MINIMIZING NITRATE LOSS FROM MANURE-AMENDED WISCONSIN SANDY SOILS

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Abstract

The impact of dairy manure application on nitrate leaching was evaluated at two sites with no manure history. Manure treatment (separated-solid manure, separated-liquid manure, separated-liquid manure plus a nitrification inhibitor, and two treatments with no manure) was the main plot. Each manured plot was split into six subplots with three receiving a single sidedress fertilizer application of 0, 56, or 112 kg N ha^{-1} while the others had two sidedress applications totaling 112 kg N ha^{-1} with varying percentage of N being applied in each split. Subplots in one of the no manure treatments received 0 to 280 kg N ha^{-1} in increments of 56 kg N ha^{-1} while subplots in the second no manure plot received a total of 224 kg N ha^{-1} in differing percentages of total N split between two sidedressings. After manure application and planting, ceramic suction cup lysimeters were installed 1.5 m below the soil surface to collect water leaching below the root zone in the 0 and 112 kg N ha^{-1} subplots of all manure treatments as well as the 224 kg N ha^{-1} subplot of one of the no manure treatments. Water samples were collected weekly from installation until two weeks after harvest and were analyzed for nitrate concentration. Nitrate concentrations ranged from non-detectable (<0.02 mg L^{-1}) to more than 300 mg L^{-1}. As expected, plots amended with higher rates of nitrogen fertilizer generally had greater nitrate concentrations. Nitrate leached from plots amended with separated solid manure was not different than where no manure and no fertilizer N were applied. Nitrate leaching from plots where a nitrification inhibitor was used varied by location.

Justification and Objectives

Large dairy confined animal feeding operations (CAFOs) are moving into the Central Sands area of Wisconsin and many are using solid-liquid manure separation technology. There is great public concern about how these large dairies will impact groundwater quality, especially when NO_3-N levels are already greater than 10 mg L^{-1} in some wells. The objectives of this study were to 1) determine the impact of spring applied separated-liquid and separated-solid manure on nitrate leaching and 2) evaluate the effectiveness of Instinct ™ nitrification inhibitor (nitrapyrin, Dow AgroSciences) on reducing nitrate leaching from separated-liquid manure.

Materials and Methods

Two locations were selected for this study, one in Coloma (Billett sandy loam) and the other in Grand Marsh (Billett and Richford loamy sand). A split-plot experimental design was used, with manure treatment being the main plot (separated-solid, separated-liquid, separated-liquid plus Instinct, and two no manure plots). Selected manure properties are provided in Table 1. The manure plots were split into six subplots, with three receiving a single sidedress of 0, 56, or 112 kg N ha^{-1}, while the others had two sidedress applications totaling 112 kg N ha^{-1} with varying percentages of N (25:75, 50:50, 75:25) being applied in each split. The no manure 1 treatment subplots received 0 to 280 kg N ha^{-1} in increments of 56 kg N ha^{-1}, while the subplots in no manure 2 treatment received 224 kg N ha^{-1} in differing percentages (25:75, 50:50, 75:25) between two sidedressings. There were four replications per treatment, with a subplot size of four 0.76 m rows by 10.64 m long.

Manure was applied on April 24 and 25. The liquid manures were injected at 20 cm below the surface at a rate of 131 kL ha^{-1}. Instinct was applied at a rate of 2.6 L ha^{-1}. The separated-solid manures were surface applied at a rate of 40.3 Mg ha^{-1} and were chisel plowed within one hour of application. The no manure plots were chisel plowed as well.

Both locations were planted on May 11. The first sidedress was 28% urea ammonium nitrate (UAN) injected on June 11. The second sidedress was broadcast ammonium nitrate (NH_4NO_3) on June 26. Standard crop management practices were employed, including center pivot irrigation. Biomass yield at physiological maturity and grain yield were collected.

Ceramic suction cup lysimeters were installed 1.5 m deep in the 0 and 112 kg N ha^{-1} subplots of all treatments and also the 224 kg N ha^{-1} of no manure 1 treatment on May 22 and 24. Upon installation, samples were collected weekly until two weeks after harvest. Samples were stored in a refrigerator at 4°C, and nitrate-N was analyzed using the single regent method with vanadium chloride as a reductanct (Doane and Horwáth, 2003).

A mixed model with manure treatment and N fertilizer rate as fixed effects and time as the random effect was used for statistical analysis of the nitrate leaching data. A square root transformation of the data was used to improve normality, with Tukey's LSD ($p<0.10$) used for means separation.

Results and Discussion

At the Coloma location, the separated-solid and no manure plots leached less NO_3-N than separated-liquid manure ($p<0.10$) (Table 2, Figure 1). Instinct significantly ($p<0.10$) reduced the NO_3-N leached from separated-liquid manures at the 0 and 112 kg N ha^{-1} sidedress rates. In the no manure plots, more NO_3-N leached from the plots where 224 kg ha^{-1} was sidedressed compared to the 0 and 112 kg N ha^{-1} application rates ($p<0.10$).

At the Grand Marsh location, the separated-solid and no manure plots leached less NO_3-N than separated-liquid manure ($p<0.10$) (Table 2, Figure 1). Instinct had no effect on reducing NO_3-N leaching from separated-liquid manures. In the no manure plots, NO_3-N leaching increased as the sidedress N application rate increased ($p<0.10$).

At both locations, differences in NO_3-N leaching between treatments were not observed until the end of July. Gehl et al. (2005) observed nitrate leaching in irrigated sandy soils as early as late June. Drought conditions resulted in less downward water movement during the summer of 2012, which may have created a lag time in detecting NO_3-N leaching differences at the 1.5 m depth. Although the fields were irrigated, water was not applied in excess of the crop's needs.

At both locations, less NO_3-N leaching was observed where separated-solid manure was applied compared to separated liquid manure. This is attributed to the separated-solid manure having a lower total N application rate, lower NH_4-N application rate, and a lower estimated first-year N availability than the separated-liquid manures (Table 1). In addition, separated-liquid manures are more prone to macropore movement, resulting in more NO_3-N leaching (Robbins, 2004). In addition, the separated-solid manures had higher C:N ratios. In a laboratory incubation study, Earhart (2009) found raw and separated-solid manures with large C:N ratios sometimes immobilized N. Although this study used separated-solid manures with similar C:N ratios as Earhart (2009), there was no visual evidence of N deficiency in the separated-solid manure plots, even where no fertilizer N was sidedressed.

Instinct reduced nitrate leaching where separated-liquid manure was applied at Coloma but not at Grand Marsh. The conflicting results may be attributed to differences in soil pH, organic matter (OM), and amounts and timing of irrigation water applications. The soil pH was significantly greater ($p<0.05$) at Grand Marsh (pH = 6.6) than Coloma (pH = 6.2). The effectiveness of nitrapyrin has been shown to decrease with increasing pH because of increased degradation (Touchton et al., 1978). However, Touchton et al. (1978) made this observation with much larger differences in pH values (5.5 versus 7.3) than observed at these sites. There was a significantly greater ($p<0.05$) percentage of OM at Grand Marsh (1.6%) compared to Coloma (1.2%). Studies have shown that nitrapyrin sorption increases with increasing OM content (Wolt, 2000; Touchton et al., 1978). However, it should be noted that the relationship between nitrapyrin sorption and OM was observed on soils with greater concentrations and a wider range of OM (2.0 and 5.5 %) than those in this study. Grand Marsh received 2.3 cm of irrigation water in two applications beginning on May 16 before the first irrigation at Coloma took place on June 3. Grand Marsh received a larger total amount of irrigation water (33 versus 30.5 cm) throughout the summer compared to Coloma. Perhaps, the greater OM at the Grand Marsh site resulted in less movement of the nitrapyrin, while some of the N was able to mineralize, nitrify, and leach out of the manure application zone before it could interact with the nitrapyrin.

The drought of 2012 resulted in record corn yields at both sites (17.56 Mg ha^{-1}), with very few treatments differences. The economically optimum N rate (0.10 N:corn price ratio) where no manure was applied was 73 and 75 kg N ha^{-1} for Coloma and Grand Marsh, respectively. This is much lower than what is usually observed for this area (224 kg N ha^{-1}). It should be noted that the amount of irrigation water applied during the growing season was greater than during a typical field season (30.5 to 33 cm versus 25.4 cm). With these rates and high irrigation NO_3-N concentrations (16 to 18 mg L^{-1}; which is not atypical for this area), 43 to 52 kg N ha^{-1} was applied to the growing crops. There were no visual signs of N deficiency in the no manure, no sidedress N treatments, indicating that the NO_3-N from irrigation water and soil N mineralization provided enough N for crop growth during this particular year. In addition, high NO_3-N leaching concentrations from separated-liquid manures observed at the end of the growing season could be the result of excess N applied via irrigation in conjunction with the addition of manure and fertilizer N.

Summary

The amount of N leached from separated-solid manures and no manure plots was not different ($p > 0.10$) at both locations. Separated-solid manures had less NO_3-N leaching than separated-liquid manures, but total N application was much less for separated-solid than separated-liquid. Instinct reduced the amount of NO_3-N leached from separated-liquid manure plots at one location, but had no impact at the other. Soil pH and OM as well as time of initial irrigation may have resulted in the differential effects of Instinct.

References

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Table 1: Total N applied, estimated first-year N availability, dry matter, and C:N ratios of applied manures.

Location	Manure	Total N applied	NH_4-N applied	First year Est. N Availability	Dry Matter	C:N ratio
		kg ha^{-1}			%	
Coloma	Separated-liquid	462	276	231	5.6	5
	Separated-liquid+ Instinct	478	279	239	5.9	5
	Separated-solid	147	43	52	34.8	24
Grand Marsh	Separated-liquid	480	278	240	5.6	5
	Separated-liquid + Instinct	496	287	248	6.7	6
	Separated-solid	155	43	54	35.0	22

Table 2: Means separation for NO_3-N leached throughout the growing season from manure and no manure plots. Within each location, treatments with the same letter are not significantly different ($p>0.10$).

Manure	N rate	Coloma	Grand Marsh
	kg ha^{-1}	means separation	
Separated-liquid	0	AB	BC
	112	A	A
Separated-liquid + Instinct	0	C	B
	112	B	A
Separated-solid	0	E	E
	112	D	D
No manure	0	E	E
	112	DE	CD

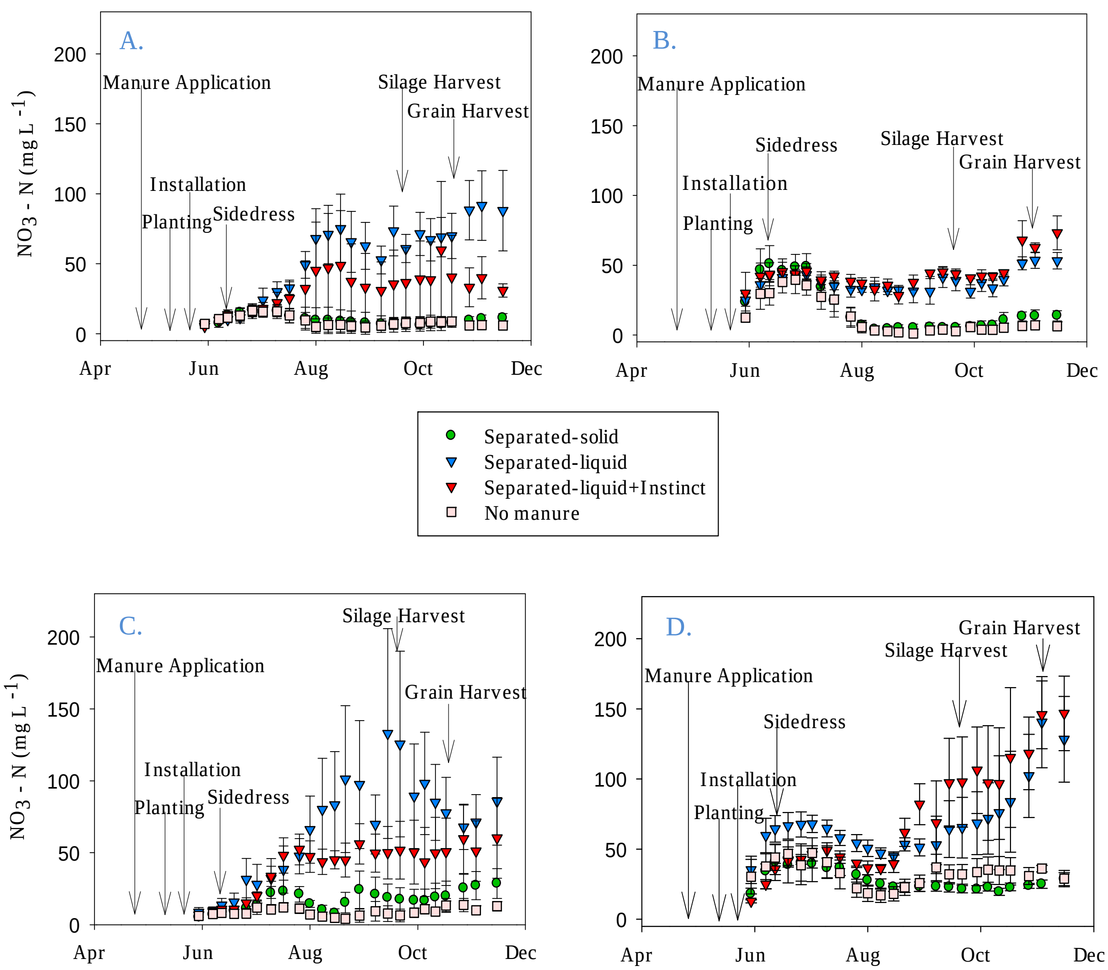

Figure 1: NO_3-N concentrations (mg L^{-1}) in ceramic suction cup lysimeters. A: Coloma manure treatments with 0 kg N ha^{-1} sidedress; B: Grand Marsh manure treatments with 0 kg N ha^{-1} sidedress; C: Coloma manure treatments with 112 kg N ha^{-1} sidedress;
D: Grand Marsh manure treatments with 112 kg N ha^{-1} sidedress.

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