MANURE TREATMENTS CHANGE NITROGEN CYCLING IN SOILS RECEIVING REPEATED APPLICATIONS OF DAIRY-WASTES

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ABSTRACT

Our objective was to assess effects of treated dairy-waste on soil N pools, nitrification, plant N availability, and yield in a silage cornfield treated with ammonium sulfate (AS), dairy-waste compost (DC) or liquid dairy-waste (LW) as N sources at two levels of application over 5 years. Increases in soil C and N, nitrate and available P and K were observed for the DC treated soils throughout the 5-year period. Soil organic C increases for the high-level DC treated soil doubled the C pool resulting in an increase of 14 Mg C ha^{-1}. The highest nitrate accumulation was at the 60-90 cm depth for soils receiving high level of DC (200 kg N ha^{-1}), which moved to lower depths in subsequent years. Soils receiving a high-level of DC or LW showed a 3-fold increase in nitrifier activity compared to the control. There was a positive silage corn yield response with all the treatments, with DC having the highest yields. While N from AS and LW are available for plant uptake almost immediately, the organic N in compost continued to mineralize throughout the growing season, after harvest and in subsequent years. Careful management of application rates to optimize the timing of N release versus plant demand and of post-harvest nutrient pools are suggested for the prevention of excessive nitrate accumulations and movement from repeated dairy-waste applications.

INTRODUCTION

Improved understanding of the effects of dairy-waste treatment and land application on microbial processes and products is required to predict the outcome of waste applications and avoid undesirable environmental impacts.

METHODS

Our objective was to assess effects of treated dairy-waste on soil N pools, nitrification, plant N availability, and yield in a silage cornfield. We applied ammonium sulfate (AS), dairy-waste compost (DC) or liquid dairy-waste (LW) as N sources at two levels of application annually from 1997-2002. Dairy-waste compost and liquid dairy-waste were applied to supply approximately 100 and 200 kg available N ha^{-1} to match the fertilizer N supplied. Short-term dynamics of N transformations were also investigated using N-15 pool dilution techniques during midseason in several years.

RESULTS AND DISCUSSION

The nitrogen content of the composted dairy manure ranged from 1.1% to 2.0% N (dry weight basis) and averaged 1.6% N while the dairy lagoon effluent ranged from 34-193 lbs N/acre-inch (avg. 120 lbs N/acre-in). As N content of the dairy waste materials varied considerably, producers are advised to base waste application rates on actual nutrient analysis of the materials to be applied. Based upon laboratory studies, we estimated that 10% of the total N in the composted dairy-waste would be available in the first season and approximately 5% in the subsequent year after application. However, based upon the N-recovery in corn silage yield trials, this was a significant underestimate. N analysis of silage resulted in values that were lower than those found in the study region except for the DC200 (Griggs et al., 2004). The 5-year average leaf N contents were in the deficiency range for all treatments except for DC200. In year 1997, leaf N contents from plots receiving DC100, DC200, and AS200 were not in N deficient range. Based on leaf N content, however, all the plants were N deficient for years 1998 and 2001. Plant N contents were lowest for control, LW100, and AS100 (Table 1).

The plant N content and the end of season corn stalk nitrate test values associated with DC200 indicated that N was sufficient (plant N) or in excess (stalk nitrate) (Table 1). In contrast, DC100 resulted in stalk nitrate concentrations that were within the optimal range (Table 1). We did not observe a yield response between DC100 and DC200 after 1999 further indicating that the available N in DC200 was in excess of the plant requirement. The average N removed in the silage corn was approximately 250, 190, 160, and 120 kg N ha^{-1} for DC200, DC100, AS200, and LW200 treated soils, respectively, from 1997-2002.

Corn yields, plant N contents, and soil N pools suggest that LW did not supply adequate N for crop growth. For example, in 1999 the LW200 plots received 202 kg N ha^{-1} and 112 kg N ha^{-1} was recovered in the chopped corn compared to AS200 recovery of 165 kg N ha^{-1}. The difference between the application rate estimate and recovery data suggest that significant N loss occurred in the field from the LW200 plots. There is a higher tendency for loss of the inorganic N contained in LW treated soil during and immediately following application through ammonia volatilization or denitrification.

Table 1. Mean corn stalk nitrate, leaf and chopped corn N contents averaged for six years (1997 – 2002), and annual silage corn yield (dry weight basis) for plots receiving DC, LW or AS to supply about 100 and 200 kg available N ha^{-1}. Leaf N content data for year 1999 was not available. Values with the same letter superscripts within a column are not significantly different.

Treatment	Silage corn N	Leaf N	Corn Stalk NO_3^-	Silage corn yield					
				1997	1998	1999	2000	2001	2002
	-------------g N kg^{-1}	-----------		---------------------------Mg ha^{-1}			--------------------------		
Control	5.6^{c}	11.1^{d}	0.18^{b}	18.0^{b}	6.3^{c}	4.5^{d}	10.5^{c}	6.6^{d}	15.0^{c}
AS-100	5.7^{c}	13.5^{dc}	0.17^{b}	23.1^{ba}	10.5^{bac}	14.1^{bc}	17.7^{bac}	11.1^{dc}	18.3^{bc}
AS-200	8.1^{b}	17.3^{bc}	0.76^{b}	23.7^{ba}	11.7^{bac}	18.3^{ba}	21.6^{a}	15.3^{bc}	26.1^{a}
DC-100	8.9^{ba}	18.9^{ba}	1.19^{b}	27.0^{a}	15.3^{a}	23.1^{a}	22.5^{a}	17.7^{ba}	24.6^{ba}
DC-200	11.4^{a}	22.3^{a}	5.30^{a}	27.0^{a}	13.8^{ba}	21.6^{a}	23.1^{a}	21.3^{a}	23.1^{ba}
LW-100	5.3^{c}	13.6^{dc}	0.23^{b}	22.2^{ba}	9.3^{bc}	11.7^{c}	13.2^{bc}	7.2^{d}	12.6^{c}
LW-200	6.3^{c}	16.9^{bc}	0.14^{b}	25.8^{ba}	15.3^{a}	16.2^{bc}	20.4^{ba}	12.0^{dc}	19.5^{bac}

Over the course of the study all the soils repeatedly treated at the high rates (approximately 200 kgN ha^{-1} available) showed elevated soil nitrate levels (Fig. 1) and nitrification potentials (Fig. 2). The DC200 treatment was generally the highest level or rate.

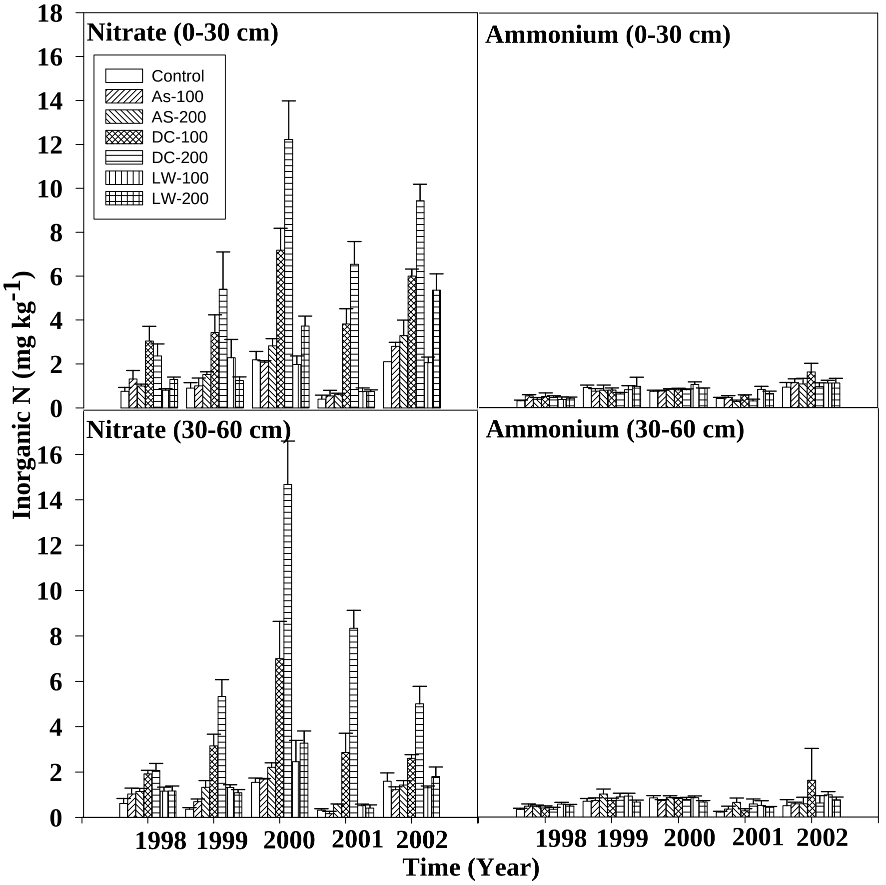

Figure 1: Preseason nitrate and ammonium pool sizes for two depth intervals in cornfield soils that received DC, LW, or AS to supply about 100 and 200 kg available N ha^{-1} annually for six years. Values represent means ± 1 SE (n = 4).

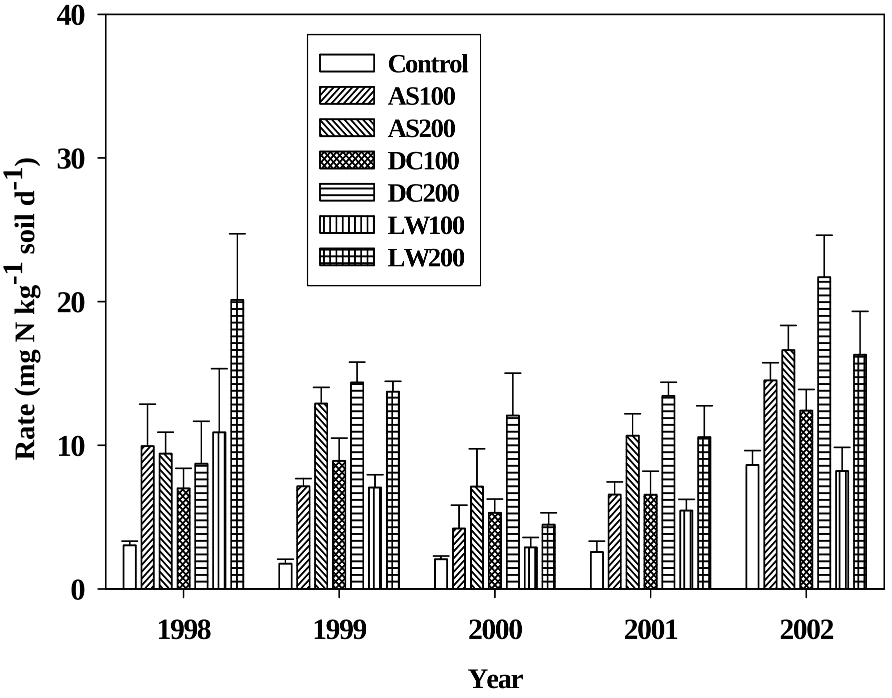

Figure 2: Nitrification potential for cornfield soils that received DC, LW, or AS to supply about 100 and 200 kg available N ha^{-1} annually for six years. Soil samples were collected 90 days after planting time. Values represent means ± 1 SE (n = 4).

At the end of the season deep cores revealed the potential for nitrate movement to depths beyond the root zone for the high rate compost (DC200) treatment (Fig. 3). Our results indicates that compost application at this rate is producing more nitrate than needed for plant use and that timing of N release from compost and plant N demand contributes to nitrate movement down through the profile (Shi et al., 2004).

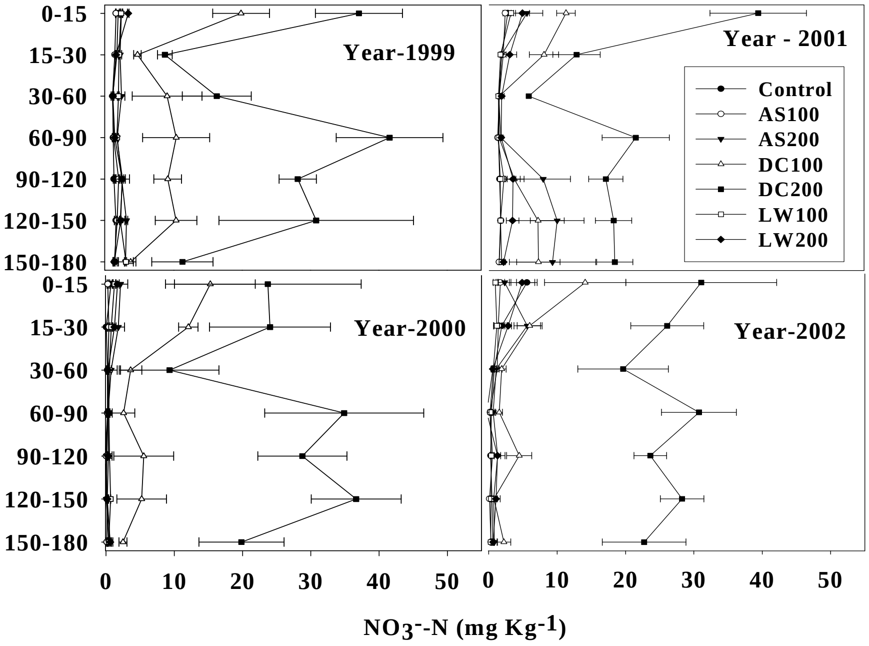

Figure 3: Post-harvest nitrate concentration at different depth intervals for field soils that received DC, LW or AS to supply about 100 and 200 kg available N ha^{-1} for years 1999-2002. Values represent means ± 1 SE (n = 4).

Low rate compost (DC100) met crop N demand but did not result in elevated amounts of nitrate in the lower depth of the profile until 1999-2001 suggesting that excess nitrate production versus plant demand during the growing season was not the only contribution to the downward movement of nitrate. While ammonium sulfate and liquid dairy-waste release N quickly during the early growing season, the continuing mineralization of the compost after harvest led to post-harvest nitrate production and downward movement. We noted a decrease in nitrate of 14, 20, and 17 mg N kg-1 soil (0-30 cm depth) between the post-harvest to the preseason sampling from 1999-2002. During these non-growing seasons total precipitation was 165, 202, and 271mm, sufficient to leach the accumulated and produced nitrate deeper into the profile. Therefore, in addition to careful prediction of mineralizable N, the ability to time the release of N to coincide with plant N demand becomes an important consideration for minimizing the downward movement of nitrate through the profile particularly after repeated application of compost.

Peak plant nitrogen demand can easily be met by compost, but continued nitrogen release after harvest makes nitrate leaching likely. We suggest that careful management of dairy compost needs to account for the amount and timing of N release from multiple year applications. We also found soil accumulation of available phosphorus and potassium could become problematic but in this calcareous soil we did not see movement downward below 30 cm.

Table 2. Soil organic-C, total N, $NaHCO_3$ extractable (available) P and K determinations for soil treated with DC, LW or AS to supply about 100 and 200 kg available N ha^{-1}. Preseason samples for 1998 and 2002 (Organic C and Total N) and 1999 and 2002 (available P and K) for 0-30 cm depth shown. Values within the year with the same letter superscripts are not significantly different ($p \geq 0.05$).

Treatment	Organic C		Total N		Available K		Available P	
	1998	2002	1998	2002	1999	2002	1999	2002
	-------------g kg^{-1} soil------------				------------mg kg^{-1} soil---------			
AS100	5.1^{a}	7.0^{b}	0.70^{c}	0.82^{b}	64^{c}	181^{c}	7^{c}	16^{c}
AS200	4.7^{a}	7.0^{b}	0.72^{bc}	0.94^{b}	65^{c}	168^{c}	8^{c}	22^{c}
DC100	6.9^{a}	10^{b}	0.94^{a}	1.12^{b}	390^{b}	1003^{ba}	23^{ba}	69^{b}
DC200	7.9^{a}	17^{a}	0.85^{ba}	1.61^{a}	687^{a}	1528^{a}	34^{a}	132^{a}
LW100	5.8^{a}	7.0^{b}	0.73^{bc}	0.86^{b}	77^{c}	162^{c}	11^{bc}	23^{c}
LW200	4.8^{a}	11^{b}	0.67^{c}	1.03^{b}	73^{c}	591^{bc}	10^{bc}	45^{cb}

While we might have predicted that the applications of composted manure would be more environmentally friendly than liquid wastes; we observed that if compost is applied as the sole nitrogen source at the rates necessary for high yields there is significant risk of nitrate leaching. An additional management challenge is that nitrogen continues to be released from compost after the crop is harvested and in subsequent years. On the positive side, the build up of soil organic carbon was significant in the high rate compost treated plots, approximately doubling the soil organic carbon storage resulting in an increase of 14 Mg C ha^{-1}. In the end, the management of dairy wastes requires a careful consideration of the timing of carbon versus nitrogen availability to the soil microorganisms. Additions of high carbon materials or use of a cover crop to trap available nitrogen after corn harvest are possible solutions to prevent leaching.

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