2015

Corn Cropping Systems to Improve Economic and Environmental Health

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NW CROPS & SOILS PROGRAM

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2015 CORN CROPPING SYSTEMS TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

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In 2015, 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, 2015.

Crop	Management method	Treatment abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	New corn (2nd 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 0-25% slopes (Table 2). Each cropping system was replicated 4 times in 20' x 50' plots. This site has been in a cropping systems study for the last seven years. 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 TMF2L395, which has a relative maturity (RM) of 94 days. The NC, CC, and WCCC treatments were plowed on 4-May. Corn was seeded in 30" rows on 7-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, 2015.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Amenia silt loam, 0-25% 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 TMF2L395 (94 RM)
Seeding rates (seeds ac^{-1})	34,000
Planting equipment	John Deere 1750 corn planter
Plow date	4-May
Planting date	7-May
Row width (in.)	30
Corn Starter fertilizer (at planting)	250 lbs acre^{-1} 10-20-20
Chemical weed control for corn	3 qt. Lumax® acre^{-1}, 17-May
Additional fertilizer (corn topdress)	19-Jun, based on plot recommendation (Table 6)
Forage 1st cut date	4-Jun
Forage 2nd cut date	17-Jul
Forage 3rd cut date	4-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 19-Jun (Table 6). The PSNT soil samples were collect 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), 30-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 4-Jun, second cut biomass samples were cut using the same procedure on 17-Jul, and third cut biomass samples were cut using the same procedure on 4-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 30-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 example below, 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 2015 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 most of the growing season were near historical averages, with warmer than normal temperatures at the beginning and end of the growing season (May and September). Rainfall through the growing season was much less than normal – a total of 11.42 inches below normal from April through September. The one exception was the month of June that was well below normal for temperature and much wetter than average. Adverse weather during this month likely impacted early season corn growth and had longer lasting effects on end of season yields. There were a total of 2577 Growing Degree Days (GDDs) for corn for May through September—366 GDDs more than the historical average. There were a total of 4065 Growing Degree Days (GDDs) for forages for April through September— 362 GDDs more than the historical average (Table 4).

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2015.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	61.9	63.1	70.0	69.7	65.2
Departure from normal	5.5	-2.7	-0.6	0.9	4.6
Precipitation (inches)	1.94	6.42	1.45	0.00	0.34
Departure from normal	-1 .51	2.73	-2.70	-3.91	-3.30
Corn GDDs (base 50°F)	416	416	630	624	492
Departure from normal	218	-58	-10	43	174

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, 2015.

Alburgh, VT	April	May	June	July	August	September
Average temperature (°F)	43.4	61.9	63.1	70.0	69.7	65.2
Departure from normal	-1.4	5.5	-2.7	-0.6	0.9	4.6
Precipitation (inches)	0.09	1.94	6.42	1.45	0.00	0.34
Departure from normal	-2.73	-1.51	2.73	-2.70	-3.91	-3.30
Perennial forage GDDs (base 32°F)	191	655	669	908	903	740
Departure from normal	77	178	-75	-10	41	152

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 28-Apr, before planting corn, soil samples were collected on all plots (Table 5). The PF and NT treatments had significantly higher aggregate stability with 56.2% and 50.5%, respectively. The PF treatment also had the highest available water capacity at 0.25 m per meter of soil. This was statistically the same as the CC, NC, and NT treatments. Surface hardness was lowest in the WCC treatment, with only the PF treatment significantly higher. Sub-surface hardness was lowest in the CC treatment although there was no significant difference between treatments. Percent organic matter was highest in the PF (4.2%) and NC (4.0%) treatments. These two treatments were also highest in active carbon although there was no significant difference between the other treatments. Mineralized nitrogen was highest in the PF treatment, which was statistically similar to the NC and NT treatments. Soil respiration was highest in the PF treatment, which was significantly different from all other treatments.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2015.

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	23.9	0.24*	145	**262**	3.6	626	7.5	0.4
NC	45.7	0.25*	153*	282	4.0*	675	8.1*	0.6
NT	50.5*	0.24*	158*	268	3.7	637	7.7*	0.6
WCCC	32.7	0.21	**123**	276	3.4	642	6.9	0.5
PF	**56.2**	**0.25**	196	284	**4.2**	**687**	**8.7**	**0.8**
LSD (0.10)	10.2	0.02	35	NS	0.34	NS	1.11	1.78
Trial Mean	41.8	0.24	155	274	3.8	653	7.8	0.6

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

On 17-Jun, soil samples were collected for PSNT analysis in corn crop plots (Table 6). The mean soil nitrate-N (NO^{-3}) among the treatments was 7.38 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, 2015.

Corn cropping system	NO^{-3} -N (ppm)	N recommendation for 25 ton ac^{-1} corn
CC	**8.93**	123*
NC	8.79*	**115**
NT	4.55	138
WCCC	7.25*	129*
PF	N/A	N/A
LSD (0.10)	2.63	14
Trial Mean	7.38	126

Treatments shown in **bold** are top-performing in a particular column.
* Treatments with an asterisk did not perform significantly lower than the top-performing treatment in a particular column.

Corn Silage Data

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 26,245 plants per acre (CC) to a high of 29,621 plants per acre (NC). The CC treatment had significantly lower populations than the other treatments. Yields (adjusted to 35% dry matter basis) ranged from 23.9 to 27.9 tons per acre. While the NC treatment had the highest yield, there was no significant difference between treatments (Figure 1).

Pest and disease scouting occurred on 3-Jun (data not shown). Pest were scouted at harvest but no pest damage was identified. While some ribboning was noted, no foliar diseases were identified. Pests identified included corn borers, cut worms, and corn maggots. The NT treatment had the highest number of pests per plot (an average of 8.75 pests per plot). The other treatments all had much lower pests populations (an average of 2 pests per plot for the CC and NC treatments, and an average of 2.25 pests per plot for the WCCC treatment).

Table 7. Corn silage population, harvest dry matter and yield by treatment, Alburgh, VT, 2015.

Corn cropping system	Harvest population plants ac^{-1}	Harvest dry matter %	Yield at 35 DM t ac^{-1}
CC	26,245	41.9	26.9
NC	**29,621**	42.7	**27.9**
NT	28,532*	42.9	23.9
WCCC	29,512*	**43.7**	27.6
LSD (0.10)	2332	NS	NS
Trial mean	28,477	42.8	26.6

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

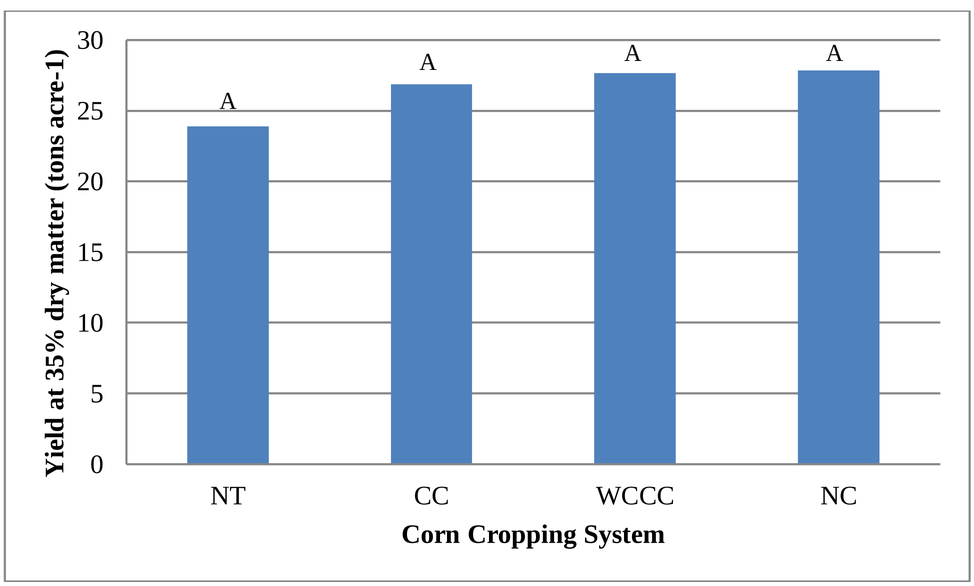

Figure 1. Dry matter yields of corn cropping systems in tons per acre, Alburgh, VT, 2015. Treatments that share a letter were not significantly different from one another (p=0.10).

Standard components of corn silage quality were analyzed (Table 8). There was no significant difference in quality between cropping systems. The WCCC treatment had the highest crude protein. The NT treatment had the highest ADF and NDFD. The CC treatment had the highest NDF. The NC 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, 2015.

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 ac^{-1} lbs
CC	7.3	25.7	**47.0**	63.2	0.64	2,785	26,123
NC	7.4	25.0	45.7	**64.4**	**0.65**	**2,872**	**27,995**
NT	7.5	**26.2**	47.0	63.9	0.64	2,836	23,943
WCCC	**7.5**	25.3	46.7	63.3	0.64	2,796	27,008
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS
Trial mean	7.4	25.5	46.6	63.7	0.64	2,822	26,267

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 20.1%. The first cutting was lowest in protein at 14.7% of dry matter. The third cutting was highest quality in terms of ADF and NDF. The harvest yields improved throughout the growing season, more than doubling between the first and second cutting dates.

Table 9. Impact of harvest date on perennial forage quality, 2015.

Alfalfa/Fescue cutting	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	Harvest Moisture %	Yield at 35 DM t ac^{-1}
1st cut 4-Jun	14.7	31.6	57.1	64.3	65.6	7.12
2nd cut 17-Jul	20.1	32.7	60.0	68.5	77.9	14.59
3rd cut 4-Sep	16.0	38.0	66.2	58.1	71.3	16.07
Trial mean	16.9	34.1	61.1	63.6	71.6	12.59

Multi-year comparison

Figures 2-5 compare yields and soil health characteristics over the past two years of the trial. Overall, yields were higher in 2015 than in 2014. It is interesting to note that while yields were higher within each treatment, the ranking of each cropping system did not change between years. NC had the highest yield for each year, followed by WCCC, CC, NT and PF. The treatments maintained the same ranking in terms of most soil health characteristics (including organic matter, Fig 2). The NC and PF treatments were consistently the best in terms of soil quality characteristics. In 2014, the NC treatment was the highest in terms of active carbon, soil proteins and soil respiration, with PF a close second, while in 2015 PF was the highest ranked in these characteristics with NC a close second. The PF treatment showed the greatest increase in active carbon, soil respiration, and soil proteins between 2014 and 2015.

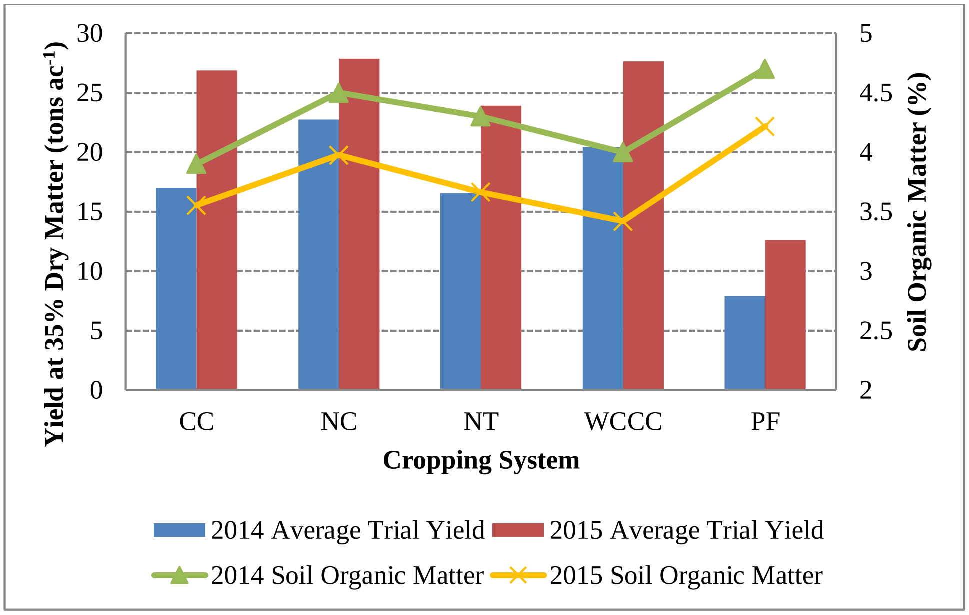

Figure 2. Comparison of cropping systems yields and soil organic matter in 2014 and 2015, Alburgh, VT.

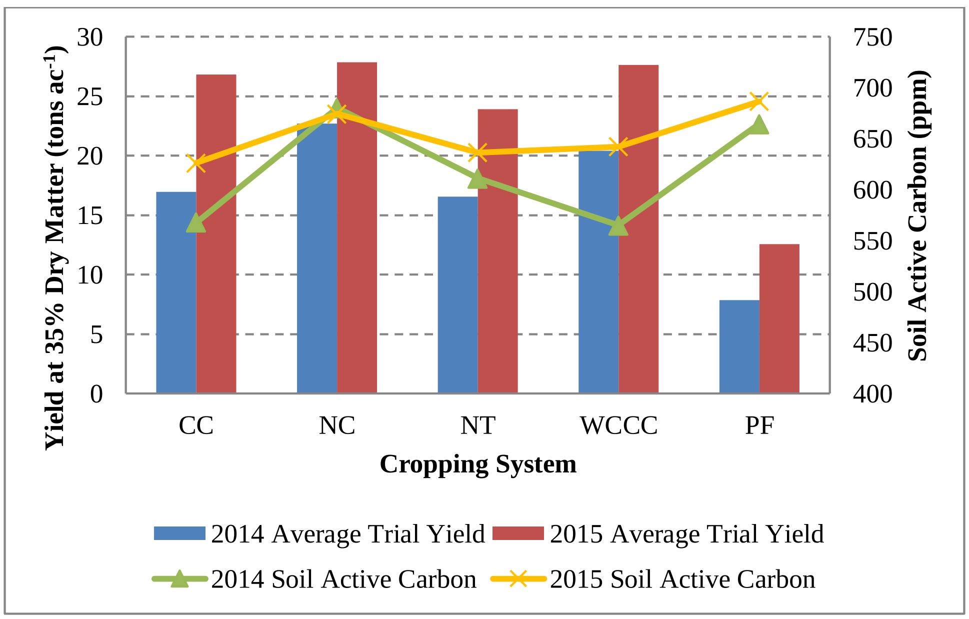

Figure 3. Comparison of cropping systems yields and soil active carbon in 2014 and 2015, Alburgh, VT.

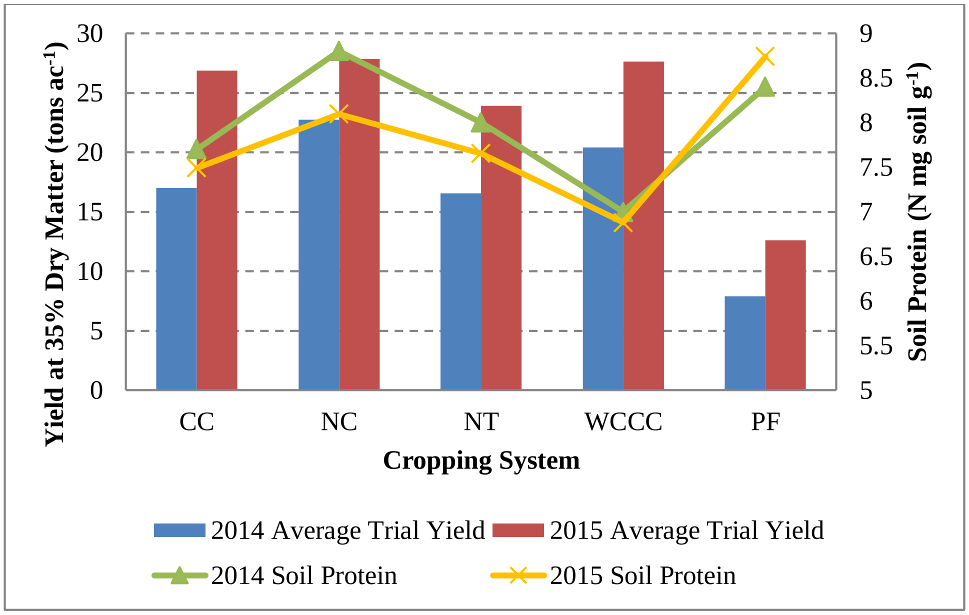

Figure 4. Comparison of cropping systems yields and soil protein in 2014 and 2015, Alburgh, VT.

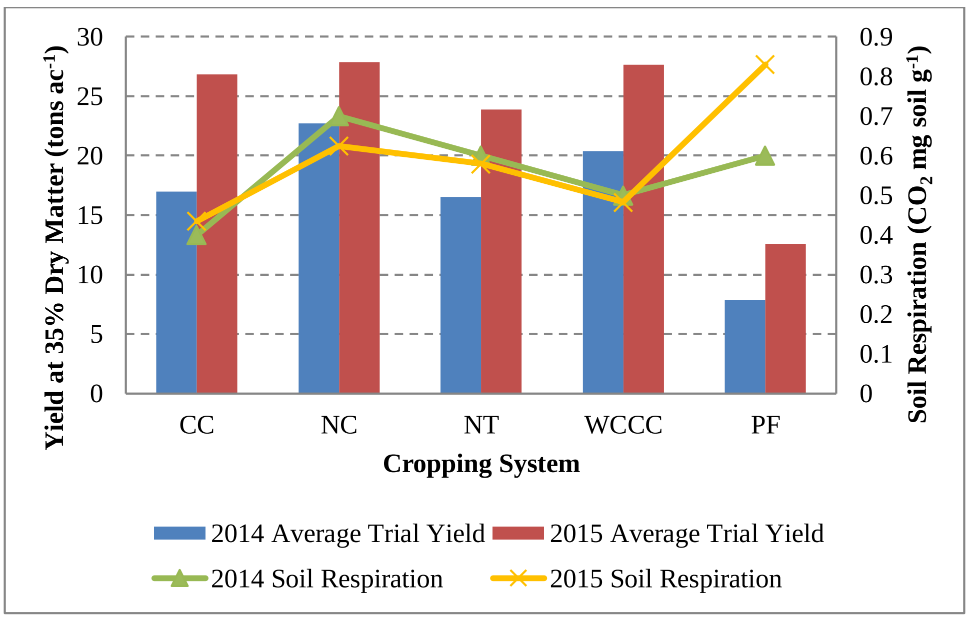

Figure 5. Comparison of cropping systems yields and soil respiration in 2014 and 2015, Alburgh, VT.

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. 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. Interestingly, the WCCC treatment had the lowest surface compaction which indicates that cover crops can help improve the aeration of the soil. The WCCC also had the lowest available water capacity compared to other treatments. Given the dry spring that occurred in 2015, the addition of a growing cover crop would have further dried out the soil profile. In a wet spring, a cover crop can dry out the soil profile but this quality might have a negative impact on the subsequent crop in a dry year.

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. The soil quality of the NT treatments closely rivaled the PF and NC. This treatment clearly reflects the potential for NT corn to maintain soil quality during the corn years of a rotation. 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 but did seem to improve it a bit over CC. Corn in a short rotation with sod (NC) was still maintaining higher levels of aggregate stability even after its second year of tillage. Biological properties also remained quite high in this system. The CC treatment performed worst in soil quality in all areas except soil hardness. This system has the least potential to reduce erosion and nutrient runoff.

The NC had the highest corn populations and highest yield in this year's trial, although all treatments had statistically similar yields. 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. Corn pests were present in all treatments and particularly prevalent in the NT treatment. The NT treatment also had the lowest yield in the trial, but it is difficult to determine if the lower yield was actually due to the higher prevalence of pests in this treatment.

The perennial forage first cutting had overall lower quality and yield than the second and third cuttings. The quality of the forages was very high through the season. Even the lowest quality first cutting was higher quality than any of the corn systems. Yields, however, were much lower than the corn yields with the average forage yield about half 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.

Overall, the NC cropping system was the highest performing corn cropping system in terms of yield and feed quality, although there was no significant difference between treatments, and performed very well in terms of soil quality. The perennial forages outperformed the corn treatments in terms of both feed quality and soil quality although their yields were far lower than the corn treatments. The NT treatment performed very well in soil quality but yield drag was still an issue with this system. Special attention in the early season crop fertility may help ameliorate this issue. The winter cover cropping corn system did appear to improve soil quality of the CC system. The high soil quality, feed quality and yields of the NC cropping system suggests that years of established perennial forages will improve soil quality, crop yield, and provide the forage that winter cover crop does not necessarily produce. It is clear that the soil health benefits of the NC were beginning to diminish in its 2nd year of tillage, however yields were still excellent with lower pesticide and fertility inputs required compared to the other cropping systems.

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