2014 Corn Cropping Systems to Improve Economic and Environmental Health

Dr. Heather Darby, UVM Extension Agronomist
Lindsey Ruhl, Erica Cummings, Susan Monahan, Julian Post, and Sara Zeigler
UVM Extension Crops and Soils Technicians
802-524-6501

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2014 CORN CROPPING SYSTEM TO IMPROVE ECONOMIC AND ENVIRONMENTAL HEALTH

Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

In 2014, UVM Extension's Northwest Crops & Soils Program initiated a 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, 2014.

Crop	Management Method	Treatment Abbreviation
Corn silage	Continuous corn, tilled	CC
Corn silage	New corn, in tilled alfalfa/fescue	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'x50' plots. This site has been in a cropping systems study for the last six years. Soil samples were taken on 7-May 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 Seedway's '5554GT,' which has a relative maturity (RM) of 105 days and is glyphosate tolerant. The NC, CC, and WCCC treatments were plowed on 10-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 the starter fertilizer 10-20-20 was applied.

Table 2. Agronomic information for corn cropping system, Alburgh, VT, 2014.

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	Seedway '5554GT' (105 RM)
Seeding rates (seeds ac^{-1})	34,000
Planting equipment	John Deere 1750 corn planter
Plow date	10-May
Planting date	13-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® $acre^{-1}$, 5-Jun
Additional fertilizer (corn topdress)	Based on plot recommendation (Table 6)
Forage 1st cut date	6-Jun
Forage 2nd cut date	1-Aug
Corn harvest date	25-Sep

On 5-Jun, 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 2-Jul (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 25-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 6-Jun and second cut biomass samples were cut using the same procedure on 1-Aug. 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 to the right, 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 2014 growing season (Table 3). Historical weather data are from 1981-2010 at cooperative observation stations in Burlington, VT, approximately 45 miles from Alburgh, VT.

The spring of 2014 was wetter with 3.81 inches more rain than the average year. This delayed corn planting for many farmers. However, after June the summer was drier and cooler than normal. GDDs are calculated below at a base temperature of 50°F for corn (Table 3) and 32°F for perennial forage (Table 4). Between corn planting in May and harvest in September, there was a total of 2,241 corn GDDs, 30 more than the 30-year average. There were 5,299 GDDs accumulated for perennial forage crops between April and September (50 less than the historical average). In mid-September there was an early frost that prevented the corn from maturing and drying down quickly.

Table 3. Consolidated weather data and GDDs for corn, Alburgh, VT, 2014.

Alburgh, VT	May	June	July	August	September
Average temperature (°F)	57.4	66.9	69.7	67.6	60.6
Departure from normal	1.0	1.1	-0.9	-1.2	0.0
Precipitation (inches)	4.90	6.09	5.15	3.98	1.33
Departure from normal	1.45	2.40	1.00	0.07	-2.31
Corn GDDs (base 50°F)	238	501	613	550	339
Departure from normal	40	27	-27	-31	21

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, 2014.

Alburgh, VT	April	May	June	July	August	September
Average temperature (°F)	43.0	57.4	66.9	69.7	67.6	60.6
Departure from normal	-1.8	1.0	1.1	-0.9	-1.2	0.0
Precipitation (inches)	4.34	4.90	6.09	5.15	3.98	1.33
Departure from normal	1.52	1.45	2.40	1.00	0.07	-2.31
Perennial forage GDDs (base 32°F)	330	789	1041	1171	1108	860
Departure from normal	-54	33	27	-27	-31	2

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). The NC and PF treatments had significantly higher aggregate stability with 57.6% and 55.8%, respectively. However, there was no significant difference in available water capacity among the cropping systems. Surface and sub-surface hardness was lowest in the CC treatment. Percent organic matter was highest in the PF (4.7%) and NC (4.5%) treatments. In addition, active carbon was highest in those two treatments (NC, 380.2 ppm; PF, 664.6 ppm). Potentially, mineralized nitrogen and soil respiration was highest in the NC, PF, and NT cropping systems.

Table 5. Soil quality for five corn cropping systems, Alburgh, VT, 2014.

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	34.7	0.2	**85.0***	**200.0***	3.9	568.0	7.7*	0.4
NC	**57.6***	0.2	125.6	257.5	4.5*	**680.2***	**8.8***	**0.7***
NT	54.7	0.2	140.0	248.8	4.3	611.2	8.0*	0.6*
WCCC	37.1	0.2	84.4*	233.1	4.0	565.2	7.0	0.5
PF	55.8*	0.2	120.6	255.0	**4.7***	664.6*	8.4*	0.6*
LSD (0.10)	10.3	NS	20.6	26.2	0.36	62.2	1.2	0.10
Trial Mean	48.0	0.2	111	239	4.3	618	8.0	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 2-Jul, soil samples were collected for PSNT analysis in corn crop plots (Table 6). There was no significant difference among the tested corn cropping systems of nitrogen in the soil or medium and high recommendations. The mean soil nitrate-N (NO^{-3}) among the treatments was 14.31 ppm. Nitrogen fertilization recommendations were highest for continuous corn and lowest for corn planted into winter cover crop. Nitrogen, in the form of urea, was applied to the corn treatments based on their respective PSNT results. Hence, WCCC treatments received 65 lbs. of N per acre and CC treatments 95.0 lbs. of N per acre.

Table 6. Soil nitrate-N and N recommendations for medium and high yield potential, Alburgh, VT, 2014.

Corn cropping system	NO^{-3} -N (ppm)	Medium N recommendation	High N recommendation
CC	8.25	95.0	118.75
NC	10.75	87.5	108.75
NT	21.75	67.5	83.75
WCCC	16.50	65.0	78.75
PF	N/A	N/A	N/A
LSD (0.10)	NS	NS	NS
Trial Mean	14.31	78.75	97.50

NS – No significant difference was determined.

Corn Silage Data

On 25-Sep, data was collected on corn silage populations and plots were harvested to determine moisture and yield (Table 7). Corn silage planted in tilled winter cover crop or in no-till conditions had significantly higher populations with 19,907 and 21,301 corn plants per acre, respectively. Corn borer populations were lowest in the NC plots and highest in the CC plots. However, there was no statistical difference among corn borer populations by corn cropping treatment. With respective dry matter yields of 22.72 and 20.40 tons per acre, NC and WCCC cropping systems had significantly higher yields (Figure 1).

Table 7. Corn Silage and corn borer population and yield by treatment, Alburgh, VT, 2014.

Corn cropping system	Harvest population plants ac^{-1}	Corn pest population % ac^{-1}	Harvest dry matter %	Yield at 35 DM t ac^{-1}
CC	18,687	20.3	31.6	16.98
NC	18,513	**0.0**	34.5	**22.72***
NT	19,907	9.54	33.8	16.54
WCCC	21,301*	13.3	**35.3**	20.40*
LSD (0.10)		NS	NS	2.5
Trial mean	19,602	10.9	33.8	16.16

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.

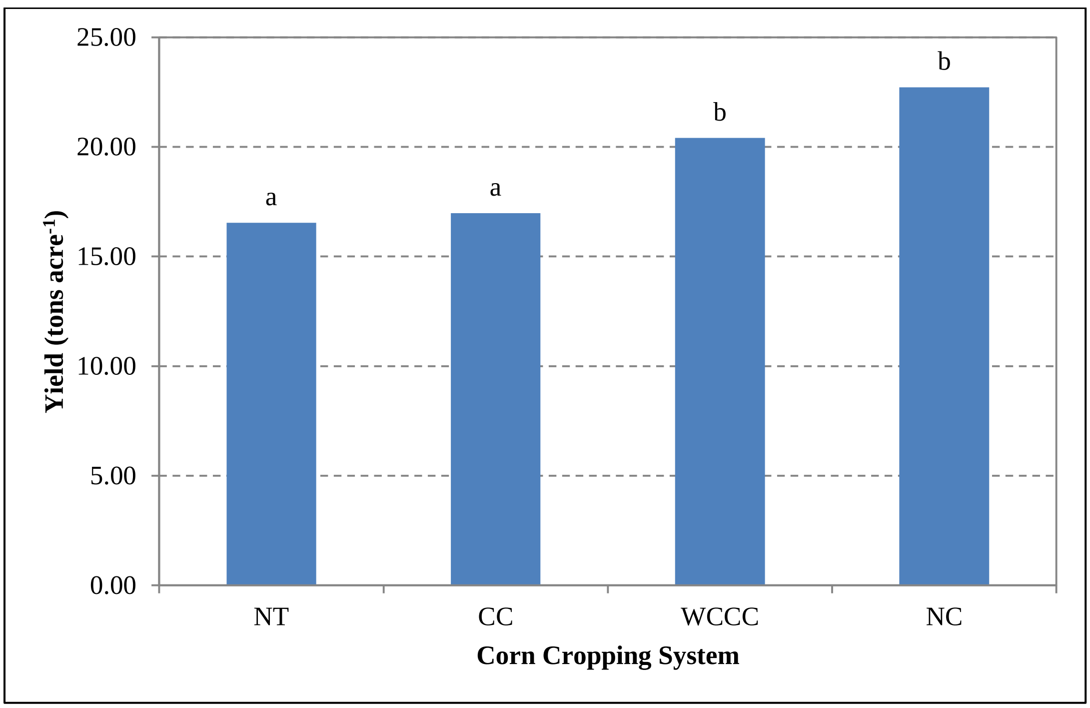

Figure 1. Dry matter yields of corn cropping systems in tons per acre, Alburgh, VT, 2014. Treatments that share a letter were not significantly different from one another (p=0.10).

Standard components of corn silage quality were analyzed (Table 8). There was no significant difference in NDF, NDFD, starch, TDN, NE_L, or Milk ton^{-1}. Crude protein was significantly higher in the NC cropping system than the NT and WCCC treatments (Figure 2). Milk per acre was significantly higher for NC and WCCC treatments. This measurement is calculated using yield, as well as quality data, which is why higher yielding plots also result in greater milk per acre.

Table 8. Impact of cropping systems on corn silage quality, 2014.

Corn cropping system	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	TDN % of DM	NE_L Mcal lb^{-1}	Milk lbs ton^{-1}	Milk ac^{-1} lbs
CC	7.0*	23.1	43.2	45.2	71.4	0.7	3,298	19,591
NC	**7.5***	**24.4***	43.6	46.0	71.6	0.7	3,314	**26,387***
NT	6.8	23.4*	**42.8**	45.6	**72.0**	0.7	**3,342**	19,360
WCCC	6.4	23.2*	43.1	**45.0**	71.5	0.7	3,300	23,580*
LSD (0.10)	0.6	1.3	NS	NS	NS	NS	NS	3,297
Trial mean	6.9	23.5	43.2	45.4	71.6	0.70	3,313	22,229

Treatments indicated in **bold** had the top observed performance.

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

NS – No significant difference was observed between treatments.

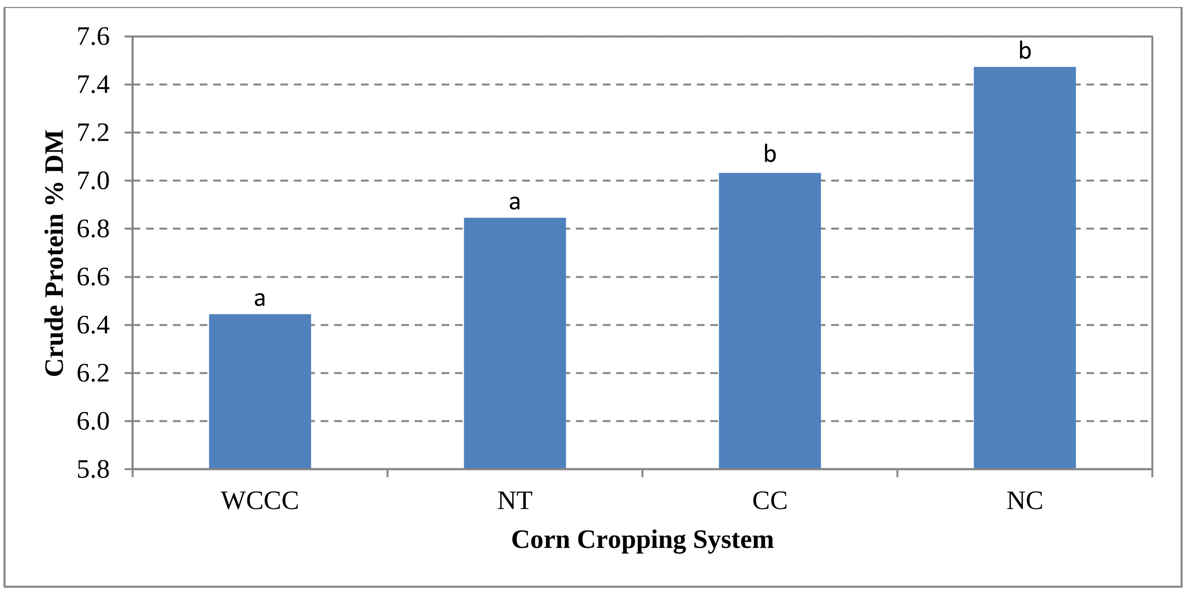

Figure 2. Crude protein as percent DM in corn cropping systems, Alburgh, VT, 2014. Treatments that share a letter were not significantly different from one another (p=0.10).

Perennial Forage Data

The perennial forage plots were analyzed for basic quality parameters (Table 9). Percent crude protein and acid digestible feed were affected by cutting date. The first harvest had higher CP and the second cutting had higher ADF. There was no statistical difference between NDF and NDFD between first and second dates. Although there was nearly twice as much dry matter yield per acre in the second cutting, there was no statistical difference of dry matter yield between the cutting dates.

Table 9. Impact of harvest date on perennial forage quality, 2014.

Alfalfa/Fescue cutting	CP % of DM	ADF % of DM	NDF % of DM	NDFD % of NDF	Yield at 35 DM t ac^{-1}
6-Jun	**14.2***	32.9	55.9	62.4	1.76
1-Aug	12.6	**35.5***	57.26	62.3	3.52
LSD (0.10)	1.2	1.7	NS	NS	NS
Trial mean	13.4	34.2	56.6	62.3	2.64

Treatments indicated in **bold** had the top observed performance.

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

NS – No significant difference was observed between treatments.

DISCUSSION

It is important to note that the results of this trial represent only one year of data and only in one location. 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, NC and PF systems performed best overall, particularly in areas of aggregate stability, organic matter, active carbon, potential nitrogen, and soil respiration. These two cropping systems have the greatest potential to reduce erosion and nutrient runoff and likely provide resiliency to extreme weather conditions. The CC and WCCC treatments had the lowest aggregate stability indicating that these soils would be more prone to runoff and erosion. The higher microbial activity represents that ability for these soils to cycle nutrients and also better retain nutrients. The NT treatments were transitioned from PF to corn 3 years ago and the lack of soil disturbance is reflected in 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. Interestingly, the CC and WCCC cropping systems had less surface and subsurface compaction in the spring. This likely is due to the fact that these treatments are regularly tilled and compacted layers disturbed.

Despite the difference in microbial activity among the cropping systems, there was no significant difference in either nitrate-N in the soil or recommended nitrogen application among any of the treatments. This suggests that although the potential nitrogen was higher in the NC cropping system, the plowed plant biomass had not fully mineralized to meet the needs of the corn crop. The organic nitrogen bound in the plowed plant biomass should be available for next year's corn crop. Interestingly, these results do indicate that winter cover crops do provide nitrogen value to the subsequent crop and likely can reduce N applications by 30 or more lbs. per acre.

Although NT and CC cropping systems had higher corn populations, NC and WCCC cropping systems had the highest yields. Since treatments were fertilized to meet the needs of the crop, the increase in yield was likely due to better soil conditions for crop growth. Overall corn populations were low and may have been due to heavy rains in early June and/or difficult seeding conditions in the case of newly plowed sod in the NC treatment. Corn pests were prevalent in all treatments with the exception of NC. This indicates that proper rotation can minimize corn borer and corn rootworm issues. It is difficult to determine if these corn pests had an impact on yield but NC did out yield all other corn treatments.

The perennial forage first cutting had nearly twice as much crude protein as the highest corn silage cropping system (new corn), but the perennial forage total harvest was 23% the DM yield ton per acre than the new corn cropping system. 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 performed best in terms of soil quality and yield. The NT treatment improved soil quality but yield drag was still an issue with this system. Furthermore, the winter cover cropping corn system did not appear to remediate the low soil quality of the CC system in one year. The high soil 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.

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