



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 on 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, 2018.

| Crop | Management method | Treatment abbreviation |
|------------------|--|------------------------|
| Corn silage | Continuous corn, tilled | CC |
| Corn silage | Corn (5 th 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 7-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°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 that microbial activity can mineralize from soil organic matter and make plant-available. Soil respiration (CO₂ mg/soil g) is measured by amount of CO₂ 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 D32VC56, which has a relative maturity (RM) of 92 days. The winter rye cover crop in the NC, CC, and WCCC treatments was plowed on 16-May. Corn was seeded in 30" rows on 16-May with a John Deere 1750 corn planter. Due to planting error, corn was seeded at 17,000 seeds per acre. At planting, 250 lbs per acre of a 19-19-19 starter fertilizer was applied.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2018.

| 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) | 17,000 |
| Planting equipment | John Deere 1750 corn planter |
| Plow date | 16-May |
| Planting date | 16-May |
| Row width (in.) | 30 |
| Corn Starter fertilizer (at planting) | 250 lbs ac ⁻¹ 19-19-19 |
| Chemical weed control for corn | 3 pt. Lumax [®] ac ⁻¹ , 24-May 1.5 oz Accent [®] ac ⁻¹ , 9-Jun |
| Additional fertilizer (corn topdress) | 200 lbs ac ⁻¹ urea (46-0-0), 27-Jun |
| Forage 1st cut date | 24-May |
| Forage 2nd cut date | 29-Jun |
| Forage 3rd cut date | 27-Aug |
| Corn harvest date | 5-Sep |

On 24-May, 3 pints of Lumax[®] were applied per acre for weed control on corn plots. A subsequent application of 1.5 oz of Accent[®] was spot applied per acre for weed control on 9-Jun. Corn was topdressed with nitrogen fertilizer by broadcast according to Pre-Sidedress Nitrite Test (PSNT) recommendations on 27-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 5-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. 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), 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 24-May, 29-Jun, and 27-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 2018 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, which felt cooler and wetter than normal, 2018 was much drier and warmer than the 30-year average (Table 3). Although June was a little cooler than usual, May-August, was an average of 6.4° F higher and received 2.7 inches less rainfall. There were a total of 2651 Growing Degree Days (GDDs) for corn for May through September—440 GDDs more than the historical average (Table 3). There were a total of 4054 GDDs for forages for April through September — 351 GDDs more than the historical average (Table 4).

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2018.

| Alburgh, VT | May | June | July | August | September |
|--------------------------|-------|-------|-------|--------|-----------|
| Average temperature (°F) | 59.5 | 64.4 | 74.1 | 72.8 | 63.4 |
| Departure from normal | 3.10 | -1.38 | 3.51 | 3.96 | 2.76 |
| Precipitation (inches) | 1.9 | 3.7 | 2.4 | 3.0 | 3.5 |
| Departure from normal | -1.51 | 0.05 | -1.72 | -0.95 | -0.16 |
| Corn GDDs (base 50°F) | 352 | 447 | 728 | 696 | 427 |
| Departure from normal | 154 | -27 | 88 | 115 | 109 |

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, 2018.

| Alburgh, VT | April | May | June | July | August | September |
|-----------------------------------|-------|-------|-------|-------|--------|-----------|
| Average temperature (°F) | 39.2 | 59.5 | 64.4 | 74.1 | 72.8 | 63.4 |
| Departure from normal | -5.58 | 3.10 | -1.38 | 3.51 | 3.96 | 2.76 |
| Precipitation (inches) | 4.4 | 1.9 | 3.7 | 2.4 | 3.0 | 3.5 |
| Departure from normal | 1.61 | -1.51 | 0.05 | -1.72 | -0.95 | -0.16 |
| Perennial forage GDDs (base 32°F) | 118 | 582 | 701 | 1007 | 974 | 671 |
| Departure from normal | 4 | 105 | -43 | 89 | 112 | 83 |

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 7-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 four years, the PF treatments consistently had significantly higher soil respiration than other treatments. Among the corn treatments, the NT treatment had the highest aggregate stability, organic matter, active carbon, soil

proteins, and soil respiration. It was not significantly different from PF for aggregate stability and soil proteins, but significantly different from the other corn systems.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2018.

| 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 ₂ mg/soil g) |
|-----------------|-----------------------|--------------------------------|----------------------|--------------------------|------------------|-------------------|-----------------------------|--|
| CC | 29.7 | 0.298 | 70.6* | 168 | 4.07 | 546 | 7.52 | 0.438 |
| NC | 32.3 | 0.302 | 66.9 | 173* | 4.22 | 509 | 7.32 | 0.508 |
| NT | 56.7* | 0.269 | 92.3 | 176* | 4.34 | 570 | 8.51* | 0.569 |
| WCCC | 34.8 | 0.265 | 81.6 | 169* | 4.09 | 562 | 7.30 | 0.519 |
| PF | 65.0 | 0.279 | 107 | 200 | 4.88 | 648 | 8.66 | 0.870 |
| LSD (0.10) | 9.43 | NS | 11.6 | 14.7 | 0.305 | NS | 0.910 | 0.075 |
| Trial Mean | 44.7 | 0.282 | 83.7 | 177 | 4.3 | 567 | 7.86 | 0.581 |

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

On 19-Jun, soil samples were collected for PSNT analysis (Table 6). The mean soil nitrate-N (NO⁻³) among the treatments was 17.4 ppm with a mean N recommendation of 72.2 N lb ac⁻¹. There were no significant differences in PSNT results or N recommendations. Nitrogen, in the form of urea, was applied to the corn treatments to meet the most demanding treatment, NT, at a rate of 110 N lb ac⁻¹.

Table 6. Soil nitrate-N and N recommendations for medium and high yield potential, Alburgh, VT, 2018.

| Corn cropping system | NO ⁻³ -N (ppm) | N recommendation for 25 ton ac ⁻¹ corn |
|----------------------|---------------------------|---|
| CC | 17.0 | 68.8 |
| NC | 21.8 | 55.0 |
| NT | 10.3 | 111 |
| WCCC | 20.5 | 53.8 |
| LSD (0.10) | NS | NS |
| Trial Mean | 17.4 | 72.2 |

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

Corn Silage Results

On 5-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 a five-ton difference between the lowest yielding treatment (NT) and the highest yielding treatment (NC). The NT treatment had significantly lower yields than the other corn treatments.

Pest and disease scouting occurred in 17.5 feet length in each plot when corn was in V5 stage on 19-Jun (data not shown). No disease was noted at the V5 stage. However, pest pressure was slight. The only core borer presence was on one plant in the CC treatment. The only wireworm presence was on one plant in the WCCC treatment. Minimal thrip presence was noted in one plot of each treatment.

Table 7. Corn silage population, harvest dry matter and yield by treatment, Alburgh, VT, 2018.

| Corn cropping system | Harvest population plants ac ⁻¹ | Harvest dry matter % | Yield at 35% DM ton ac ⁻¹ |
|----------------------|--|----------------------|--------------------------------------|
| CC | 12,000 | 37.2 | 15.1* |
| NC | 11,875 | 37.0 | 16.3 |
| NT | 12,125 | 36.4 | 13.0 |
| WCCC | 13,125 | 37.3 | 15.0* |
| LSD (0.10) | NS | NS | 1.82 |
| Trial mean | 12,281 | 37.0 | 14.9 |

* 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.

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, 2018.

| Corn cropping system | CP % of DM | ADF % of DM | NDF % of DM | TDN % of DM | NE _L Mcal lb ⁻¹ | Milk | |
|----------------------|------------|-------------|-------------|-------------|---------------------------------------|-----------------------|----------------------|
| | | | | | | lbs ton ⁻¹ | lbs ac ⁻¹ |
| CC | 9.0 | 25.3 | 45.4 | 68.0 | 0.661 | 3,035 | 12,473 |
| NC | 9.2 | 25.7 | 45.5 | 68.3 | 0.665 | 3,062 | 12,738 |
| NT | 9.1 | 25.5 | 45.7 | 66.0 | 0.640 | 2,889 | 12,943 |
| WCCC | 9.3 | 25.1 | 44.9 | 68.3 | 0.664 | 3,055 | 12,943 |
| LSD (0.10) | NS | NS | NS | NS | NS | NS | NS |
| Trial mean | 9.2 | 25.4 | 45.4 | 67.7 | 0.658 | 3,010 | 12,597 |

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). Each subsequent cut produced an increasingly significantly higher dry matter yield, up to the highest value at the 3rd cut. Crude protein significantly decreased with each subsequent cut. For NDF, while the 1st cut was significantly lower, the 2nd and 3rd cuts were not significantly different from each other. The first cut had the most metrics indicating higher quality (higher CP, lower ADF, and lower NDF) than the other cuts. The 3rd cut had the highest NDFD and the highest yield.

Table 9. Impact of harvest date on perennial forage quality, 2018.

| Alfalfa/Fescue cutting | CP % of DM | ADF % of DM | NDF % of DM | NDFD % of NDF | Yield % DM t ac⁻¹ |
|-----------------------------------|---------------------------|----------------------------|----------------------------|------------------------------|---|
| 1 st cut 24-May | 17.6 | 25.1 | 47.1 | 34.7 | 0.752 |
| 2 nd cut 29-Jun | 14.8 | 31.2 | 54.7 | 30.7 | 1.36 |
| 3 rd cut 27-Aug | 13.4 | 29.3 | 54.7 | 35.6 | 2.38 |
| LSD (0.10) | 1.24 | 1.24 | 3.13 | 0.793 | 0.415 |
| Trial mean | 15.3 | 28.5 | 52.2 | 33.7 | 1.50 |

Treatments shown in **bold** are top-performing in a particular column.

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 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. 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) soil quality parameters are lower than the first year of the corn rotation. The CC treatment performed near the bottom, in soil quality in all areas except soil hardness. This system has the least potential to reduce erosion and nutrient runoff.

Keeping in mind that there was planting error in all plots, the WCCC had the highest corn populations, although statistically similar to the other treatments. Yield was significantly lower in the NT treatment. The perennial forage cuttings differed statistically by cut for the most part, and overall had similar good quality. The PF treatment continued to have the best soil quality of all the treatments, sharing the high levels of aggregate stability, organic matter, soil proteins, and soil respiration with the NT treatment.

ACKNOWLEDGEMENTS

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 John Bruce, Erica Cummings, Catherine Davidson, Hillary Emick, Amanda Gervais, and Haley Jean for their assistance with data collection and entry. This study was funded by the Vermont Integrated Research and Extension Competitive Awards and by the Ben & Jerry's Caring Dairy Program. 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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