2016

Corn Cropping Systems to Improve Economic and Environmental Health

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NW CROPS & SOILS PROGRAM

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2016 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

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In 2016, 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 after perennial forage, corn planted after a cover crop of winter rye, and a perennial forage fescue.

MATERIALS AND METHODS

The corn cropping system 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, 2016.

Crop	Management method	Treatment abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	New corn (3rd year), in tilled alfalfa/fescue w/ cover crop	NC
Corn silage	No-till 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 taken on 28-Apr for Cornell Soil Health analysis. Ten soil samples from five locations within each plot were collected 6 inches in depth with a trowel, thoroughly mixed, put in a labeled gallon bag, and mailed with 2-day shipping on blue ice. Compaction was measured at 0-6 inch depth and 6-12 inch depth by penetrometer twice at the same 5 stops the soil samples were collected. The compaction measurements and soil types were used by the Cornell Nutrient Analysis 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^{o} C to remove water then ashed for two hours at 500^{o} 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 (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 Mycogen's TMF2Q419, which has a relative maturity (RM) of 96 days. The NC, CC, and WCCC treatments were plowed on 7-May. Corn was seeded in 30" rows on 10-May with a John Deere 1750 corn planter at 34,000 seeds per acre. At planting, 200 lbs per acre of a 10-20-20 starter fertilizer was applied.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2016.

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	Mycogen TMF2Q419 (96 RM)
Seeding rates (seeds ac^{-1})	34,000
Planting equipment	John Deere 1750 corn planter
Plow date	7-May
Planting date	10-May
Row width (in.)	30
Corn Starter fertilizer (at planting)	200 lbs ac^{-1} 10-20-20
Chemical weed control for corn	3 qt. Lumax® ac^{-1}, 17-May
Additional fertilizer (corn topdress)	19-Jun, based on plot recommendation (Table 6)
Forage 1st cut date	31-May
Forage 2nd cut date	19-Jul
Forage 3rd cut date	7-Sep
Corn harvest date	16-Sep

On 17-May, 3 quarts of Lumax® were applied per acre for weed control on corn plots. Corn was topdressed with nitrogen fertilizer by broadcast according to Pre-Sidedress Nitrite Test (PSNT) recommendations on 17-Jun (Table 6). The PSNT soil samples were collected with a 1-inch diameter Oakfield core to 6 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 16-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 first cut biomass samples were harvested by hand with clippers in an area of 12' x 3' section in fescue treatments on 31-May, second cut biomass samples were cut using the same procedure on 19-Jul, and third cut biomass samples were cut using the same procedure on 7-Sep. Perennial forage moisture and dry matter yield were calculated and yields adjusted to 35% dry matter. An approximate 2 lb subsample of the harvested material 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 hybrids were treated as fixed. Hybrid 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 2016 growing season (Table 3). Historical weather data are from 1981-2010 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT.

Temperatures through June and July of the growing season were near historical averages, with warmer than normal temperatures during May, August, and September of the growing season. April was colder than usual. Rainfall through the growing season was less than normal – a total of 7.53 inches below normal from April through September. There were a total of 2562 Growing Degree Days (GDDs) for corn for May through September—268 GDDs more than the historical average. There were a total of 3984 GDDs for forages for April through September— 195 GDDs more than the historical average (Table 4).

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2016.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	58.1	65.8	70.7	71.6	63.4
Departure from normal	1.80	0.00	0.10	2.90	2.90
Precipitation (inches)	1.50	2.80	1.80	3.00	2.50
Departure from normal	-1.92	-0.88	-2.37	-0.93	-1.17
Corn GDDs (base 50°F)	340	481	640	663	438
Departure from normal	74	7	1	82	104

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, 2016.

Alburgh, VT	April	May	June	July	August	September
Average temperature (°F)	39.8	58.1	65.8	70.7	71.6	63.4
Departure from normal	-4.9	1.8	0.0	0.1	2.9	2.9
Precipitation (inches)	2.6	1.5	2.8	1.8	3	2.5
Departure from normal	-0.26	-1.92	-0.88	-2.37	-0.93	-1.17
Perennial forage GDDs (base 32°F)	154	543	745	919	942	681
Departure from normal	-52	68	1	1	82	95

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 25-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. The PF and NT treatments had significantly higher aggregate stability with 61.7% and 54.5%, respectively. Surface hardness was lowest in the NC treatment, with the WCCC treatment statistically the same. Percent organic matter was highest in the PF (4.23%) treatment.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2016.

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	30.4	**0.203**	165	336	3.48	533	8.18	0.425
NC	47.0	0.198	**129***	352	3.80	529	8.43	0.550
NT	54.5*	0.190	187	**310**	3.70	547	8.43	0.500
WCCC	30.4	0.200	137*	333	3.50	511	7.93	0.500
PF	**61.7***	**0.203**	200	358	**4.23***	**605**	**9.63***	**0.850***
LSD (0.10)	10.6	NS	19.1	NS	0.42	NS	1.19	0.069
Trial Mean	44.8	0.199	137	338	3.70	545	8.52	0.565

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

On 17-Jun, soil samples were collected for PSNT analysis (Table 6). The mean soil nitrate-N (NO^{-3}) among the treatments was 8.06 ppm. The NT treatment had significantly lower soil nitrate-N and higher N amendment recommendation than the other cropping systems. 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, 2016.

Corn cropping system	NO^{-3} -N (ppm)	N recommendation for 25 ton ac^{-1} corn
CC	10.5*	111*
NC	9.35	118
NT	6.35	131
WCCC	**11.8***	**103***
LSD (0.10)	2.35	12.6
Trial Mean	8.06	120.5

* Treatments with an asterisk did not perform significantly lower than the top-performing treatment which is shown in **bold**.

Corn Silage Results

On 16-Sep, data was collected on corn silage populations and plots were harvested to determine moisture and yield (Table 7). Corn populations ranged from a low of 29,403 plants per acre (WCCC) to a high of 32,706 plants per acre (CC). The WCCC treatment had significantly lower populations than the other treatments. Yields (adjusted to 35% dry matter basis) ranged from 23.1 to 28.1 tons per acre. The WCCC treatment had the highest yield, with the NT treatment being significantly lower than the others. (Figure 1).

Pest and disease scouting occurred on 3-Jun (data not shown). Pest were scouted at harvest but no pest damage was identified. No foliar diseases were identified. Pests identified included corn borers, cut worms, and corn maggots. The CC treatment had the highest number of pests per plot (an average of 2.50 pests per plot). The other treatments had similar pest populations (an average of 2.0 pests per plot for the NC treatment, and an average of 1pests per plot for the WCCC and NT treatments).

Table 7. Corn silage population, harvest dry matter and yield by treatment, Alburgh, VT, 2016.

Corn cropping system	Harvest population plants ac^{-1}	Harvest dry matter %	Yield at 35 DM t ac^{-1}
CC	**32,706**	**37.7**	27.8*
NC	32,489*	35.8	27.1*
NT	31,327*	34.9	23.1
WCCC	29,403	37.2	**28.1***
LSD (0.10)	2288	NS	2.11
Trial mean	31481	36.4	26.5

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

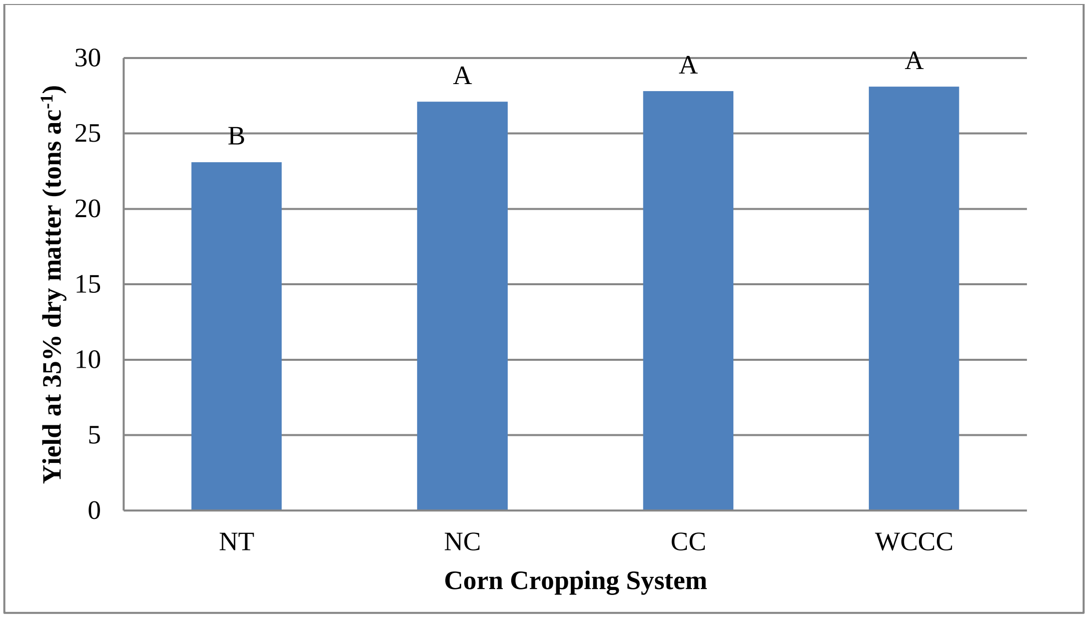

Figure 1. Dry matter yields of corn cropping systems in tons per acre, Alburgh, VT, 2016. Treatments that share a letter were not significantly different from one another (p=0.10).

Standard components of corn silage quality were analyzed (Table 8). There were a few significant differences in quality between cropping systems. The NT treatment had the highest crude protein, significantly more than any other treatment. The NT treatment also had significantly lower milk production in terms of milk per acre than the rest of the treatments. There were no significant differences in terms of the ADF, NDF, TDN, NE_L and milk per ton. The NT treatment had the lowest ADF and NDF. The WCCC treatment had the highest TDN, NE_L, and milk production in terms of both milk per ton (reflecting only feed quality) and milk per acre (reflecting both feed quality and yield).

Table 8. Impact of cropping systems on corn silage quality, 2016.

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	7.43	**24.0**	48.8	72.7	0.693	3284	31999*
NC	7.48	26.3	51.4	72.6	0.690	3271	31033*
NT	**8.20***	**24.0**	**47.8**	73.3	**0.703**	3355	27049
WCCC	7.35	24.2	48.3	**73.7**	**0.703**	**3360**	**32772***
LSD (0.10)	0.53	NS	NS	NS	NS	NS	2673
Trial mean	7.61	24.6	49.1	73.0	0.697	3317	30713

* Treatments with an asterisk did not perform significantly lower than the top-performing treatment in a particular column. 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 second cutting had the highest protein level at 22.0%. The first cutting was lowest in protein at 15.3% of dry matter. The first cutting was highest quality in terms of ADF and NDF. The 2nd cut had highest yield at 8.55 tons per acre.

Table 9. Impact of harvest date on perennial forage quality, 2016.

Alfalfa/Fescue cutting	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	Yield at 35 DM t ac^{-1}
1st cut 31-May	15.3	33.2	64.4	57.2	8.47
2nd cut 19-Jul	22.0	30.3	58.2	60.2	8.55
3rd cut 7-Sep	19.2	32.3	59.0	58.5	6.96
Trial mean	18.8	32.0	60.5	58.6	7.99

Multi-year comparison

Figures 2-5 compare yields and soil health characteristics over the past two years of the trial. Overall, yields were relatively the same between the two years, with the exception being the PF treatment, which had a much lower yield in 2016 compared to 2015. The trends among yields for the corn cropping system were similar to 2015. The NT corn treatment had consistently lower yields compared to corn grown in tillage treatments. There was little observed yield difference between CC, NC, and WCCC.

Active carbon went down from 2015 to 2016 across all treatments (Figure 2). Soil proteins went up from 2015 to 2016 across all treatments (Figure 4). The treatments maintained the same ranking in terms of most soil health characteristics (including organic matter, Fig 2). The PF treatment was consistently the best in terms of soil quality characteristics ranking the highest in organic matter, active carbon, proteins, and respiration. The NT and NC treatments were general second and third in terms of soil health, with the WCCC and CC treatments performing at the bottom.

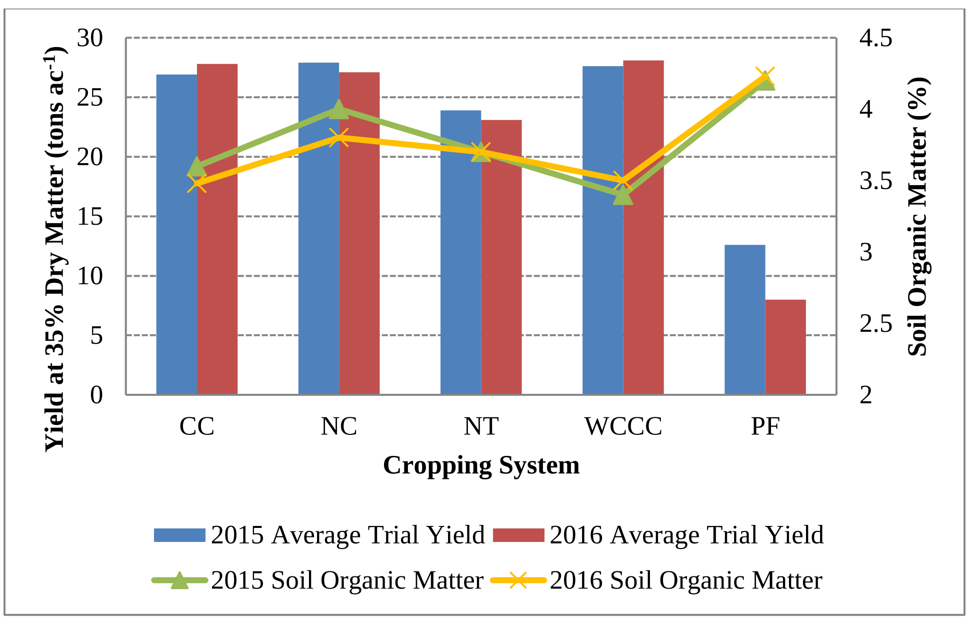

Figure 2. Comparison of cropping systems yields and soil organic matter in 2015 and 2016, Alburgh, VT.

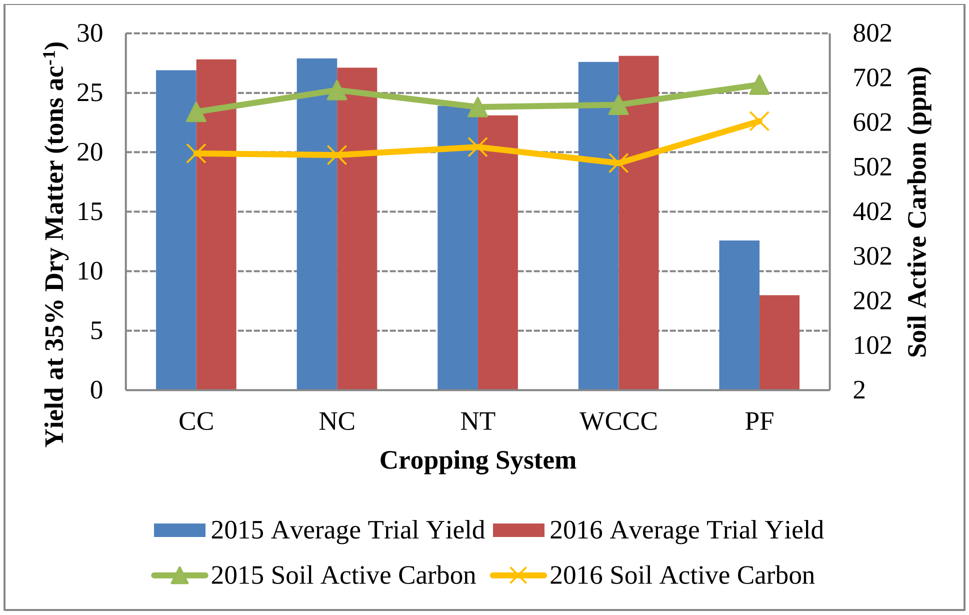

Figure 3. Comparison of cropping systems yields and soil active carbon in 2015 and 2016, Alburgh, VT.

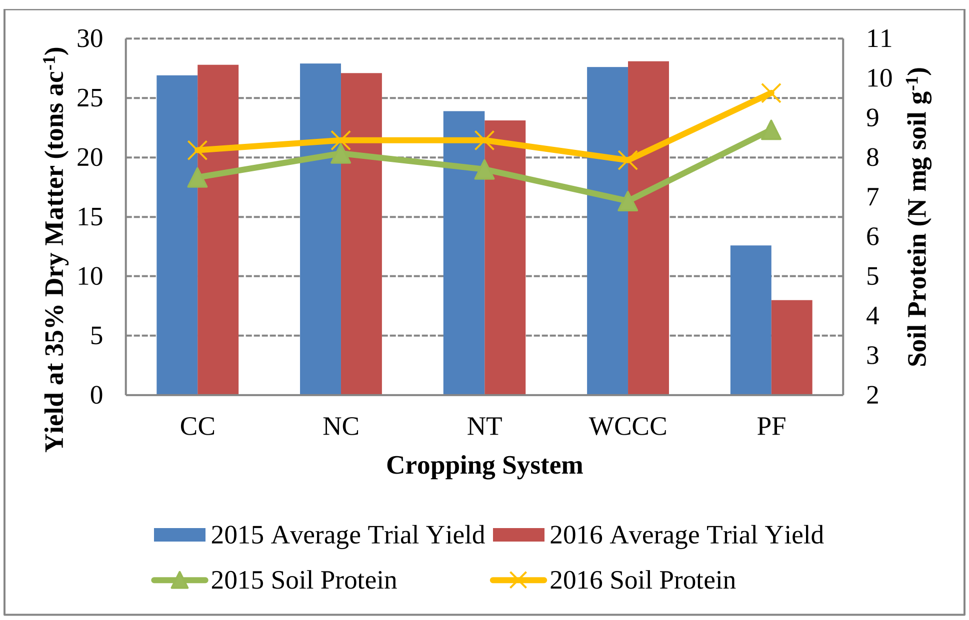

Figure 4. Comparison of cropping systems yields and soil protein in 2015 and 2016, Alburgh, VT.

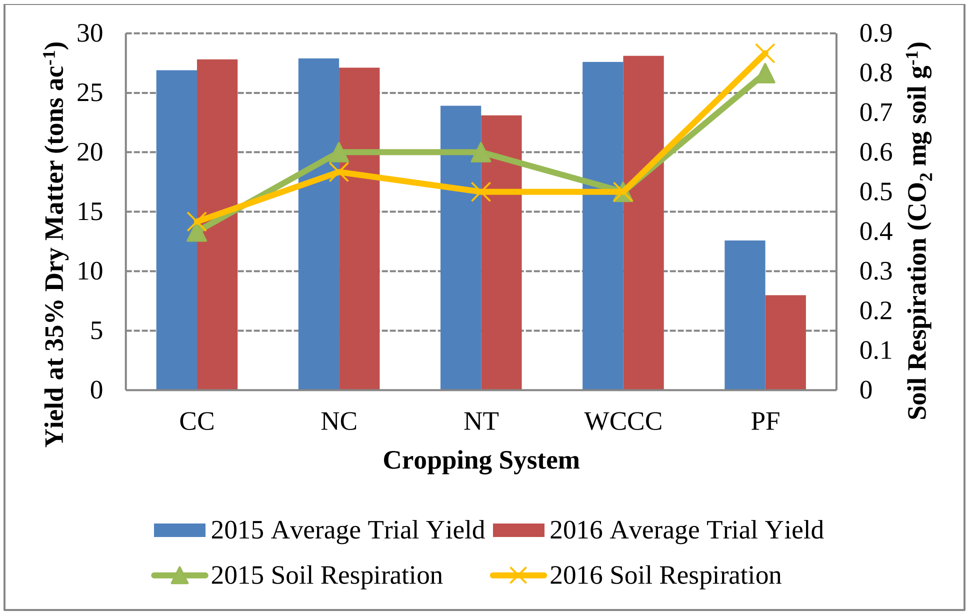

Figure 5. Comparison of cropping systems yields and soil respiration in 2015 and 2016, Alburgh, VT.

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 both surface and subsurface hardness, where it was the lowest performing treatment, same as last year. 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. The NT corn and PF treatment 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 5 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. This system has the least potential to reduce erosion and nutrient runoff.

The CC had the highest corn populations although statistically similar to NC and NT. WCCC had significantly lower populations although the highest in terms of yield. Interestingly, 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, significantly less than the other three treatments. All treatments performed well in terms of population and yield, reflecting a good corn season with warm temperatures and a high number of growing degree days 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. Yields were much lower than the corn yields with the average forage yield about a third that of the average of the corn yields. 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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