineralize from soil organic matter and make plant-available.

Percent organic matter was measured by loss on ignition when soils are dried at 105°C to remove water then ashed for two hours at 500°C. Total carbon (organic and inorganic forms) is measured using complete oxidation of carbon at high temperature combustion (2,000° F). Total nitrogen is measured with DUMAS combustion methodology. It measures organic (living and non-living) and inorganic (mineral) forms of nitrogen. Active carbon (active C mg/soil kg) was measured with potassium permanganate and is used as an indicator of available carbon (i.e. food source) for the microbial community. Soil respiration ($CO_2$ mg/soil g) is measured by amount of $CO_2$ released over a four-day incubation period and is used to quantify metabolic activity of the soil microbial community. The Overall Quality Score is an average of all soil health indicator ratings. It includes the aforementioned quality indicators as well as pH, phosphorus, and potassium levels. It should be considered as a general summary for soil quality. The scores range between 0-100%. Less than 20% is regarded as very low, 20-40% is low, 40-60% is medium, 60-80% is high, and greater than 80% is very high.

On 27-Apr, cover crops were sampled in all WCCC plots. Dried and coarsely-ground plot samples were reground using a cyclone sample mill (1mm screen) from the UDY Corporation and brought to UVM's Agricultural and Environmental Testing Laboratory (AETL) where they were analyzed for carbon and nitrogen using gas chromatography. The cover crop in the NTCC plots was terminated on 27-Apr with 1 qt ac$^{-1}$ Glystar Plus. The CC, WCCC, and RotYr4 plots were tilled with a Pottinger TerraDisc on 27-Apr (Table 2). Corn was seeded in 30" rows with a John Deere 1750 corn planter on 9-May in the CC, WCCC, NT, NTCC, and RotYr4 plots. At planting, 200 lbs ac$^{-1}$ of 10-20-20 starter fertilizer was applied to all corn plots. The corn variety was Pioneer P9608AM, relative maturity (RM) of 96 days, seeded at 34,000 seeds ac$^{-1}$.

**Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2023.**

| Location | Borderview Research Farm – Alburgh, VT |
|---|---|
| **Soil type** | Amenia silt loam, 0-2% slope |
| **Previous crop** | Corn or Alfalfa/Fescue |
| **Plot size (ft)** | 20 x 50, except 10 x 50 for NT & NTCC |
| **Replications** | 4 |
| **Management treatments** | Tilled continuous corn (CC), tilled rye cover crop (WCCC), 4$^{th}$ year corn (RotYr4), no-till corn (NT), no-till with cover crop (NTCC), 4$^{th}$ year perennial forage (RotYr9) |
| **Corn variety** | Proseed P9608AM (96 RM) |
| **Seeding rates (seeds ac$^{-1}$)** | 34,000 |
| **Planting equipment** | John Deere 1750 corn planter |
| **Cover crop (2022)** | 75 lbs ac$^{-1}$ organic hazlet winter rye, 10-Sep-2022 |
| **Tillage date** | 27-Apr (CC, WCCC, RotYr4) |
| **Planting date** | 9-May (CC, WCCC, NT, NTCC, RotYr4) |
| **Row width (in.)** | 30 |
| **Corn Starter fertilizer (at planting)** | 200 lbs ac$^{-1}$ 10-20-20, 9-May |
| **Corn nitrogen sidedress** | 250 lbs ac$^{-1}$ (46-0-0) with ContaiN Max™, 21-Jun |

**Table 2 (cont'd). Agronomic information for corn cropping system, Alburgh, VT, 2023.**

| Location | Borderview Research Farm – Alburgh, VT |
|---|---|
| **RotYr9 1st harvest date** | 26-May |
| **Forage fertilizer** | 100 lbs ac$^{-1}$ 46-0-60, 30-May |
| **RotYr9 2nd harvest date** | 16-Jul |
| **Forage fertilizer** | 100 lbs ac$^{-1}$ 0-0-60, 17-Jul |
| **RotYr9 3rd harvest date** | 3-Aug |
| **Forage fertilizer** | 200 lbs ac$^{-1}$ 5-11-22, 4-Aug |
| **Corn harvest date** | 14-Sep |

The PSNT soil samples were collected on 12-Jun with a 1-inch diameter Oakfield core to six inches in depth at five locations per plot. The samples were combined by plot and analyzed by UVM's AETL using KCl extract and ion chromatograph. Corn was top-dressed on 21-Jun with 250 lbs ac$^{-1}$ urea (46-0-0) with ContaiN Max™, a nitrogen urease inhibitor, by broadcast.

Corn was harvested for silage from NT, NTCC, WCCC, CC, and RotYr4 plots on 14-Sep with a John Deere 2-row chopper and weighed in a wagon fitted with scales. Corn populations were determined by counting number of corn plants the entire length of the plot (50 feet) in the middle two rows of each plot. Dry matter yields were calculated and adjusted to 35% dry matter. Silage quality was analyzed using the FOSS NIRS (near infrared reflectance spectroscopy) DS2500 Feed and Forage analyzer. Dried and coarsely-ground plot samples were brought to the E. E. Cummings Crop Testing Laboratory at the University of Vermont where they were reground using a cyclone sample mill (1mm screen) from the UDY Corporation. The samples were then analyzed using the FOSS NIRS DS2500 for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), and Net Energy-Lactation ($NE_L$).

Perennial forage was harvested and weighed with a Carter Forage Harvester fitted with scales in one 3' x 50' strips. RotYr9 was harvested on 26-May, 16-Jul, and 3-Aug. After 1st cut, RotYr9 plots received 100 lbs ac$^{-1}$ 46-0-60 on 30-May. After 2nd cut, RotYr9 received 100 lbs ac$^{-1}$ 0-0-60 on 17-Jul. After 3rd cut, RotYr9 received 200 lbs ac$^{-1}$ 5-11-22 on 4-Aug. Perennial forage moisture and dry matter yield were calculated with an approximate two-pound subsample of the harvested material from each strip was collected, dried, ground, and then analyzed at the E. E. Cummings Crop Testing Laboratory at the University of Vermont for quality analysis with the methods outlined above. CP, ADF, NDF and 30-hour digestible NDF (NDFD) were determined.

Mixtures of true proteins, composed of amino acids and non-protein nitrogen, make up the CP content of forages. The CP content of forages is determined by measuring the amount of nitrogen and multiplying by 6.25. The bulky characteristics of forage come from fiber. Forage feeding values are negatively associated with fiber since the less digestible portions of plants are contained in the fiber fraction. The detergent fiber analysis system separates forages into two parts: cell contents, which include sugars, starches, proteins, non-protein nitrogen, fats and other highly digestible compounds; and the less digestible components found in the fiber fraction. The total fiber content of forage is contained in the neutral detergent fiber (NDF). Chemically, this fraction includes cellulose, hemicellulose, and lignin. Because of these chemical components and their association with the bulkiness of feeds, NDF is closely related to feed intake and rumen fill in cows. In recent years, the need to determine rates of digestion in the rumen of the cow has led to the development of NDFD. This in vitro digestibility calculation is very important when looking at how fast feed is being digested and passed through the cow's rumen. Higher rates of digestion lead to higher dry matter intakes and higher milk production levels. Similar types of feeds can have varying NDFD values based on growing conditions and a variety of other factors. In this research, the NDFD calculations are based on 30-hour in vitro testing.

Net energy for lactation ($NE_L$) is calculated based on concentrations of NDF and ADF. $NE_L$ can be used as a tool to determine the quality of a ration, but should not be considered the sole indicator of the quality of a feed, as $NE_L$ is affected by the quantity of a cow's dry matter intake, the speed at which her ration is consumed, the contents of the ration, feeding practices, the level of her production, and many other factors. Most labs calculate $NE_L$ at an intake of three times maintenance. Starch can also have an effect on $NE_L$, where the greater the starch content, the higher the $NE_L$ (measured in Mcal per pound of silage), up to a certain point. High grain corn silage can have average starch values exceeding 40%, although levels greater than 30% are not considered to affect energy content and might in fact have a negative impact on digestion. Starch levels vary from field to field, depending on growing conditions and variety.

Milk per acre and milk per ton of harvested feed are two measurements used to combine yield with quality and arrive at a benchmark number indicating how much revenue in milk can be produced from an acre or a ton of corn silage. This calculation relies heavily on the $NE_L$ calculation and can be used to make generalizations about data, but other considerations should be analyzed when including milk per ton or milk per acre in the decision-making process.

Yield data and stand characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and corn cropping systems were treated as fixed. Treatment mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

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 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 treatments 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. Treatments that did not perform significantly different from each other share the same letter. In this example, treatment C is significantly different from treatment A, but not from treatment 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 treatments 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 with these treatments were significantly different from one another. The shared letter indicates that treatment B was not significantly lower than the top yielding treatment C, indicated in bold.

| Treatment | Yield |
|---|---|
| A | 6.0[b] |
| B | 7.5[a] |
| C | **9.0[a]** |
| **LSD** | **2.0** |

# RESULTS

## Weather Data

Weather data were collected with an onsite Davis Instruments Vantage Pro2 weather station equipped with a WeatherLink data logger. Temperature, precipitation, and accumulation of Growing Degree Days (GDDs) are consolidated for the 2023 growing season (Tables 3 and 4). Historical weather data are from 1991-2020 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT.

On average, the 2023 corn growing season was 1.8° F cooler than the 30-year average. Although there was a rainfall deficit early in the season (May), in July and August there was 7.78 more inches than the 30-year average. The corn growing season had a total of 2037 Growing Degree Days (GDDs) for corn from May through August—123 GDDs less than the historical average (Table 3). All months except April and July had lower than average GDDs. The forage growing season was also wetter and cooler than usual (Table 4). Beginning with 2.70 more inches of rain in April than the 30-year average, the forage growing season ended with 9.65 more inches than the 30-year average. There was a total of 2191 GDDs for forages from April through August—53 GDDs less than the historical average.

**Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2023.**

| **Alburgh, VT** | May | June | July | August |
|---|---|---|---|---|
| Average temperature (°F) | 57.1 | 65.7 | 72.2 | 67.0 |
| Departure from normal | -1.28 | -1.76 | -0.24 | -3.73 |
| | | | | |
| Precipitation (inches) | 1.98 | 4.40 | 10.8 | 6.27 |
| Departure from normal | -1.78 | 0.14 | 6.69 | 2.73 |
| | | | | |
| Corn GDDs (base 50°F) | 303 | 483 | 712 | 540 |
| Departure from normal | 1.00 | -41.0 | 17.0 | -101 |

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.

**Table 4. Consolidated weather data and GDDs for perennial forage, Alburgh, VT, 2023.**

| **Alburgh, VT** | April | May | June | July | August |
|---|---|---|---|---|---|
| Average temperature (°F) | 48.3 | 57.1 | 65.7 | 72.2 | 67.0 |
| Departure from normal | 2.70 | -1.28 | -1.76 | -0.24 | -3.73 |
| | | | | | |
| Precipitation (inches) | 4.94 | 1.98 | 4.40 | 10.8 | 6.27 |
| Departure from normal | 1.87 | -1.78 | 0.14 | 6.69 | 2.73 |
| | | | | | |
| Perennial forage GDDs (base 41°F) | 306 | 499 | 749 | 991 | 819 |
| Departure from normal | 91.0 | -40.0 | -44.0 | 17.0 | -101 |

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.

## Soil Test Results

On 14-Apr, before field operations, soil samples were collected on all plots. There were statistical differences in soil health indicators and soil health scores among the cropping systems (Tables 5 and 6). The soil health score of NT treatments (NT and NTCC) were significantly higher than the cropping systems, RotYr9 (forage), WCCC, and CC. The treatment RotYr9 (forage) is in its fourth year of perennial forage and these results suggest that it may take years of non-disturbance of soil and perennial forage to recover from years of continuous corn and tillage. Overall, RotYr4 (corn) had superior soil health when compared to any of the cropping systems. This indicates that the soil health accrued during the perennial forage years of this rotation were still observed after 4 years of continuous corn. The CC treatment consistently had the lowest soil health metric measurements among any of the treatments.

There were other individual soil health indicator differences among treatments. The RotYr4 treatment had significantly higher organic matter, active carbon, total carbon, total nitrogen, soil protein. For four years previous to 2023, RotYr4 consistently had significantly higher soil respiration and aggregate stability than the continuous corn treatments. However, in 2023, soil respiration and aggregate stability did not differ between RotYr4 and NTCC. This suggests that either the cover crop/no-till synergy is having an effect or the positive soil health legacy effects of perennial forage are waning.

NT and NTCC had statistically similar levels of all soil health indicators except soil respiration where NTCC had higher soil respiration than NT. WCCC performed similarly to CC in all metrics except soil respiration, in which it was significantly higher than CC. The differences among systems with cover crop and those without may be that the soil samples were taken too early in the easy to capture the additional carbon and nitrogen that would be released from the soil micro-organisms feeding on the living roots and decomposing the dying cover crop vegetation.

The WCCC and CC treatments had the lowest aggregate stability among any of the treatments. With the exception of aggregate stability, RotYr9 (forage) had similar results to WCCC. This is a shift from previous years' results when RotYr8 had similar results to WCCC. This indicates that it may take about four years after transition from continuous corn with tillage to perennial forage to begin building up aggregate stability.

**Table 5. Organic matter, active carbon, total carbon, total nitrogen, soil proteins, and soil respiration for six cropping systems, Alburgh, VT, 2023.**

| Cropping system | Organic matter % | Active carbon ppm | Total carbon % | Total nitrogen % | Soil proteins N mg/soil g | Soil respiration $CO_2$ mg/soil g |
|---|---|---|---|---|---|---|
| CC | 3.35$^{d†}$ | 542$^{b}$ | 2.09$^{c}$ | 0.217$^{c}$ | 5.80$^{c}$ | 0.346$^{e}$ |
| RotYr4 (corn) | 4.55$^{a}$ | 654$^{a}$ | 3.02$^{a}$ | 0.289$^{a}$ | 8.10$^{a}$ | 0.534$^{a}$ |
| NT | 3.69$^{bc}$ | 506$^{b}$ | 2.46$^{b}$ | 0.250$^{b}$ | 7.25$^{b}$ | 0.382$^{de}$ |
| NTCC | 3.89$^{b}$ | 553$^{b}$ | 2.48$^{b}$ | 0.248$^{b}$ | 7.13$^{b}$ | 0.509$^{ab}$ |
| WCCC | 3.47$^{cd}$ | 557$^{b}$ | 2.10$^{c}$ | 0.213$^{c}$ | 5.74$^{c}$ | 0.420$^{cd}$ |
| RotYr9 (forage) | 3.62$^{c}$ | 515$^{b}$ | 2.21$^{c}$ | 0.221$^{c}$ | 5.94$^{c}$ | 0.470$^{bc}$ |
| LSD (0.10)‡ | 0.220 | 53.3 | 0.216 | 0.020 | 0.532 | 0.061 |
| Trial Mean | 3.76 | 554 | 2.39 | 0.240 | 6.66 | 0.443 |

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.

**Table 6. Aggregate stability, available water capacity, surface hardness, sub-surface hardness, and overall soil health score for six cropping systems, Alburgh, VT, 2023.**

| Cropping system | Aggregate stability % | Available water capacity m/m | Surface hardness psi | Sub-surface hardness psi | Soil health score |
|---|---|---|---|---|---|
| CC | 22.9[d†] | 0.226 | 137 | 172 | 67.7[c] |
| RotYr4 (corn) | 49.6[a] | 0.229 | 101 | 179 | 79.2[a] |
| NT | 42.1[b] | 0.227 | 109 | 171 | 72.9[b] |
| NTCC | 46.0[ab] | 0.230 | 195 | 176 | 72.0[b] |
| WCCC | 23.8[d] | 0.222 | 142 | 182 | 67.5[c] |
| RotYr9 (forage) | 33.0[c] | 0.230 | 138 | 177 | 66.6[c] |
| LSD (0.10)[‡] | 5.84 | NS[§] | NS | NS | 4.00 |
| Trial Mean | 36.2 | 0.227 | 137 | 176 | 71.0 |

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

On 1-Jun, soil samples were collected for PSNT analysis (Table 7). There was no significant difference in corn cropping systems for soil nitrate concentrations or nitrogen recommendations to obtain 25 ton $ac^{-1}$ yields. Mean soil nitrate-N ($NO^-_3$-N) among the treatments was 11.6 ppm with a mean N recommendation of 104 N lbs $ac^{-1}$. Nitrogen as urea (46-0-0) with Contain Max**™** was applied to all corn plots on 21-Jun at a rate of 250 lbs $ac^{-1}$ (115 N lbs $ac^{-1}$).

**Table 7. Soil nitrate-N and N recommendations for high yield potential, Alburgh, VT, 2023.**

| Corn cropping system | $NO^-_3$-N ppm | N recommendation for 25 ton $ac^{-1}$ corn lbs N $ac^{-1}$ |
|---|---|---|
| CC | 9.79 | 115 |
| RotYr4 | 16.6 | 76.3 |
| NT | 12.6 | 98.9 |
| NTCC | 7.70 | 124 |
| WCCC | 11.3 | 105 |
| LSD (0.10)[†] | NS[‡] | NS |
| Trial Mean | 11.6 | 104 |

† LSD – Least Significant Difference at p=0.10.
‡ NS – No significant difference was determined among the treatments.

**Cover Crop Results**

On 27-Apr, cover crop samples were taken in the NTCC and WCCC plots. The winter rye cover plots yielded an average of 1769 dry matter (DM) lbs $ac^{-1}$. On average, cover crop biomass was 43.1% carbon and 2.98% nitrogen for an average C:N ratio of 43:3. This means the cover crop contributed 760 lbs $ac^{-1}$ of carbon and 56.8 lbs $ac^{-1}$ of nitrogen to the soil.

**Corn and Perennial Forage Crop Results**

On 14-Sep, data was collected on corn silage populations and corn plots were harvested to determine moisture and yield (Table 8). Forage plots were harvested on 26-May, 16-Jul, and 3-Aug to determine moisture and yield (Table 8). There were no differences in dry matter yield or yield at 35% DM among any of the cropping systems indicating the potential of perennial forage to rival corn silage yields especially in a wet and cool season (Table 8, Figure 1).

**Table 8. Corn silage population, harvest dry matter, and yield by treatment, Alburgh, VT, 2023.**

| Corn cropping system | Harvest population plants ac$^{-1}$ | Yield at DM ton ac$^{-1}$ | Yield at 35% DM ton ac$^{-1}$ |
|---|---|---|---|
| CC | 33,672 | 8.10 | 23.1 |
| RotYr4 | 35,937 | 8.75 | 25.0 |
| NT | 26,659 | 6.12 | 17.5 |
| NTCC | 32,017 | 7.53 | 21.5 |
| WCCC | 33,977 | 7.69 | 22.0 |
| RotYr9 | n/a | 7.20 | 20.6 |
| LSD (0.10)‡ | NS§ | NS | NS |
| Trial mean | 32,452 | 7.57 | 21.6 |

‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

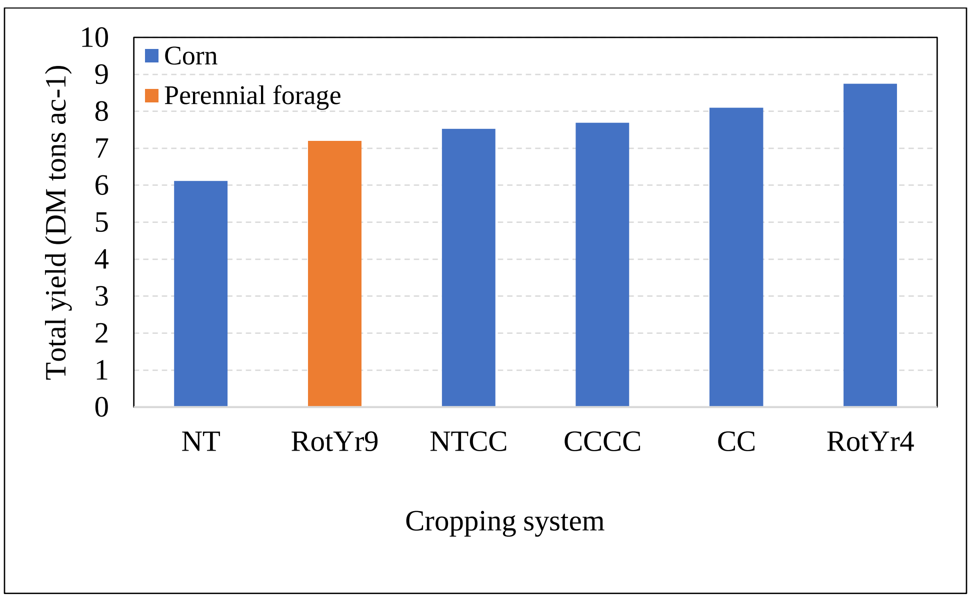


**Figure 1. Cropping system total yield, Alburgh, VT, 2023.**

Standard components of corn silage and the average RotYr9 perennial forage were analyzed for basic quality parameters (Table 9). There were no significant differences in NDF among any of the treatments. Among the corn treatments, CP was higher in NT than RotYr4 and NTCC. Also among the corn treatments, WCCC and RotYr4 had higher NDFD30 concentrations than CC. Among the corn treatments, there is no clear connection between soil health quality and differences in forage quality e.g., RotYr4 has higher soil nitrate and soil protein content than NT, but CP is lower in RotYr4. Despite these differences in forage quality indicators among corn treatments, there were no differences in ADF, TDN, $NE_L$, milk lbs ton$^{-1}$, and milk lbs ac$^{-1}$. This indicates that the corn forage quality indicators did not significantly result in impacts to milk energy content or production. Although the perennial forage in RotYr9 had comparable yields, higher CP, and higher NDFD 30 than the corn treatments, overall RotYr9 had lower forage quality and less milk lbs ton$^{-1}$ and milk lbs ac$^{-1}$ production.

**Table 9. Impact of cropping systems on crop quality, 2023.**

| | | | | | | | Milk | |
|---|---|---|---|---|---|---|---|---|
| **Cropping system** | **CP % of DM** | **ADF % of DM** | **NDF % of DM** | **NDFD 30 % of NDF** | **TDN % of DM** | **$NE_L$ Mcal lb$^{-1}$** | **lbs ton$^{-1}$** | **lbs ac$^{-1}$** |
| CC | 7.28[bc†] | 23.2[a] | 41.3 | 50.8[c] | 64[a] | 1.45[a] | 3,212[a] | 24,772[a] |
| RotYr4 | 7.10[c] | 24.6[a] | 43.9 | 53.2[b] | 63[a] | 1.41[a] | 3,117[a] | 26,718[a] |
| NT | 7.80[b] | 22.8[a] | 41.0 | 52.7[bc] | 63[a] | 1.46[a] | 3,211[a] | 24,624[a] |
| NTCC | 6.93[c] | 23.6[a] | 42.5 | 52.5[bc] | 63[a] | 1.44[a] | 3,172[a] | 23,875[a] |
| WCCC | 7.30[bc] | 23.3[a] | 41.6 | 54.3[b] | 64[a] | 1.45[a] | 3,216[a] | 23,177[a] |
| RotYr9 | 17.7[a] | 33.1[b] | 48.4 | 58.7[a] | 60[b] | 1.31[b] | 1,693[b] | 4,069[b] |
| LSD (0.10)[‡] | 0.556 | 3.74 | NS[§] | 2.44 | 1.25 | 0.042 | 119 | NS |
| Trial mean | 9.02 | 25.1 | 43.1 | 53.7 | 63 | 1.42 | 2,937 | 21,206 |

† Within a column, treatments with the same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
§ NS – No significant difference was determined among the treatments.

# DISCUSSION

The goal of this project is to monitor long-term soil and crop health in these cropping systems. Based on the analysis of the data, some conclusions can be made about the results of this year's trial. In terms of soil quality, the system with the most recent rotation from sod, RotYr4, performed best overall. Continuous corn treatments in tillage or treatments recently out of continuous corn (CC, WCCC, & RotYr9) had the statistically lowest soil health scores. This indicates that it may take more than four years of perennial forage to build soil health levels different from continuous corn production or similar to NT production.

No-till plots (NT & NTCC) had the second highest soil health scores. This indicates that there are some benefits from not tilling the soil. The NT and NTCC treatments were transitioned from perennial forage to corn over ten years ago and the lack of soil disturbance is reflected in many of the soil quality measurements. These treatments clearly show the potential for no-till corn to maintain soil quality during the corn years of a rotation. The similar scores of NT and NTCC indicate that perhaps it takes more than three years for the synergistic effects of no-till and cover cropping to make an effective difference on soil health.

There were no significant differences among the plant populations of the corn treatments and no yield differences among any of the treatments. Typically, we observe suppressed yields in the NT corn treatment compared to other corn treatments with tillage. However, in an unusually cool and wet year, the corn and perennial forage treatments did not have significantly different yields from each other. However, overall perennial forage quality and production $ac^{-1}$ and $lb^{-1}$ of milk was lower than the corn forage quality of any of the other production systems. The data presented here only represents one year and data analysis over multiple years provides an opportunity to make observations about long-term trends. In 2024, we will collect more data to inform long-term trend analysis.


# ACKNOWLEDGEMENTS

This project was funded by a grant through the Ben and Jerry's Homemade, Inc. UVM Extension Northwest Crops and Soils Program would like to thank Roger Rainville and the staff at Borderview Research Farm for their generous help with this research trial as well as Catherine Davidson, Ivy Krezinski, and Sophia Wilcox Warren for their assistance with data collection and entry. The information is presented with the understanding that no product discrimination is intended and no endorsement of any product mentioned or criticism of unnamed products is implied.


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