LOW-DISTURBANCE MANURE APPLICATION METHODS IN A CORN SILAGE-RYE COVER CROP SYSTEM[1]

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Introduction

Manure can provide valuable nutrients, especially nitrogen, to high N-requiring crops such as corn. However, a large portion of manure N, about half in typical liquid dairy manure, is in the ammonium or urea form and can potentially be lost to the air as ammonia if the manure is not incorporated into the soil promptly (Jokela and Meisinger, 2008). Tillage is the most common method of incorporation, but tillage and, to a lesser extent, standard injection reduce crop residue cover, leaving the field more susceptible to erosion. Tillage may also be incompatible with management requirements to meet criteria in nutrient management plans. Corn production for silage is particularly problematic because whole-plant removal leaves minimal residue cover after harvest. Establishment of a cover crop such as winter rye after harvest can provide adequate residue cover, but timely seeding (preferably by mid-September) is critical. Farmers need a system that incorporates manure while still maintaining crop residue cover.

The overall objective of this study is to evaluate several relatively new methods for applying liquid dairy manure designed to maximize manure N availability while maintaining crop residue cover for erosion control in a silage corn system in the northern Corn Belt, specifically central Wisconsin.

Methods

Four novel manure application methods designed to inject or encourage infiltration of liquid manure were compared to conventional broadcast application either left on the surface or incorporated with a disk (Fig. 1.). Four pre-plant nitrogen fertilizer treatments (including zero N) provide a crop yield response curve to evaluate manure N availability of the various manure application methods. This resulted in the following ten treatments:

1) Low-disturbance sweep injection (Dietrich/DSI)
2) Manure/strip-till (Dietrich/DSI sweep injectors with paired disks designed to create a ridge for planting in the spring)
3) Coulter injection (Yetter Avenger) a narrow V-slot for manure followed by covering disks
4) Aerator/band application: rotary tine aerator (Gen-Till) with manure applied in bands over aerator slots to encourage manure infiltration
5) Broadcast manure with disk incorporation
6) Broadcast manure – surface (no incorporation)
7) Control: No manure or fertilizer N
8) Fertilizer N 60 lb/acre
9) Fertilizer N 120 lb/acre
10) Fertilizer N 180 lb/acre

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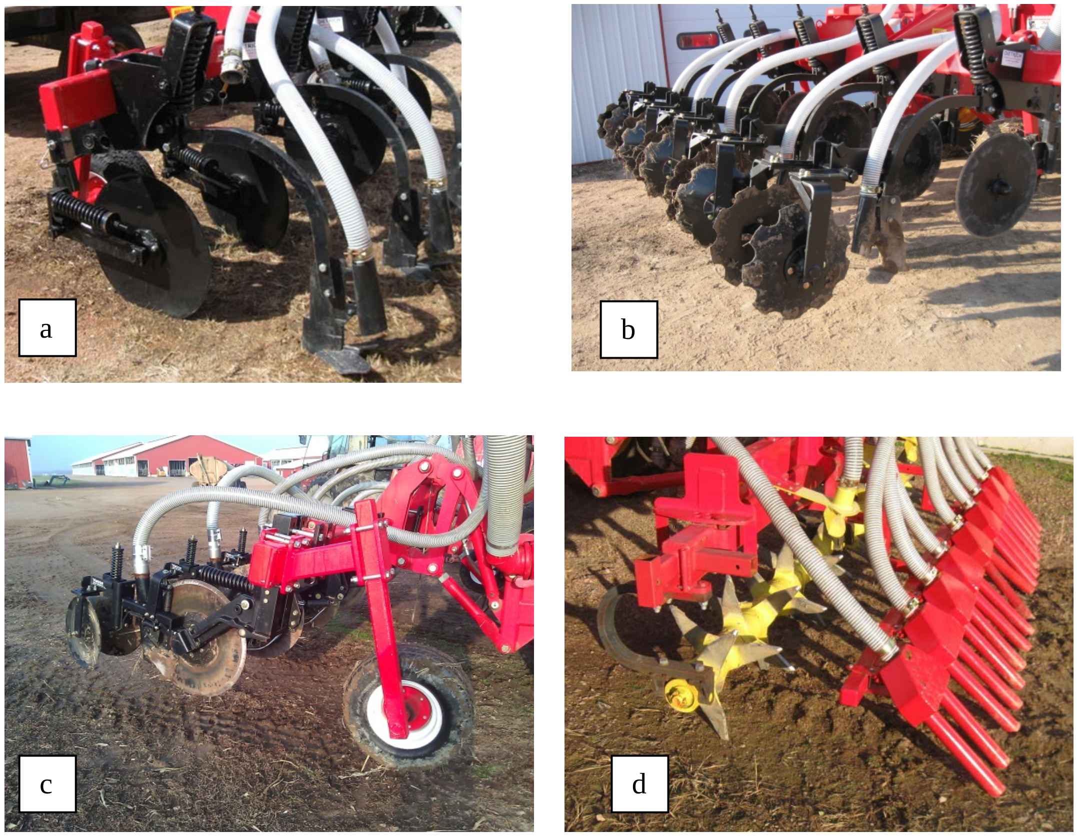


Figure 1. Manure application attachments: a) Dietrich/DSI slurry injector, b) DSI injector with paired disks for strip-till, c) Yetter Avenger coulter injector with covering disks, d) Aerator-band applicator.

This field trial was established on a Withee silt loam soil at the UW Marshfield Agricultural Research Station in Stratford, WI. Treatments were applied to plots 15 x 50 feet in size. Each treatment was replicated four times in a randomized complete block design. Blocks are separated by alleys 75 feet wide to allow adequate space for turning of the spreader and tractor. The experiment was established with limited measurements in the 2012 growing season (fall 2011 manure application) and continued on the same plots in 2013 and 2014.

Corn (a mid-season relative maturity hybrid) was planted in late May 2012 and 2014 and early June 2013, particularly late in 2013 because of unusually wet and cool conditions. Silage was harvested on 9/6/2012, 10/1/2013, and 9/30/14. Winter rye was seeded with a no-till drill by mid-September (Sept 13) in 2012 but an extended dry period delayed germination. In 2013, in anticipation of delayed silage harvest, rye was seeded manually to simulate aerial seeding on Sept 6, but growth was limited by cold weather and, perhaps, herbicide carry-over. Manure treatments were applied Nov 9, 2012, Nov 5, 2013, and Oct 21, 2014 for the following year's cropping season. Target manure rate was 8000 gal/acre, a rate estimated to supply about 80% of the corn N needs. Both application rate and manure nutrient content varied but on average manure supplied 190, 90, 80, and 200 lb/acre of total N, NH_4-N, P_2O_5, and K_2O. Starter fertilizer was applied each year with the planter (100 lb/acre of 9-11-30-6S) and potash was applied to all plots in May of

2013 (180 lb K_2O/acre) and 2014 (120 lb K_2O/acre). All treatments except manure/strip-till (#2) were field cultivated each spring before planting.

Soil samples for the pre-sidedress nitrate test (PSNT, 1-ft depth) were taken at 8- to 12-inch plant height. Ear leaf samples were collected at silking to assess nutrient status. At the same time an active canopy sensor (Crop Circle by Holland Scientific) was used to measure reflectance of three different wavelengths (670, 730, and 760 nm), from which three indexes -- NDVI, NDRE , and CCCI – were calculated. Silage yields were determined by harvesting the center two rows of each plot with a field-scale chopper and a wagon equipped with weigh cells. Surface residue cover was measured using photographs (2 per plot) and digital imagery analysis before and after fall manure application and the following spring to determine the effect of manure application method and associated tillage on residue cover. Ammonia emission from manure was measured using the dynamic chamber/equilibrium concentration technique during the three days immediately following manure application.

In 2014 a separate experiment was conducted on an area adjacent to the main trial to evaluate the effect of manure application method on loss of nutrients and eroded sediment in runoff using a portable rainfall simulator (Joerns, Inc., West Lafayette, IN). Selected manure treatments were applied in late October, followed two days later by rain simulation to generate runoff (1.6 inches of rain per hour for 30 minutes). Runoff was sampled and analyzed for suspended sediment, total and dissolved P, and total and dissolved N.

Preliminary Results

Because the project is still in progress no final conclusions can be made and interpretations of the data will be limited. Extreme weather conditions during these years created a further limitation in interpreting the results. In 2012 precipitation ranged from only one-third of 30-year norm in July to more than double the norm in October. 2013 was also a year of extremes with twice the norm for total precipitation during April, May, and October but about half the normal for August and September. Precipitation was above the long-term average in 2014 with almost twice the average in April, a third higher in May, and 60% above average in August. The growing season was also cooler than average with lower average temperatures most months and 196 fewer GDD units than the long-term average.

One indicator of the availability of N to the crop is the pre-sidedress nitrate soil test, or PSNT (Table 1). In 2012, while there were some treatment effects, all but the Control and Broadcast-Surface treatments were above the 21 ppm level for adequacy of N (Laboski and Peters, 2012). In 2013, however, all but the highest fertilizer N rates were well below the 21 ppm threshold, indicating a need for additional N. This likely reflects the excessive rainfall during April and May that created conditions for loss of N via leaching and/or denitrification. In 2014, all but the no N Control treatment were above the critical level. The Sweep Injected manure and the fertilizer N treatments had the highest levels.

The nutrient concentration of the leaf opposite and below the ear, or ear leaf, at 50% silk is another indicator of the nutrient status of the corn plant (Table 2). In 2012 N concentration was above the sufficiency level (2.5%) for most treatments, with the exception of the Broadcast-Surface, Control, and 60 lb N/acre treatments, indicating there was inadequate N applied or large N losses from those treatments. Nitrogen

Table 1. Pre-sidedress soil nitrate test (PSNT) concentrations. 2012-2014

Treatment	2012	2013	2014
		NO_3-N ppm	
Sweep Inject	36.2 abcd†	14.3 bcd	47.5 bc
Strip-Till Inject	39.0 abc	11.9 cde	24.6 d
Coulter Inject	23.4 def	8.1 cde	22.7 d
Aerator/Band	21.1 ef	7.2 de	21.0 d
Broadcast-Disk	31.0 bcde	12.5 cde	21.6 d
Broadcast-Surf	19.7 ef	6.3 e	22.6 d
Control	15.6 f	7.1 de	16.7 d
N 60 lbs/acre	28.4 cdef	15.2 bc	40.3 c
N 120 lbs/acre	45.5 a	20.7 ab	56.4 b
N 180 lbs/acre	43.5 ab	24.8 a	80.5 a
P-value	0.01	0.01	0.01
CV, %	35	46	34

† In each column, least square means followed by the same letter are not statistically different at P-value = 0.10 based on Duncan's Multiple Range Test.

Table 2 Nitrogen concentrations in ear leaf samples at silking. 2012-2014

	2012	2013‡	2014
Treatment		N concentration	
		%	
Sweep Inject	2.87 a†	1.77 b	2.36 ab
Strip-Till Inject	2.60 ab	1.56 bc	1.76 c
Coulter Inject	2.60 ab	1.54 bc	1.92 c
Aerator/Band	2.64 ab	1.45 cd	1.76 c
Broadcast-Disk	2.57 ab	1.43 cd	1.76 c
Broadcast-Surf	2.39 bc	1.23 d	1.67 c
Control	2.02 c	1.38 cd	1.24 d
N 60 lbs/acre	2.30 bc	1.63 bc	1.80 c
N 120 lbs/acre	2.82 a	2.09 a	2.27 b
N180 lbs/acre	2.66 ab	2.25 a	2.61 a
P-value	0.01	0.01	0.01
CV, %	10	8	9

† Within each column, values followed by the same letter are not significantly different at P = 0.05 based on Duncan's Multiple Range Test.
‡Reps 1, 2, and 4 only

concentrations in 2013 were all below the sufficiency level, probably a function of excessive rainfall and perhaps limited manure N release due to unusually cool spring temperatures. Ear leaf N concentrations for 2014 were lowest for the Control and highest for the sweep injection manure and highest fertilizer N treatments, which met or approached the sufficiency level. The general pattern was similar to that of PSNT results, though specific statistical effects varied. One or more of the indexes of canopy reflectance (NDVI, NDRE , and CCCI) showed good relationships with measured N concentration of ear leaf at silking. This suggests that canopy sensors could be a useful tool to indicate crop N status, assuming the crop can benefit from additional N late in the season and application equipment is available.

There were no significant effects of treatment on silage yields in 2012, but the no-N control had the lowest yield values (Table 3). Nitrogen uptake was affected by treatment, with the Control and Broadcast-Surface N lowest, providing further evidence of N loss (most likely ammonia-N) from surface-applied manure. The other manure treatments were statistically similar to those receiving N fertilizer. In 2014 yield and N uptake from treatments receiving injected or disk-incorporated manure were statistically similar to N fertilizer treatments; those manure and N treatments were approximately twice or more that of the no N Control. No data is shown for 2013. Unusually wet soil conditions at planting and through the spring, followed by an extended dry spell in late summer, led to poor stands and growth in substantial portions of the plot area. This led to extreme variability, which was compounded by problems with weighing equipment during silage harvest.

Ammonia emission was measured during the three days following manure application in 2013 using the dynamic chamber/equilibrium concentration method. Even though temperatures were low (maximum of 43 F) during the measurement period and there was a 0.6 inch rain during the first night, there was measurable ammonia emission, with the greatest amount from the surface-applied manure. Ammonia loss was reduced by about 85% by coulter injection and >95% by strip-till injection, with the aerator/band and disk incorporation intermediate (30 to 55% reduction). Results from 2014 showed generally similar patterns with dramatic reductions from the injected manure treatments and substantial, but lower, reductions from disk and aerator-band.

Crop residue cover (corn residue, rye, and weeds) in November before manure application was 30 to 40% in 2012 and averaged about 40% in 2013 (See Figure 4 for 2013-2014). Residue cover was reduced by all methods that involve soil disturbance, the most by disking and the least by coulter-injection. Note that manure cover is not included in the data shown in the figures. This explains the decrease in residue cover for the broadcast-surface treatment in 2013, for which no reduction would be expected. (Residue covered with manure was not visible and not counted.) Residue cover the following spring (pre-tillage 2014) increased to levels close to the fall pre-manure amounts (with the exception of the Broadcast-Disk treatment), primarily due to growth of the rye cover crop. Following spring field cultivation and planting (post-plant), residue cover was reduced to 10 to 15% in all treatments except Strip-till Injection (25%), which is the only treatment that was not spring-tilled.

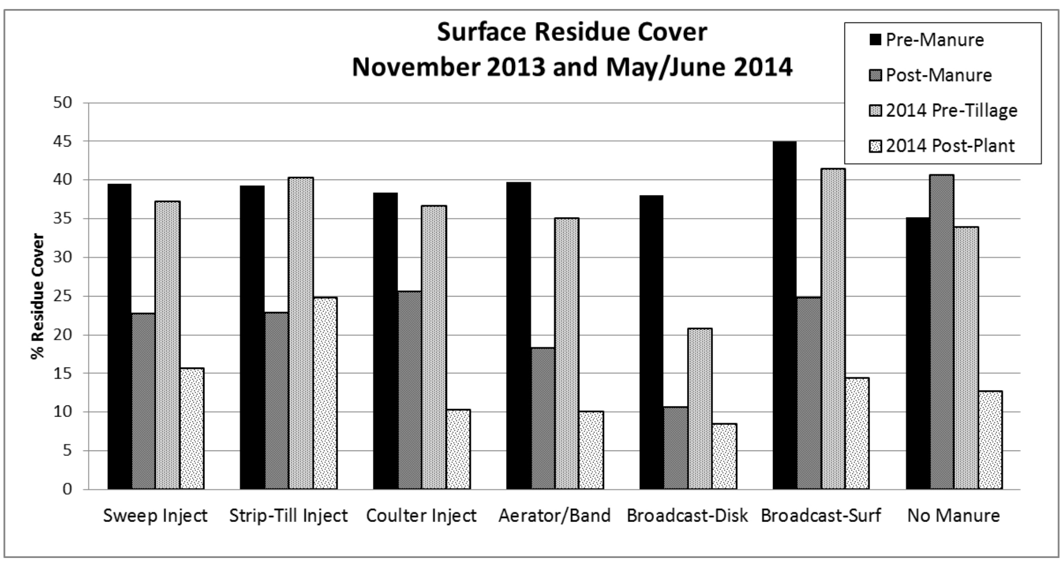
Preliminary results from the rain simulation-runoff experiment show the highest runoff losses of total and dissolved P from surface-applied manure, as would be expected. Total P loss was reduced by approximately 35% by the aerator band method, 70% by disk incorporation, and almost 90% by strip-till injection, which was not statistically different from the control treatment that received no manure. Results for dissolved P losses followed a similar pattern but with even greater reductions from injected or incorporated manure.

Table 3. Silage yield and N uptake for 2012 and 2014.

Treatment	2012 Yield	2012 N uptake	2014 Yield	2014 N uptake
	Ton DM/a	lb/a	Ton DM/a	lb/a
Sweep Inject	6.55	172 a	8.34 a	189 a
Strip-Till Inject	6.50	158 ab	6.70 ab	140 abc
Coulter Inject	6.93	154 ab	5.43 bcd	120 bcd
Aerator/Band	6.68	151 ab	4.26 bcd	88 cde
Broadcast-Disk	6.34	150 ab	5.24 bcd	111 bcde
Broadcast-Surf	6.47	126 bc	3.57 cd	70 de
Control	5.88	102 c	2.91 d	49 e
N 60 lbs/acre	6.05	145 ab	6.46 ab	134 abcd
N 120 lbs/acre	6.27	174 a	5.99 abc	136 abc
N180 lbs/acre	6.19	169 a	6.67 ab	165 ab
P-value	NS	0.01	0.01	0.01
CV, %	8	14	26	30

† In each column, means followed by the same letter are not statistically different at P-value = 0.05 based on Duncan's Multiple Range Test. NS = nonsignificant.
‡Silage yield not reported for 2013 (See text for explanation.)

Figure 2. Surface residue cover pre-and post-manure application in November 2013 and pre-tillage and post-planting in May/June 2014.



Preliminary Conclusions

- Manure N availability, as indicated by the PSNT, ear leaf N concentration at silking, and silage N uptake, was generally highest from injected or disk-incorporated manure and lowest from surface broadcast manure. The best manure treatments were similar to fertilizer N treatments (specific N rate depending on year and indicator).
- Differences in manure N availability reflect losses from ammonia volatilization, as indicated by similar differences in measured ammonia emission – surface broadcast highest, injected lowest, and others intermediate. Ammonia emission was a function of the amount of manure left on the surface.
- Silage yields followed a similar pattern, but differences were less pronounced and sometimes lacked statistical significance.
- Residue cover was reduced by all methods that involve soil disturbance, the most by disking and the least by coulter-injection. Cover increased by spring due to growth of rye cover crop, approaching pre-manure application levels, except for disk incorporation; but cover in all treatments except strip-till (no spring tillage) was greatly reduced by spring field cultivation.
- Preliminary results for phosphorus runoff losses shortly after manure application reflected the degree of manure incorporation, with greatest loss from surface broadcast and the least from injection.
- Overall, preliminary results from this study show that the low-disturbance manure application methods can greatly reduce ammonia-N emission and nutrient runoff losses and improve manure N availability compared to surface application; and that they maintain residue cover better than disk incorporation of manure.

References

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