2019 Corn Cropping Systems to Improve Economic and Environmental Health

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2018 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

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In 2018, 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. Yields are important and they affect the bottom line immediately and obviously. Management choices involving crop rotation, tillage, nutrient management, and cover crops also make differences in the long term. 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).

Table 1. Corn cropping system specifics for corn yield and soil health, Alburgh, VT, 2019.

Crop	Management method	Treatment abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	Corn (5th year), in a rotation with fescue	NC
Corn silage	No-till corn in alfalfa/fescue	NT
Corn silage	Winter cover crop, tilled	WCCC
Perennial Forage	Fescue	PF

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. Soil samples were collected on 29-Apr and were submitted to the Cornell Soil Health Laboratory for the Comprehensive Assessment of Soil Health analysis. 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. Percent available water capacity was calculated with a Random Forest model to predict AWC from a suite of measured parameters, including percent sand, percent silt, percent clay, organic matter, active carbon, ACE Protein, respiration, wet aggregate stability, potassium, magnesium, iron, and manganese (Cornell Soil Health Manual Series, Fact Sheet Number 19-05b). 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. 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 proteins (N mg/soil g) are measured with citrate buffer extract, then autoclaved. This measurement is used to quantify organically bound nitrogen (N) that microbial activity can mineralize from soil organic matter and make plant-available. 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 corn variety was Syngenta's NK8618-GTA.0, which has a relative maturity (RM) of 86 days. The winter rye cover crop in the NC, CC, and WCCC treatments was plowed on 9-May. Corn was seeded in 30" rows on 13-May with a John Deere 1750 corn planter. Corn was seeded at 35,500 seeds ac^{-1}. At planting, 250 lbs ac^{-1} of an 18-18-18 starter fertilizer was applied.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2019.

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), tilled fescue (NC), no-till (NT), perennial forage (PF)
Corn variety	Syngenta NK8618-GTA.0 (86 RM)
Seeding rates (seeds ac^{-1})	35,500
Planting equipment	John Deere 1750 corn planter
Plow date	9-May
Planting date	13-May
Row width (in.)	30
Corn Starter fertilizer (at planting)	250 lbs ac^{-1} 18-18-18
Chemical weed control for corn	1 qt. Power Max® ac^{-1}, 8-May on NT plots 3 pt. Lumax® EZ and 1.5 oz. Steadfast® Q ac^{-1}, 7-Jun on all corn plots
Additional fertilizer (corn topdress)	500 lbs ac^{-1} (28-0-23), 29-Jun
Forage 1st cut date	28-May
Forage 2nd cut date	28-Jun
Forage 3rd cut date	14-Aug
Forage fertilizer	110 lbs ac^{-1} 46-0-0 on 4-Jun and 2-Jul
Corn harvest date	18-Sep

On 8-May, 1 quart of Power Max® was applied per acre for weed control on NT plots. A subsequent application of 3 pints of Lumax®EZ and 1.5 ounces of Steadfast®Q was applied per acre for weed control on 7-Jun on all corn plots. Corn was topdressed with nitrogen fertilizer by broadcast according to Pre-Sidedress Nitrate Test (PSNT) recommendations on 29-Jun. (Table 6). The PSNT soil samples were collected 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 on 18-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 17.5 feet section in the middle two rows of each plot. Dry matter yields were calculated and yields were 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), 30-hour digestible NDF (NDFD), 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 two 3' x 50' strips on 28-May, 28-Jun, and 14-Aug in fescue treatments. Perennial forage moisture and dry matter yield were calculated and yields adjusted to 35% dry matter. 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 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 the following 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.

Treatment	**Yield**
A	6.0
B	7.5*
C	**9.0**
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 2019 growing season (Table 3 and Table 4). Historical weather data are from 1981-2010 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT.

In 2019, most months of the growing season were cooler than the 30-year average. July, with an average of more than 2° F higher than the 30-year average, was the exception (Table 3). There was 1.17 inches less rainfall from May-September compared to the 30-year average. There were a total of 2254 Growing Degree Days (GDDs) for corn for May through September—42 GDDs more than the historical average (Table 3). There were a total of 3667 GDDs for forages for April through September — 36 GDDs less than the historical average (Table 4).

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2019.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	53.3	64.3	73.5	68.3	60.0
Departure from normal	-3.11	-1.46	2.87	-0.51	-0.62
Precipitation (inches)	4.90	3.06	2.34	3.50	3.87
Departure from normal	1.45	-0.63	-1.81	-0.41	0.23
Corn GDDs (base 50°F)	189	446	716	568	335
Departure from normal	-9	-29	76	-13	17

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

Table 4. Consolidated weather data and GDDs for perennial forage, Alburgh, VT, 2019.

Alburgh, VT	April	May	June	July	August	September
Average temperature (°F)	42.7	53.3	64.3	73.5	68.3	60.0
Departure from normal	-2.11	-3.11	-1.46	2.87	-0.51	-0.62
Precipitation (inches)	3.65	4.90	3.06	2.34	3.50	3.87
Departure from normal	0.83	1.45	-0.63	-1.81	-0.41	0.23
Perennial forage GDDs (base 41°F)	163	391	700	995	846	572
Departure from normal	49	-86	-44	77	-16	-16

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.

Soil Test Results

On 29-Apr, before planting corn, soil samples were collected on all plots (Table 5). Overall treatments that were in PF had superior soil quality when compared to any of the corn cropping systems. For the last five years, the PF treatment consistently had statistically significantly higher soil respiration than other treatments. When compared to the PF treatment, the corn treatments did not statistically significantly differ among each other in organic matter, active carbon, or soil respiration. Among the corn treatments, the NT treatment had statistically significantly higher aggregate stability, but also had significantly higher surface hardness. Overall, soil health scores among all five treatments did not have a significant difference.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2019.

Cropping system	Aggregate stability %	Available water capacity m/m	Surface hardness psi	Sub-surface hardness psi	Organic matter %	Active carbon ppm	Soil proteins N mg/ soil g	Soil respiration CO_2mg/ soil g
CC	32.8^{d}[†]	0.223^{ab}	52.5^{a}	180^{a}	3.37^{b}	640^{ab}	7.15	0.435^{b}
NC	42.6^{c}	0.228^{a}	52.3^{a}	186^{ab}	3.56^{b}	593^{b}	7.31	0.410^{b}
NT	60.6^{b}	0.231^{a}	85.0^{b}	215^{b}	3.62^{b}	607^{b}	7.75	0.471^{b}
WCCC	37.9^{cd}	0.214^{b}	63.8^{a}	201^{ab}	3.33^{b}	640^{ab}	6.68	0.419^{b}
PF	74.7^{a}	0.228^{a}	107.5^{c}	251^{c}	4.34^{a}	703^{a}	8.17	0.783^{a}
LSD (0.10) [‡]	6.08	0.011	20.3	34.0	0.36	68.6	NS[¥]	0.137
Trial Mean	49.7	0.225	72.2	207	3.64	636	7.41	0.504

[†] 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 26-Jun, soil samples were collected for PSNT analysis (Table 6). The mean soil nitrate-N (NO_3^-) among the treatments was 22.3 ppm with a mean N recommendation of 63.8 N lb ac^{-1}. There were no statistically significant differences in PSNT results or N recommendations. Nitrogen, in the form of 28-0-23, was applied to the corn treatments at a rate of 140 N lb ac^{-1}.

Table 6. Soil nitrate-N and N recommendations for medium and high yield potential, Alburgh, VT, 2019.

Corn cropping system	NO_3^- -N ppm	N recommendation for 25 ton ac^{-1} corn
CC	27.3	0
NC	13.3	95
NT	20.5	60
WCCC	28.0	0
LSD (0.10)[†]	NS[‡]	NS[‡]
Trial Mean	22.3	40

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

Corn Silage Results

On 10-Sep, data was collected on corn silage populations and plots were harvested on 18-Sep to determine moisture and yield (Table 7). Although the NT system had statistically significantly higher plant populations at harvest, it was the NC treatment that had statistically significantly higher yield. This year, there was four-ton difference between the lowest yielding treatment (WCCC) and the highest yielding treatment (NC). The CC, WCCC, and the NT treatments had significantly lower yields than the NC treatment.

Table 7. Corn silage population, harvest dry matter and yield by treatment, Alburgh, VT, 2019.

Corn cropping system	Harvest population plants ac^{-1}	Harvest dry matter %	Yield at 35% DM ton ac^{-1}
CC	20,125^{b†}	40.5^{b}	20.1^{b}
NC	22,250^{b}	46.9^{a}	23.4^{a}
NT	24,750^{a}	39.8^{b}	20.7^{b}
WCCC	19,875^{b}	42.3^{b}	19.3^{b}
LSD (0.10)‡	2,416	3.37	2.55
Trial mean	21,750	42.4	20.9

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

Standard components of corn silage quality were analyzed (Table 8). With the exception of CP, there were no significant differences in quality among cropping systems. The 2019 corn growing season had significantly less precipitation than usual which may have acted as an equalizer, decreasing silage quality to a minimum. However, it is interesting to note that the WCCC treatment had the highest amount of available nitrogen (NO^{-}_{3})

Table 8. Impact of cropping systems on corn silage quality, 2019.

Corn cropping system	CP % of DM	ADF % of DM	NDF % of DM	TDN % of DM	NE$_L$ Mcal lb^{-1}	Milk lbs ton^{-1}	Milk lbs ac^{-1}
CC	10.1^{a†}	21.3	39.6	63.8	0.737	3,644	24,399
NC	9.93^{a}	21.7	39.9	64.0	0.738	3,647	27,159
NT	9.65^{ab}	20.0	36.9	64.3	0.742	3,676	24,403
WCCC	9.13^{b}	21.4	39.2	64.5	0.739	3,653	23,205
LSD (0.10)‡	0.581	NS¥	NS	NS	NS	NS	NS
Trial mean	9.2	25.4	45.4	67.7	0.658	3,010	2,4791

† 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.

Perennial Forage Results

The perennial forage plots were analyzed for basic quality parameters (Table 9). The third harvest of PF treatments in August had a statistically significantly higher yield. This may be due to 16 days more of growth between second and third harvests (47 days) than the first and second harvest (31 days). It may also be due to higher rainfall and cooler temperatures experiences in August compared to July. Crude protein and NDFD were statistically significantly higher in the first harvest than in subsequent harvests. The first harvest had the most metrics indicating higher quality (higher CP, higher NDFD, lower ADF, and lower NDF) than the other harvests.

Table 9. Impact of harvest date on perennial forage quality, 2019.

Alfalfa/Fescue Harvest	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	Yield % DM lb ac^{-1}
1st harvest 28-May	25.9[a†]	29.6	44.9	82.7[a]	2,192[b]
2nd harvest 28-Jun	22.1[b]	31.3	50.5	75.6[b]	1,995[b]
3rd harvest 14-Aug	20.9[b]	32.1	52.4	70.7[b]	3,946[a]
LSD (0.10) ‡	2.46	NS[¥]	NS	6.13	744
Trial mean	23.0	31.0	49.2	76.3	2,710

† 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 soil and crop health in these cropping systems over a six-year period. 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, PF systems performed best overall, with the exception of available water capacity, surface, and subsurface hardness, where it was the lowest performing treatment. This makes sense to some extent as the soil has not been aerated in these plots compared to other treatments. It also indicates that perennial forage crops may benefit from soil aeration to help alleviate soil compaction and improve nutrient cycling, water infiltration, and yields. 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 had the best soil structure as indicated by aggregate stability and would be less prone to erosion and runoff. The NT treatments were transitioned from PF to corn six years ago and the lack of soil disturbance is reflected in many of the soil quality measurements. This treatment clearly reflects the potential for NT corn to maintain soil quality during the corn years of a rotation. However, we continue to observe a yield drag in the NT corn treatment compared to other corn treatments with tillage. Among the corn plots, the NT plots had the highest levels of compaction. The CC treatment had the lowest aggregate stability as would be predicted knowing that constant tillage will significantly impair the structure of the soil. WCCC had a small impact on aggregate stability and did not seem to improve it over CC. This system has the least potential to reduce erosion and nutrient runoff. Among the corn treatments, overall soil health score did not differ.

Although the NT treatment had statistically significantly higher populations, the NC treatment had significantly higher yield. Overall, the first harvest of the PF had the highest quality, but the third harvest had significantly higher yield. The PF treatment continued to have the best overall soil health of all the treatments.

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