NW CROPS & SOILS PROGRAM

2017 Corn Cropping Systems to Improve Economic and Environmental Health

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2017 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

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In 2017, 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. 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, 2017.

Crop	Management method	Treatment abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	Corn (4th year), in a rotation with alfalfa/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 4-May 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 measured by placing soil samples on ceramic plates that are inserted into high pressure chambers to determine field capacity and permanent wilting point. 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℃. 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 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 4-day incubation period and is used to quantify metabolic activity of the soil microbial community.

The corn variety was Dyna Gro's D32RR56, which has a relative maturity (RM) of 92 days. The winter rye cover crop in the NC, CC, and WCCC treatments was plowed on 13-May. Corn was seeded in 30" rows on 13-May with a John Deere 1750 corn planter at 34,000 seeds per acre. At planting, 250 lbs per acre of a 10-20-20 starter fertilizer was applied.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2017.

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	Dyna Gro D32RR56 (92 RM)
Seeding rates (seeds ac^{-1})	34,000
Planting equipment	John Deere 1750 corn planter
Plow date	13-May
Planting date	13-May
Row width (in.)	30
Corn Starter fertilizer (at planting)	250 lbs ac^{-1} 10-20-20
Chemical weed control for corn	3 qt. Lumax® ac^{-1}, 5-Jun 1 qt Round-Up® ac^{-1}, 5-Jul
Additional fertilizer (corn topdress)	300 lbs ac^{-1} Agrotain (46-0-0), 5-Jul
Forage 1st cut date	30-May
Forage 2nd cut date	7-Jul
Forage 3rd cut date	18-Sep
Corn harvest date	18-Sep

On 5-Jun, 3 quarts of Lumax® were applied per acre for weed control on corn plots. A subsequent application of 1 quart of Round-Up® was applied per acre for weed control on 5-Jul. Corn was topdressed with nitrogen fertilizer by broadcast according to Pre-Sidedress Nitrite Test (PSNT) recommendations on 5-Jul (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 two rows the entire length of the plot (50 feet). Corn borer and corn rootworm populations were based on number of damaged plants observed per 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), 48-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 30-May, 7-Jul, and 18-Sep 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.

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 was 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 2017 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.

Especially compared to last year (April-August) when rainfall was 6.4 inches below the 30-year average, this year felt cooler and wetter than normal. From May-August, 62 of the 123 days (50%) received rainfall greater than .01 inches (data not shown). The average temperature departure of the 2017 April-August was 0.35°F below the 30-year average while the same period of time received an average 1.5 inches more rain than usual. Temperatures on either end of the season in April and September were slightly higher than usual while the temperature in the middle of the season (June-August) were slightly lower than usual. April received over two inches more rainfall than usual while September received 1.8 inches less than usual. There were a total of 2293 Growing Degree Days (GDDs) for corn for May through September—81 GDDs more than the historical average. There were a total of 3824 GDDs for forages for April through September — 121 GDDs more than the historical average (Table 4).

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2017.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	55.7	65.4	68.7	67.7	64.4
Departure from normal	-0.75	-0.39	-1.90	-1.07	3.76
Precipitation (inches)	4.1	5.6	4.9	5.5	1.8
Departure from normal	0.68	1.95	0.73	1.63	-1.80
Corn GDDs (base 50°F)	245	468	580	553	447
Departure from normal	47	-7	-60	-28	129

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, 2017.

Alburgh, VT	April	May	June	July	August	September
Average temperature (°F)	47.2	55.7	65.4	68.7	67.7	64.4
Departure from normal	2.37	-0.75	-0.39	-1.90	-1.07	3.76
Precipitation (inches)	5.2	4.1	5.6	4.9	5.5	1.8
Departure from normal	2.40	0.68	1.95	0.73	1.63	-1.80
Perennial forage GDDs (base 32°F)	247	463	727	859	829	699
Departure from normal	133	-14	-17	-59	-33	111

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 Data

On 5-May, 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 three years, the PF treatments consistently had significantly higher soil respiration than other treatments. This year, CC, NC, and WCCC treatments had overall better soil quality in terms of the highest available water capacity, lower surface hardness, and lower sub-surface hardness. Percent organic matter was highest in the PF (4.22%) treatment.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2017.

Corn 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	19.7	**0.230**	**59**	**165**	3.48	566	7.44	0.454
NC	34.5	0.221*	65*	168*	3.77	540	7.90	0.581
NT	43.7	0.210	88	181*	3.63	540	7.76	0.504
WCCC	22.9	0.215*	69	173*	3.46	494	7.02	0.516
PF	**56.3**	0.206	110	322	**4.22**	**590**	**8.81**	**0.846**
LSD (0.10)	7.41	0.020	8.64	18.75	0.272	NS	0.713	0.062
Trial Mean	35.4	0.216	78	202	3.71	546	7.79	0.580

* Treatments with an asterisk did not perform significantly lower than the top-performing treatment shown in **bold** in a particular column.
NS – No significant difference was determined among the treatments.

On 27-Jun, soil samples were collected for PSNT analysis (Table 6). The mean soil nitrate-N (NO^{-3}) among the treatments was 8.4 ppm with a mean N recommendation of 122. There were no significant differences in PSNT results or N recommendations. Nitrogen, in the form of urea, was applied to the corn treatments based on their respective PSNT results.

Table 6. Soil nitrate-N and N recommendations for medium and high yield potential, Alburgh, VT, 2017.

Corn cropping system	NO^{-3}-N (ppm)	N recommendation for 25 ton ac^{-1} corn
CC	7.7	125
NC	9.6	115
NT	6.2	**133**
WCCC	**10**	113
LSD (0.10)	NS	NS
Trial Mean	8.4	122

Top-performing treatment shown in **bold** in a particular column.
NS – No significant difference was determined.

Corn Silage Results

On 18-Sep, data was collected on corn silage populations and plots were harvested to determine moisture and yield (Table 7). There was no statistical difference between corn populations in the corn cropping systems. This year, there was less than a two-ton difference between the lowest yielding treatment (NC) and the highest yielding treatment (WCCC). There was no significant yield difference among treatments (Figure 1).

Pest and disease scouting occurred when corn was in V3 stage on 14-Jun and at harvest (data not shown). No disease was noted at the V3 stage. However, pest pressure was slight. There was an average of less than one pest (corn borer, cut worm, or armyworm) per plot in CC and WCCC treatments. NC had an average of two pests per plot and NT had an average of three pests per plot. Notably, there were zero corn borers in the CC treatments and zero cut worms in the NT treatments. At harvest, rust was identified in all plots. The CC and NC plots had an average of 1.75 corn plants infected per plot and NT and WCCC had an average of 1.25 plants infected per plot. The CC test plots did not have any pest damage at harvest time. All other treatments had an average of 0.25 corn borers per plot.

Table 7. Corn silage population, harvest dry matter and yield by treatment, Alburgh, VT, 2017.

Corn cropping system	Harvest population plants ac^{-1}	Harvest dry matter %	Yield at 35 DM t ac^{-1}
CC	32,000	34.0	22.5
NC	**33,250**	**35.4**	22.0
NT	27,625	34.0	21.4
WCCC	31,500	33.2	**23.9**
LSD (0.10)	NS	NS	NS
Trial mean	3,688	34.2	22.4

Top-performing treatment shown in **bold** in a particular column.
NS – No significant difference was determined.

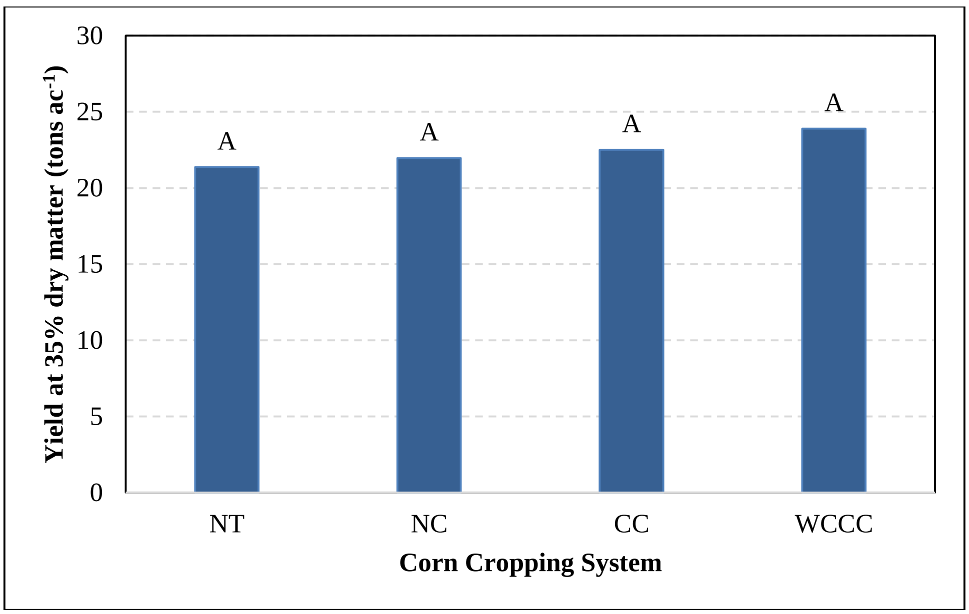

Figure 1. Dry matter yields of corn cropping systems in tons per acre, Alburgh, VT, 2017. Treatments that share a letter were not significantly different from one another (p=0.10).

Standard components of corn silage quality were analyzed (Table 8). There were no significant differences in quality among cropping systems. In previous years, there has been some statistically significant differences in quality among treatments. This year was a particularly hard growing season which may have acted as an equalizer, decreasing silage quality to a minimum.

Table 8. Impact of cropping systems on corn silage quality, 2017.

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	8.0	**23.6**	39.0	78.0	0.763	**3,754**	29,578
NC	7.7	24.3	**38.9**	78.0	0.763	**3,754**	28,867
NT	**8.1**	24.2	39.7	78.0	0.763	3,739	27,969
WCCC	8.0	24.0	39.2	78.0	0.763	3,743	**31,308**
LSD (0.10)	NS	NS	NS	NS	NS	NS	2673
Trial mean	8.0	24.0	39.2	78.0	0.763	3747	29431

Treatments shown in **bold** are top-performing in a particular column.
NS – No significant difference was observed between treatments.

Perennial Forage Data

The perennial forage plots were analyzed for basic quality parameters (Table 9). The third cutting had the highest overall quality (higher CP, lower ADF, and lower NDF). The first cutting had the highest NDFD and yield.

Table 9. Impact of harvest date on perennial forage quality, 2017.

Alfalfa/Fescue cutting	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	Yield at 35 DM t ac^{-1}
1st cut 30-May	13.6	32.0	58.6	**36.1**	**1.78**
2nd cut 7-Jul	14.9	32.0	56.2	34.0	1.48
3rd cut 18-Sep	**16.5**	**30.4**	**54.7**	33.8	1.69
Trial mean	15.0	31.5	56.5	34.6	1.65

DISCUSSION

The goal of this project is to monitor soil and crop health in these cropping systems over a five-year period. Based on the analysis of the data, some conclusions can be made about the results of this year's trials. 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. The NC and WCCC treatments had the lowest surface compaction.

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. 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. Corn in a short rotation with sod (NC) was still maintaining higher levels of aggregate stability even after its third year of tillage. Biological properties also remained quite high in this system. The CC treatment performed near the bottom, in soil quality in all areas except soil hardness and available water holding capacity and among corn cropping systems, had high active carbon. This system has the least potential to reduce erosion and nutrient runoff.

The NC had the highest corn populations although statistically similar to the other treatments. Although not significantly different this year, the WCCC consistently provides slightly higher yields than other corn treatments but very few shifts in soil quality parameters. The NT treatment was the lowest performer in terms of yield. All treatments had lower than yields from the last two years, reflecting a hard corn season with cooler temperatures and higher precipitation through the growing season.

The perennial forage cuttings had overall similar quality and yield. The quality of the forages was very high through the season. The average total PF yield for the season was 60% of the average corn silage yield. The PF treatment however, had the highest soil quality and will be an important component of the overall corn rotation to build soil productivity prior to continuous corn production.

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