2015 Manure Incorporation and Reduced Tillage Corn Trial

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Timely manure incorporation can reduce nutrient losses to the atmosphere and surface runoff. Keeping valuable nutrients, like nitrogen, in the soil can help reduce the purchase of expensive commercial fertilizers. Reduced tillage corn is becoming more common as growers recognize the benefits to soil health and water quality. There are many options to implement reduced tillage including no-tillage, strip-tillage, and vertical-tillage, as well as a plethora of strategies and technologies to implement these techniques. No-tillage planting uses metal coulters to cut a slot for the seed, rather than tilling the soil. Strip-tillage opens a strip 8-10" in both directions from the seed slot, warming and drying the soil to aid in corn germination. Vertical-tillage lightly tills the top 2-3" of the soil, as the implement is pulled quickly across a field to produce a uniform seedbed without deep tillage.

Little research has been done in the region to assess the combined effects of manure application and reduced tillage practices on silage corn yields and quality. With the increased regional availability of innovative equipment such as manure injectors, aerators, strip tillers, and no-till planters, the University of Vermont Extension's Northwest Crops & Soils Program designed a trial in 2015 to evaluate both manure incorporation and reduced tillage corn planting techniques on corn yield and quality.

MATERIALS AND METHODS

A trial was initiated at Borderview Research Farm in Alburgh, VT in 2015. The experimental design was a randomized complete block with a split plot arrangement and four replications. Main plots were comprised of three reduced tillage methods; subplots consisted of four manure incorporation methods (Table 1).

Table 1. Main plot and subplot treatments of the manure incorporation and reduced tillage corn trial, 2015.

Tillage methods	Manure incorporation methods
No	Aerator
Strip	Broadcast
Vertical	Injection
Plow	Plow

Each plot was 12' x 40' and there were 40' buffers between main plots (Table 2). The soil type at the research site was a Benson rocky silt loam. The previous crop was corn, followed by a cover crop of winter rye. Liquid manure was applied on 14-May and 15-May at a rate of 6300 gallons ac^{-1}. The manure incorporation methods were applied at the time of manure application (injection) or immediately following application (aerator and plow). Broadcasted manure was left on the surface and not incorporated. Strip and vertical tillage were completed with a Blu-Jet Coulter Pro and a John Deere 2623 Vertical Tillage machine VT, respectively, on 15-May (Figure 1).

Figure 1. Blu-Jet Coulter Pro strip tillage, left, and John Deere 2623 VT vertical tillage, right.

The corn variety planted was 'TMF2Q419' (Mycogen, 96 RM). At planting, a 10-20-20 starter fertilizer was applied at 250 lbs ac^{-1}. Soil samples were collected on 3-Jun and 17-Jun; nitrate levels were tested at the University of Vermont's Agricultural and Environmental Testing Lab. Corn populations were assessed on 23-Sep just prior to harvest.

Table 2. Trial specifics for manure incorporation and reduced tillage corn trial, Alburgh, VT, 2015.

Location	Borderview Research Farm – Alburgh, VT
Soil type	Benson rocky silt loam
Previous crop	Corn with winter rye cover crop
Plot size (ft)	12 x 40
Replications	4
Manure application date	14,15-May
Manure application rate (gal ac^{-1})	6300
Tillage (vertical)	15-May
Tillage (strip)	15-May
Corn variety	Mycogen 'TMF2Q419' (96 RM)
Seeding rate (seeds ac^{-1})	34,000
Planting equipment	John Deere 1750 corn planter
Planting date	18-May
Row width (in.)	30
Starter fertilizer (at planting)	250 lbs ac^{-1} 10-20-20
Harvest date	30-Sep

Corn plots were harvested on 30-Sep with a John Deere 2-row chopper, and forage was weighed in a wagon fitted with scales. Dry matter yields were calculated and then yields were adjusted to 35% dry matter. A subsample of the harvested material was collected, dried, ground, and then analyzed at the University of Vermont's Testing Laboratory, Burlington, VT, for quality analysis. 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 lab 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), neutral detergent fiber (NDF), acid detergent fiber (ADF), non-fiber carbohydrates (NFC), and starch.

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. Acid detergent fiber (ADF) is used to determine the digestibility and energy derived from a forage crop. ADF is a direct measurement of the cellulose, lignin, silica, insoluble CP, and ash content of a crop. These components are among the least digestible portions of a plant. Due to this, a lower ADF content correlates to higher plant digestibility.

Non-fiber carbohydrates (NFC) are composed of starch, simple sugars, and soluble fibers. Often NFC is digested more quickly than fiber and provides energy to rumen microbes. The fermentation of NFC is the precursor to volatile fatty acids, which can be used as energy by ruminant animals. Units of glucose are the building blocks of starch. Starch content and digestibility can have major impacts on milk production, specifically the NE_L, or net energy for lactation. Starch levels vary from field to field, depending on growing conditions and variety.

The silage performance indices of milk per acre and milk per ton were calculated using a model derived from the spreadsheet entitled “MILK2006,” developed by researchers at the University of Wisconsin. Milk per ton measures the pounds of milk that could be produced from a ton of silage. This value is generated by approximating a balanced ration meeting animal energy, protein, and fiber needs based on silage quality. The value is based on a standard cow weight and level of milk production. Milk per acre is calculated by multiplying the milk per ton value by silage dry matter yield. Therefore, milk per ton is an overall indicator of forage quality and milk per acre an indicator of forage yield and quality. Milk per ton and milk per acre calculations provide relative rankings of forage samples, but should not be considered as predictive of actual milk responses in specific situations for the following reasons:
1) Equations and calculations are simplified to reduce inputs for ease of use,
2) Farm to farm differences exist, and
3) Genetic, dietary, and environmental differences affecting feed utilization are not considered.

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 at 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.

Hybrid	Yield
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

RESULTS

Weather data were recorded with a Davis Instrument Vantage Pro2 weather station equipped with a WeatherLink datalogger at Borderview Research Farm in Alburgh, VT (Table 3). Growing Degree Days (GDDs) are calculated for corn at a base temperature of 50°F.

Temperatures were above average in May and September, while in June and July temperatures were below average. Alburgh had much less rain than usual during May, July, August, and September while June had more precipitation than the 30-year average. From May to September of 2015, there was an accumulation of 2578 Growing Degree Days (GDDs) which is 367 GDDs higher than the 30-year average.

Table 3. 2015 weather data for Alburgh, VT.

Alburgh, VT	May	Jun	Jul	Aug	Sep
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
Growing Degree Days (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.

Impact of Tillage Method

There was no significant difference between the tillage treatments on corn silage yield. The average yield for the trial was 21.7 tons per acre (Table 4). There was a significant difference in corn populations in plants per acre when comparing the four tillage methods (Table 4). The highest population was observed in the strip tillage corn plots (30,027 plants per acre) and was not statistically similar to any other treatment.

Table 4. Impact of tillage method on yield and population, Alburgh, VT, 2015.

Treatment	Yield tons ac^{-1}	Population plants ac^{-1}
No-till	21.5	27146
Strip till	21.1	**30027***
Vertical till	22.2	28427
Plow	21.8	29025
Trial mean	21.7	28656
LSD (0.10)	NS	1079

*Treatments with an asterisk are not significantly different than the top performer in **bold**.
NS – No significant difference amongst treatments.

Tillage method did not have a significant impact on aggregate stability (Table 5). Vertical tillage had the greatest aggregate stability, but was not significantly different from the no-till and strip till techniques. Aggregate stability was significantly lower with plowing compared to the other treatments. The trial mean for aggregate stability was 80.3%. The amount of active carbon in the soil varied based on tillage treatment. Vertical tillage treatments had the greatest amount of active carbon at 536 mg kg^{-1}. Active carbon levels were significantly higher in vertical tillage plots than in no-till, strip tilled, and plow tilled corn. The trial mean was 501 mg kg^{-1} of active carbon.

Table 5. Impact of tillage method on aggregate stability, Alburgh, VT, 2015.

Tillage method	Aggregate stability (%)	Active carbon mg kg^{-1}
No-till	81.4*	489
Strip till	79.8*	497
Vertical till	**81.6***	**536***
Plow	78.3	482
Trial mean	80.3	501
LSD (0.10)	3.2	32.9

*Treatments with an asterisk are not significantly different than the top performer in **bold**.

Corn silage quality indicators were impacted significantly by tillage treatment (Table 6). Crude protein was the greatest in no-till plots, though not significantly greater than the strip tilled or plowed plots. The vertical tillage treatment had the greatest values for ADF and NDF, however these were not significantly different from the strip tilled or plowed plots. There was no significant difference across tillage treatments concerning NFC or starch. The greatest estimate for pounds of milk per ton of corn silage would be produced by feeding the no-till treatment (2572 pounds per ton of dry matter), though it was not significantly greater than the strip tilled treatment. There was no significant difference between treatments regarding milk production measured in pounds of dry matter per acre.

Table 6. Corn silage quality indicators by tillage method, Alburgh, VT, 2015.

Treatment	Forage Quality Characteristics					Milk	
	CP % of DM	ADF % of DM	NDF % of DM	NFC % of DM	Starch % of DM	ton^{-1} lbs	ac^{-1} lbs
No-till	**7.1***	22.3	43.3	46.6	43.3	**2572***	23477
Strip till	6.9*	22.8*	44.4*	45.7	42.3	2513*	23017
Vertical till	6.7	**24.1***	**46.2***	44.1	39.7	2468	24311
Plow	7.0*	23.8*	45.7*	43.9	39.6	2484	23409
Trial mean	6.9	23.3	44.9	45.0	41.2	2509	23554
LSD (0.10)	0.3	1.7	2.8	NS	NS	82.6	NS

*Treatments with an asterisk are not significantly different than the top performer in **bold**.
NS – No significant difference amongst treatments.

Impact of Manure Incorporation Method

Soil nitrates sampled both after planting and a few weeks into the growing season were significantly different based on manure incorporation method (Table 7). Soil nitrates sampled from the injection plots on 3-Jun had the highest nitrate levels, and were significantly greater than the Aerway, broadcast, and plowed treatments. The injection plots had significantly higher nitrate levels than the broadcast plot on 17-Jun, but were not statistically significant from the Aerway and plowed treatments.

Table 7. Impact of manure incorporation method on nitrate levels, Alburgh, VT, 2015.

Treatment	3-Jun mg kg^{-1}	17-Jun mg kg^{-1}
Aerway	11.5	15.0*
Broadcast	12.0	11.7
Injection	**22.0***	**17.7***
Plow	13.9	15.7*
Trial mean	14.8	15.0
LSD (0.10)	2.0	3.0

*Treatments with an asterisk are not significantly different than the top performer in **bold**.

There was no significant difference in yield by manure incorporation treatment (Table 8). The trial mean was 21.6 tons per acre. Injection plots had the highest number of plants per acre, but did not have significantly higher populations than plowed plots (Table 8). Both injection and plowed plots had significantly greater populations than the Aerway and broadcast manure treatments on 19-Sep.

Table 8. Impact of manure incorporation on yield and populations, Alburgh, VT, 2015.

Treatment	Yield tons ac^{-1}	Population plants ac^{-1}
Aerway	21.0	27860
Broadcast	21.7	27785
Injection	21.9	**29464***
Plow	21.8	29025*
Trial mean	21.6	28534
LSD (0.10)	NS	1246

*Treatments with an asterisk are not significantly different than the top performer in **bold**.
NS – No significant difference amongst treatments.

Plots treated with broadcasted manure had significantly higher levels of aggregate stability, but this was not significantly higher than Aerway and injection treated plots (Table 9). The plowed plots were significantly lower than the others. The trial mean was 81% aggregate stability. Aerway plots had the highest level of active carbon with 54 mg kg^{-1}. Broadcast plots were not statistically different from the top performing aerway plots. The trial mean was 50 mg kg^{-1} of active carbon.

Table 9. Impact of incorporation method on aggregate stability, Alburgh, VT, 2015.

Tillage method	Aggregate stability (%)	Active carbon mg kg^{-1}
Aerway	82.8*	**54***
Broadcast	**83.2***	50*
Injection	79.5*	49
Plow	78.3	48
Trial mean	81.0	50
LSD (0.10)	3.7	3.8

*Treatments with an asterisk are not significantly different than the top performer in **bold**.

Corn silage quality did not differ by manure incorporation method (Table 10). There was no significant difference in CP, with a trial average of 6.9%. Acid detergent fiber was not significantly different by manure treatment, and averaged 23.1%. There was no significant difference between treatments for NDF, NFC, or starch. Projected milk production did not differ by treatment in pounds produced per ton or acre of corn silage. Overall, there was no best manure incorporation treatment in regards to the quality indicators for corn silage.

Table 10. Corn silage quality indicators by manure incorporation method, Alburgh, VT, 2015.

	Forage Quality Characteristics					Milk	
Treatment	CP % of DM	ADF % of DM	NDF % of DM	NFC % of DM	Starch % of DM	tons^{-1} lbs	ac^{-1} lbs
Aerway	7.0	22.2	43.6	46.2	42.7	2563	23237
Broadcast	6.8	23.0	44.6	45.8	42.3	2513	24212
Injection	6.9	23.4	44.6	45.9	42.3	2512	23008
Plow	7.0	23.8	45.7	43.9	39.6	2484	23409
Trial mean	6.9	23.1	44.6	45.5	41.7	2518	23467
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS

NS – No significant difference amongst treatments.

Tillage Method x Manure Incorporation Method Interactions

In comparing manure application strategy in no-till, there were no significant differences between broadcasted or injected manure in yield (Table 11). There were no significant differences between the treatments in regards to the forage quality. The only significant difference was seen in soil nitrates sampled on 3-Jun. The no-till injection plots had 22.0 mg kg^{-1} of nitrates, compared to only 12.0 mg kg^{-1} in the no-till broadcasted manure plots. The 17-Jun nitrates and active carbon levels were not statistically different. Overall, it appears that injection conserved more manure nitrogen in the soil compared to broadcast applications. Corn was topdressed just following the 17-Jun soil nitrates samples. All treatments received 240 lbs ac^{-1} of 46-0-0 urea on 19-Jun.

Table 11. Comparison of no-till treatments, Alburgh, VT, 2015.

		Forage Quality Characteristics				Milk		Nitrates		
No-till treatment	Yield tons ac^{-1}	CP % of DM	NDF % of DM	NFC % of DM	Starch % of DM	tons^{-1} lbs	ac^{-1} lbs	3-Jun mg kg^{-1}	17-Jun mg kg^{-1}	Active carbon mg kg^{-1}
No-till broadcast	21.7	6.9	44.0	45.6	42.2	2545	54979	12.0	11.7	485
No-till injection	22.1	7.1	43.2	46.6	43.1	2608	57462	**22.0**	17.7	444
p-value (0.1)	NS	NS	NS	NS	NS	NS	NS	0.004	NS	NS

Top performing treatment in **bold**.
NS – No significant difference amongst treatments.

When comparing the no-till treatment to the conventional plow till system, there were no differences observed between yields or quality of the corn silage crop (Table 12).

Table 12. Comparison of no-till broadcast and plowing, Alburgh, VT, 2015.

Treatment	Yield tons ac^{-1}	Forage Quality Characteristics CP % of DM	NDF % of DM	NFC % of DM	Starch % of DM	Milk tons^{-1} lbs	Milk ac^{-1} lbs	Nitrates 3-Jun mg kg^{-1}	Nitrates 17-Jun mg kg^{-1}	Active carbon mg kg^{-1}
No till	21.7	6.9	44.0	45.6	42.2	2545	54979	12.0	11.7	48
Plow	21.4	7.0	44.8	45.9	42.3	2513	53915	13.9	15.7	47
p-value (0.1)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – No significant difference amongst treatments.

A comparison between no-till manure injection and plow-till treatments indicated no difference in yield or quality. However, the soil nitrate levels were higher in the injection treatment especially at the 3-Jun sampling (Table 13). The no-till injection treatment had a nitrate level of 22.0 mg kg^{-1} whereas the plow-till treatment had soil nitrate levels of 13.9 mg kg$^{.-1}$.

Table 13. Comparison of no-till manure injection and plow-till, Alburgh, VT, 2015.

Treatment	Yield tons ac^{-1}	Forage Quality Characteristics CP % of DM	NDF % of DM	NFC % of DM	Starch % of DM	Milk tons^{-1} lbs	Milk ac^{-1} lbs	Nitrates 3-Jun mg kg^{-1}	Nitrates 17-Jun mg kg^{-1}	Active carbon mg kg^{-1}
No-till Injection	22.1	7.1	43.2	46.6	43.1	2608	57462	**22.0**	17.7	44
Plow	21.4	7.0	44.8	45.9	42.3	2513	53915	13.9	15.7	47
p-value (0.1)	NS	NS	NS	NS	NS	NS	NS	0.011	NS	NS

Top performing treatment in **bold**.
NS – No significant difference amongst treatments.

DISCUSSION

Overall, corn yields in this trial, were excellent and averaged over 21 tons per acre in each treatment. This demonstrates that growers can utilize manure incorporation and reduced tillage strategies without compromising crop yield. Manure incorporation strategies had no statistical impact on corn yield or on the forage quality indicators. Based on preliminary results, it appears that manure injection in conjunction with a reduced tillage method could be more beneficial to crop yield and quality than other methodologies. Manure injected plots had a greater number of plants per acre, as well as higher nitrate levels, indicating that injecting manure can help conserve manure N and reduce fertilizer N applications.

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