2021 Corn Cropping Systems to Improve Economic and Environmental Health

Dr. Heather Darby, UVM Extension Agronomist
Lindsey Ruhl and Sara Ziegler
UVM Extension Crops and Soils Technicians
802-524-6501

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2021 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

In 2021, 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 five different corn rotations: continuous corn, no-till, corn planted in a rotation with perennial forage, corn planted after a cover crop of winter rye, and a perennial forage fescue.

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). In 2020, in plots that were planted in corn every year since 2014, a mixture of alfalfa/fescue was planted. Also in 2020, plots that had been perennial forage since 2008 were tilled, and the first year of corn was planted after first cut. In the fall of 2020, winter cover crops were planted in conventional and no-till corn plots.

Table 1. Corn cropping system specifics for corn yield and soil health, Alburgh, VT, 2021.

Crop	Management method	Treatment abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	Second year in corn silage in 5-year corn/5-year hay rotation	RotYr2
Corn silage	No-till corn	NT
Corn Silage	No-Till with winter cover crop	NTCC
Corn silage	Winter cover crop, tilled	WCCC
Perennial Forage	Second year in perennial forage in 5-year corn/5-year hay rotation	RotYr7

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 26-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. Compaction was measured at 0-6 inch depth and 6-12 inch depth by penetrometer twice at the same five locations the soil samples were collected. The compaction measurements and soil types were used by the Cornell Soil Health Laboratory to calculate surface and sub-surface hardness (psi).

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℃ to remove water then ashed for two hours at 500℃. Total carbon (organic and inorganic forms) is measured using complete oxidation of carbon at high temperature combustion (2000° F). Total nitrogen is measured with DUMAS combustion methodology. It measured 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 and 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, WCCC cover crop was sampled. 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 where they were analyzed for carbon and nitrogen using gas chromatography. The CC, WCCC, and RotYr2 plots were tilled with a Pottinger TerraDisc on 7-May (Table 2). Corn was seeded in 30" rows with a John Deere 1750 corn planter on 7-May in the CC, WCCC, NT, NTCC, and RotYr2 plots. At planting, 250 lbs ac^{-1} of an 19-19-19 starter fertilizer was applied to all corn plots. The corn variety was Syngenta NK8618-GTA, relative maturity (RM) of 86 days, at 36,500 seeds ac^{-1}.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2021.

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
Replications	4
Management treatments	Tilled continuous corn (CC), tilled rye cover crop (WCCC), 2nd year corn (RotYr2), no-till corn (NT), no-till with cover crop (NTCC), 2nd year perennial forage (RotYr7)
Corn variety	Syngenta NK8618-GTA (86 RM)
Seeding rates (seeds ac^{-1})	36,500
Planting equipment	John Deere 1750 corn planter
Cover crop (2020)	100 lbs ac^{-1} VNS winter rye, 22-Sep-2020
Tillage date	7-May (CC, WCCC, RotYr2)
Planting date	7-May (CC, WCCC, NT, NTCC, RotYr2)
Row width (in.)	30
Corn Starter fertilizer (at planting)	250 lbs ac^{-1} 19-19-19, 7-May

Table 2 (cont'd). Agronomic information for corn cropping system, Alburgh, VT, 2021.

Location	Borderview Research Farm – Alburgh, VT
RotYr7 1st harvest date	26-May
Forage fertilizer	100 lbs ac^{-1} 0-0-51, 26-May
Additional fertilizer (all plots topdress)	400 lbs ac^{-1} 25-12-18, 17-Jun
RotYr7 2nd harvest date	7-Jul
Forage fertilizer	100 lbs ac^{-1} 0-0-51, 7-Jul
RotYr7 3rd harvest date	25-Aug
Forage fertilizer	100 lbs ac^{-1} 0-0-51 & 100 lbs ac^{-1} 46-0-0, 9-Sep
Corn harvest date	3-Sep

Corn was topdressed on 17-Jun with nitrogen fertilizer by broadcast according to the highest Pre-Sidedress Nitrate Test (PSNT) recommendation (Table 7). The PSNT soil samples were collected on 10-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 Agricultural and Environmental Testing Laboratory using KCl extract and ion chromatograph.

Corn was harvested for silage from NT, NTCC, WCCC, CC, and RotYr2 plots on 3-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 in a 17.5 feet section 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 UVM's Cereal Grain Testing Laboratory 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. RotYr7 was harvested on 26-May, 7-Jul, and 25-Aug. After 1st cut, RotYr7 plots received 100 lbs ac^{-1} 0-0-51 on 26-May and 400 lbs ac^{-1} 25-12-18 on 17-Jun. After 2nd cut, RotYr7 received 100 lbs ac^{-1} 0-0-51 on 7-Jul. After 3rd cut, RotYr7 plots received 100 lbs ac^{-1} 0-0-51 and 100 lbs ac^{-1} 46-0-0 on 9-Sep. 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 University of Vermont's Cereal Grain Testing Laboratory, Burlington, VT, for quality analysis with the methods outlined above. CP, ADF, NDF and 48-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 48-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 2021 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.

With the exception of July which was cooler, the 2021 growing season was warmer and dryer than the 30-year average. There were a total of 2613 Growing Degree Days (GDDs) for corn from May through September—64 GDDs more than the historical average (Table 3). There were a total of 3542 GDDs for forages from April through August—99 GDDs more than the historical average (Table 4). The season was also very dry, ending with a 6.24 inch rainfall deficit.

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2021.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	58.4	70.3	68.1	74.0	62.8
Departure from normal	-0.03	2.81	-4.31	3.25	0.14
Precipitation (inches)	0.66	3.06	2.92	2.29	4.09
Departure from normal	-3.10	-1.20	-1.14	-1.25	0.42
Corn GDDs (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 (1991-2020) from Burlington, VT.

Table 4. Consolidated weather data and GDDs for perennial forage, Alburgh, VT, 2021.

Alburgh, VT	April	May	June	July	August
Average temperature (°F)	48.1	58.4	70.3	68.1	74.0
Departure from normal	2.52	-0.03	2.81	-4.31	3.25
Precipitation (inches)	3.52	0.66	3.06	2.92	2.29
Departure from normal	0.45	-3.10	-1.20	-1.14	-1.25
Perennial forage GDDs (base 41°F)	284	546	866	840	1006
Departure from normal	69	6	72	-134	86

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 26-Apr, before field operations, soil samples were collected on all plots. Overall, treatments that were in RotYr2 had superior soil quality when compared to any of the cropping systems (Tables 5 and 6). The RotYr2 treatment had significantly higher organic matter, active carbon, total carbon, total nitrogen, soil protein, and aggregate stability. For the last seven years, RotYr2 consistently had significantly higher soil respiration than the corn treatments. This indicates that after its second year in corn, the legacy effects of perennial forage are still having a positive impact on soil health. Conversely, RotYr7 with its second year in perennial forage, did not have a soil health score significantly different from CC. The WCCC treatment had the lowest soil health score.

There were individual soil health metric differences among treatment. NT and NTCC had statistically similar levels of organic matter, active carbon, and aggregate stability. However, after its first year in cover crops, NTCC had lower percent total carbon and total nitrogen. However, NTCC had higher soil respiration than NC. These differences may be that the additional living roots were feeding micro-organisms, but soil samples were taken too early in the season for the micro-organisms to decompose dying cover crop vegetation, thus limiting contributions to soil carbon and nitrogen. With the exception of aggregate stability, depending on the metric, RotYr7 had similar results to either NT or NTCC. RotYr7 had lower aggregate stability than the NT treatments. This indicates that aggregate stability may take more than two years after transition from continuous corn with tillage to perennial forage to build up to the level of aggregate stability in no-till operations. CC consistently had the lowest soil health metric measurements. WCCC performed similarly to CC in all metrics except soil, respiration in which it was significantly higher than CC.

Table 5. Organic matter, active carbon, total carbon, total nitrogen, soil proteins, and soil respiration for six cropping systems, Alburgh, VT, 2021.

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	3.29[c†]	650[bcd]	2.07[d]	0.214[d]	7.24[de]	0.475[e]
RotYr2	4.25[a]	739[a]	2.77[a]	0.271[a]	8.79[a]	0.865[a]
NT	3.60[b]	663[bc]	2.42[b]	0.248[b]	9.03[b]	0.555[c]
NTCC	3.56[b]	637[cd]	2.21t[c]	0.230[c]	7.57[cd]	0.633[b]
WCCC	3.28[c]	609[d]	2.04[d]	0.211[d]	7.05[e]	0.514[d]
RotYr7	3.55[b]	691[b]	2.25[c]	0.231[c]	7.81[bc]	0.619[b]
LSD (0.10)[‡]	0.179	43.6	0.133	0.014	0.362	0.039
Trial Mean	3.59	665	2.29	0.234	7.75	0.610

† Within a column, treatments with that 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, 2021.

Cropping system	Aggregate stability %	Available water capacity m/m	Surface hardness psi	Sub-surface hardness psi	Soil health score
CC	20.3[d†]	0.231	97.0	240	73.1[de]
RotYr2	66.0[a]	0.232	102	238	85.6[a]
NT	45.2[b]	0.223	103	205	78.2[bc]
NTCC	45.1[b]	0.226	91.0	201	79.3[b]
WCCC	22.5[d]	0.227	85.0	199	72.0[e]
RotYr7	31.7[c]	0.230	86.0	235	75.8[cd]
LSD (0.10)[‡]	6.64	NS[§]	NS[§]	NS[§]	3.03
Trial Mean	38.5	0.228	93.9	220	77.3

† Within a column, treatments with that 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 10-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 for 25 ton ac^{-1} yields. Mean soil nitrate-N (NO_3^--N) among the treatments was 32.6 ppm with a mean N recommendation of 22.3 N lbs ac^{-1}. The highest nitrogen recommendations were in one CC and one NTCC plot for 100 lbs ac^{-1}. Nitrogen was applied to meet these highest N recommendations to all plots on 17-Jun as 25-12-18 at a rate of 400 lbs ac^{-1} (100 N lbs ac^{-1}).

Table 7. Soil nitrate-N and N recommendations for high yield potential, Alburgh, VT, 2021.

Corn cropping system	NO_3^--N ppm	N recommendation for 25 ton ac^{-1} corn
CC	39.2	25.0
RotYr2	30.7	17.5
NT	29.7	35.0
NTCC	28.8	37.8
WCCC	34.8	0.0
LSD (0.10)†	NS‡	NS
Trial Mean	32.6	22.3

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

Crop Results

On 2-Sep, data was collected on corn silage populations. Corn plots were harvested on 3-Sep to determine moisture and yield (Table 8). Forage plots were harvested on 26-May, 7-Jul, and 25-Aug to determine moisture and yield (Table 8). There were no differences in dry matter yield among any of the cropping systems indicating the potential of perennial forage to rival corn silage yields on a dry matter basis (Table 8 & Figure 1). Corn yields were highly variable this year likely due to the drought conditions.

Table 8. Corn silage population, harvest dry matter, and yield by treatment, Alburgh, VT, 2021.

Corn cropping system	Harvest population plants ac^{-1}	Yield at DM ton ac^{-1}	Yield at 35% DM ton ac^{-1}
CC	30,565[a†]	7.04	20.1
RotYr2	31,452[a]	6.22	17.8
NT	30,524[a]	7.95	22.7
NTCC	28,226[b]	7.53	21.5
WCCC	30,645[a]	7.77	22.2
RotYr7	n/a	5.26	15.0
LSD (0.10)‡	1,936	NS§	NS
Trial mean	30,282	6.96	19.8

† Within a column, treatments with that 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.

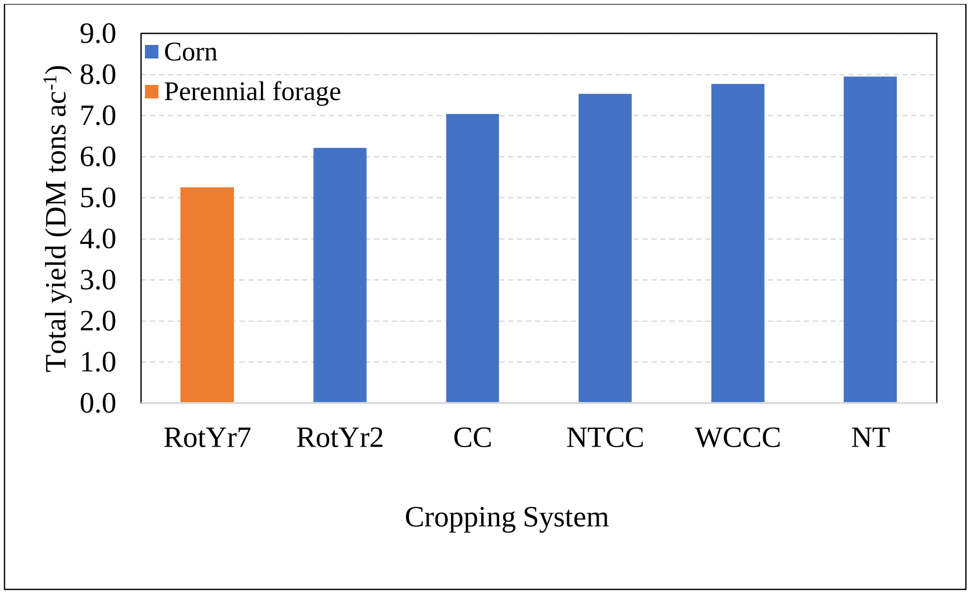

Figure 1. Cropping system total yield, Alburgh, VT, 2021.

Standard components of corn silage quality were analyzed and the average quality of first and third harvest of RotYr7 were analyzed for basic quality parameters (Table 9). There were no significant differences among NDF or NE_L among any of the treatments. Among corn treatments, there were no significant differences in ADF, NDFD 30 hr., TDN, or milk lbs ac^{-1}. Among the corn treatments, RotYr2 had higher protein than CC, NT, and NTCC treatments, but was not significantly different from WCCC. This indicates that CC, NT, and NTCC may have benefitted from additional nitrogen applications. RotYr2 had significantly lower milk lbs ton^{-1} than WCCC, but was similar to other corn treatments. RotYr7 had higher crude protein, higher fiber, lower digestibility, lower TDN, lower milk lbs ton^{-1}, and lower milk lbs ac^{-1} than any of the treatments.

Table 9. Impact of cropping systems on crop quality, 2021.

Cropping system	CP % of DM	ADF % of DM	NDF % of DM	NDFD 30 % of NDF	TDN % of DM	NE_L Mcal lb^{-1}	Milk lbs ton^{-1}	Milk lbs ac^{-1}
CC	7.62[c]	26.1[a]	45.3	54.0[a]	64.0[a]	1.43	2,921[ab]	20,410[a]
RotYr2	8.50[b]	22.8[a]	45.6	55.0[a]	63.0[a]	1.41	2,808[b]	17,454[a]
NT	7.87[c]	24.9[a]	43.6	55.0[a]	64.0[a]	1.46	2,916[ab]	23,108[a]
NTCC	7.71[c]	25.7[a]	44.1	55.0[a]	64.0[a]	1.42	2,895[ab]	21,734[a]
WCCC	8.20[bc]	24.0[a]	42.1	56.0[a]	63.0[a]	1.39	2,971[a]	23,111[a]
RotYr7	17.2[a†]	33.7[b]	43.3	50.8[b]	58.8[b]	1.32	2,066[c]	3,849[b]
LSD (0.10)[‡]	0.588	4.51	NS[§]	2.32	2.42	NS	154	11,354
Trial mean	9.52	26.9	44.0	54.1	62.8	1.40	2,763	18,278

† Within a column, treatments with that 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, RotYr2, performed best overall. Last year, this treatment, fresh out of long-term sod, had the highest surface hardness measurement. This year, there were no significant difference in surface hardness among any of the treatments indicating that one year of tillage significantly reduces surface compaction. We would expect fields with tillage to have less compact surface layers.

There were some soil quality benefits observed from not tilling the soil. Of the corn cropping systems, the NT and NTCC had the best soil structure as indicated by aggregate stability and would be less prone to erosion and runoff. The NT and NTCC treatments were transitioned from perennial forage to corn seven years ago and the lack of soil disturbance is reflected in many of the soil quality measurements. These treatments clearly shows the potential for no-till corn to maintain soil quality during the corn years of a rotation. The NT treatment had consistently better soil health than the CC and WCCC treatments. The CC system has the least potential to reduce erosion and nutrient runoff. There was not a significant difference in the soil health score of CC and WCCC.

Although the NTCC treatment had statistically significantly lower corn populations, there were no yield differences among treatments with corn. Typically, we observe suppressed yields in the NT corn treatment compared to other corn treatments with tillage. However, in an unusually dry and warm year, the NT and NTCC treatments did not perform significantly different from other corn treatments. In 2022, we will be better able to capture the soil health and yield effects of rotations into and out of sod.

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 Henry Blair, John Bruce, Catherine Davidson, and Ivy Krezinksi 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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