WATER QUALITY IN NO-TILLAGE SYSTEMS WITH NO PRIOR MANURE APPLICATIONS

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INTRODUCTION

Handling and disposal of animal wastes are significant concerns in the management of concentrated livestock operations such as dairy farms. Large amounts of waste are collected in dairy feedlot/milking parlor areas, resulting in storage and disposal problems. Nutrients in these wastes must be properly managed to minimize off-site water quality deterioration. Manure from these operations is usually applied to agricultural lands and farmers often also apply commercial fertilizers to supply crop nutrient requirements (White and Safley, 1984). This practice often results in the application of excessive amounts of nutrients, which can lead to off-site water quality problems.

Soil erosion is also a major problem in the mid-South region. In order to conserve soil and comply with federal regulations, many livestock producers in this area are using no-tillage methods in their animal feed production systems. They also routinely apply animal wastes, as well as inorganic fertilizers, to these fields. Effective conservation practices to minimize soil losses may conflict with the utilization of animal wastes in crop production. Incorporation of manures generally maximizes the efficiency of manure nutrient use, but will likely also result in an increase in soil erosion. The use of no-tillage methods may also result in enhanced preferential flow through the soil profile (Tyler and Thomas, 1977), therefore increasing the potential for subsurface water quality deterioration from leaching manure nutrients. Surface-applied manure in no-tillage or conservation-tillage systems may result in, increased losses of nitrogen (N) through NH, volatilization. However, little has been reported concerning runoff losses from manured land. Two reports indicate that runoff volume may be reduced by surface applications of manure (Mitchell and Gunther, 1976; Walter et al., 1987). If so, then leaching of nutrients may become a larger problem in no-tillage systems utilizing manures.

It is important to determine environmentally sound levels of manure application within conservation-tillage systems. High rates of manure, often applied with supplemental inorganic fertilizer, may represent a potential water quality problem. This research project is an effort to provide information for the prudent utilization of these wastes in conservation-based agricultural production systems. This paper reports on the impacts of manure applications in no-tillage silage production on yields, leachate water quality, and soil profile nutrient concentrations.

MATERIALS AND METHODS

Eighteen plots were established at the University of Tennessee's Martin Agricultural Experiment Station at Martin, TN in May of 1991. The Experiment Station is located in northwest Tennessee in the Loessal Uplands region. The plots are on a Loring silt loam (fine, silty, mixed, thermic Typic Fragiudalf) with average slopes of 4 to 6%. Prior to establishment of this experiment, the site had received no prior applications of animal manures.

Tension-free pan lysimeters (60 x 75 cm) were installed at the lower end of each plot at a depth of 90 cm as previously described (Tyler and Thomas, 1977; Tyler et al., 1992). Leachate is collected after every storm event for chemical analysis. Leachates were analyzed for NH_4-N, NO_3-N, and PO_4-P using standard methods.

Manure was applied at different rates to provide different annual N and P application rates. Total annual N treatments were four rates of liquid dairy manure (126, 252, 380, and 504 kg N ha^{-1}), a NH_4NO_3 rate (218 kg N ha^{-1}), and a control (0 kg N ha^{-1}). These rates were split into spring and fall applications. Spring N treatments were 84, 168, 252, or 336 kg N ha^{-1} as manure, 168 kg N ha^{-1} as NH_4NO_3, and the control. Fall N treatments were 42, 84, 128, and 168 kg N ha^{-1} as manure, 50 kg N $ha.^{-1}$ as NH_4NO_3 and the control. The applications ranged from deficient to excessive N rates;

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however, the high application rate is not uncommon for dairy operators in the region. Inorganic P and K were applied only to the NH_4NO_3 fertilizer plots at soil test recommendation rates. Treatments were replicated three times and arranged in a completely randomized design. All plots were 7.6 x 9.1 m (0.007 ha). The cropping sequence was no-till silage corn in the spring and an annual ryegrass/crimson clover mix in the fall for forage; this is a common rotation for this area.

Total manure N concentration was determined the day before application to permit calculation of field application rates. Slurry was transported to the field in a 1500 L agitated tank and pumped onto the plots using a submersible sewage pump. The volume applied was determined by monitoring a calibrated dipstick in the tank. Subsamples of the fresh slurry were taken during application for determination of total N, P and K, NH_4-N and dry matter. Analyses for all applications are shown in Table 1.

Corn for silage was no-till planted on May 15,1991 and April 28, 1992 in 95 cm rows. Corn silage was harvested on August 2,1991 and August 25,1992. Soil samples were also taken from these plots to monitor changes in nutrient balances and profile NH_4-N and NO_3-N. Samples were taken prior to manure applications in the spring and fall and separated into depth increments of 0-7.5, 7.5-15, 15-30, 30-45, 45-60, 60-75, and 75-90 cm. Two cores were taken per plot with a bucket auger; these were composited for each plot. Soils were analyzed for NH_4-N NO_3-N, total P, and Mehlich I extractable nutrients. Results for Meblich I orthophosphate will be discussed.

RESULTS AND DISCUSSION

Table 2 reports manure N rates, silage dry matter yields, and silage N concentrations for 1991 and 1992. In 1991, yields were quite low; this was primarily due to very dry conditions during July and August of 1991. There were no significant differences in silage yields among manure treatments, although there was certainly a trend for higher yields with increasing manure-N. The high manure rate and the inorganic N treatment were both significantly higher than the control. In 1992, rainfall was plentiful and yields were much higher. The highest manure rate resulted in the highest silage yield, although only the control and 84 kg manure-N ha^{-1} were significantly lower than the high manure-N rate and the inorganic N treatment. Based on 2 years of data, applying manure at rates above approximately 250 kg manure-N ha^{-1} does not appear warranted.

Nitrate-N concentrations in leachate collected from these plots have generally been below the **10** mg L^{-1} EPA standard (Fig. 1). In 1991, concentrations above 10 mg L^{-1} were observed in November and December, primarily from the NH_4NO_3 and the 126 and 252 kg manure-N ha^{-1} treatments. These peaks coincided wh increases in rainfall during this time period. Leaching earlier in the year was minimal due to sporadic rainfall. In 1992, concentrations above 10 mg L^{-1} were observed on June **5** from the three highest manure rates, and on July 29 from the 388 kg manure-N ha^{-1} treatment. In the late-fall flush of leachate, the nitrate concentration from the highest manure rate was highest, but still acceptable. We hypothesize that the adequate rainfall during the growing season in 1992 resulted in much higher uptake of N than in 1991, and thus, lower overall leaching losses occurred in the fall. Concentrations of nitrate have remained below four mg L^{-1} for all treatments during 1993.

Although there are few differences between treatments for leachate nitrate concentrations, differences in total N loss from the plots are apparent (Fig. 2). Differences in leachate volume resulted in relatively high losses of N from the highest manure treatment. Losses in 1991 were approximately 45 kg ha' for the NH_4NO_3 and highest manure rate. The highest loss for 1991 (approximately 50 kg ha^{-1}) occurred in the lowest manure treatment. In 1992, cumulative nitrate-N losses averaged 86 kg ha^{-1} from the highest manure rate (504 kg manure-N ha^{-1}), 53 kg ha" with NH_4NO_3 and 47 kg ha^{-1} for the 388 kg manure-N ha^{-1} treatment. All other treatments lost less than 55 kg NO3-N ha^{-1}. In 1993, lossesfrom the high manure rate (17 kg NO_3-N ha^{-1}) were more than twice as high as the other treatments through April 7.

There are two possible explanations for these differences. The lysimeter pans have a collection area of 0.46 m^2. Extrapolating this area to a hectare can obviously give rise to a magnification of differences. The placement of the pans may have resulted in the interception of a greater number of macropores under the high manure plots, resulting in higher leachate volumes. A second possibility is that the higher manure rates are in fact contributing to higher infiltration rates, resulting in increased leachate volumes. Infiltration rates should be examined in these plots to elucidate the mechanism. Soil sampling to a depth of 90 cm showed no differences among treatments in soil nitrate concentrations (data not shown). Nitrate concentrations from all plots were below 8 mg kg^{-1} at a depth of 15 cm or deeper. The low, uniform nitrate concentrations at these depths

Table 1. Manure analyses, Martin, TN, 1991 and 1992.

Application Date	Dry Matter (%)	Total N (%)	NH_4-N (%)	P (%)	K (%)
5/7/91	12.1	0.43	0.16	0.11	0.25
8/27/91	11.7	0.41	0.12	0.14	0.22
4/24/92	9.2	0.30	0.09	0.09	0.13
9/23/92	6.4	0.27	0.10	0.11	0.12

Table 2. Spring manure N rates, corn yields, and N concentrations, 1991-92. Martin, TN.

Nitrogen Source	Spring Nitrogen Rate (kg N/ha)	1991 Silage Yield (mg/ha)	1991 Silage N (%)	1992 Silage Yield (mg/ha)	1992 Silage N (%)
Control	0	5.9 c*	0.54 a	7.5 c	0.63 c
Manure	84	6.3 bc	0.61 a	11.4 b	0.73 bc
	168	6.9 abc	0.61 a	13.2 ab	0.73 bc
	252	8.2 abc	0.58 a	13.2 ab	0.78 bc
	336	9.0 ab	0.59 a	15.0 a	0.88 ab
NH_4NO_3	168	9.6 a	0.61 a	12.6 ab	1.02 a

* Means in a column followed by the same letter are not different at α = 0.05 by LSD.

indicate that preferential flow was probably the most important mechanism for nitrate loss in these soils. This observation agrees with data from an identical experiment in central Tennessee where very high concentrations of nitrate were collected in leachates under heavily manured soils, but soil nitrate concentrations were less than 4 mg kg^{-1} at similar depths (see Simmons et al., 1993; this proceedings).

In addition to concerns about N, accumulation of phosphorus in manured soils may also be a problem. Leachate concentrations of orthophosphate were low (below 300 μg L^{-1} from all treatments) in this experiment (data not shown). Runoff of excess P can result in eutrophication in surface waters. Mehlich I extractable phosphate was determined as a function of treatment and depth (Table 3). Extractable orthophosphate increased steadily in the mulch layer as manure rate increased. Mulch concentrations in the two highest treatments were significantly higher than for the inorganic fertilizer and control treatments. Available orthophosphate concentrations in the soil were not significantly different, although the concentrations did tend to increase in the 0 and 7.5 cm segment with increasing manure. The data indicate that there has been very little movement of P through the profile, as would be expected. Total P concentrations in the mulch also increased significantly as manure rate increased Table 4). Again, there were no differences among treatments in the soil fraction.

CONCLUSIONS

Data from the past 2 years showed that high rates of manure will support silage yields approaching or exceeding those from inorganic N applications. High rates of manure N may result in high leaching losses of nitrate-N. Based on 2 years' data, it appears that intermediate rates of manure-N will produce acceptable yields, while minimizing losses of N from the root zone. Losses of P from these plots via leaching has heen minimal. However, the high concentrations of available and total P in the mulch layer could present a runoff hazard on sloping land.

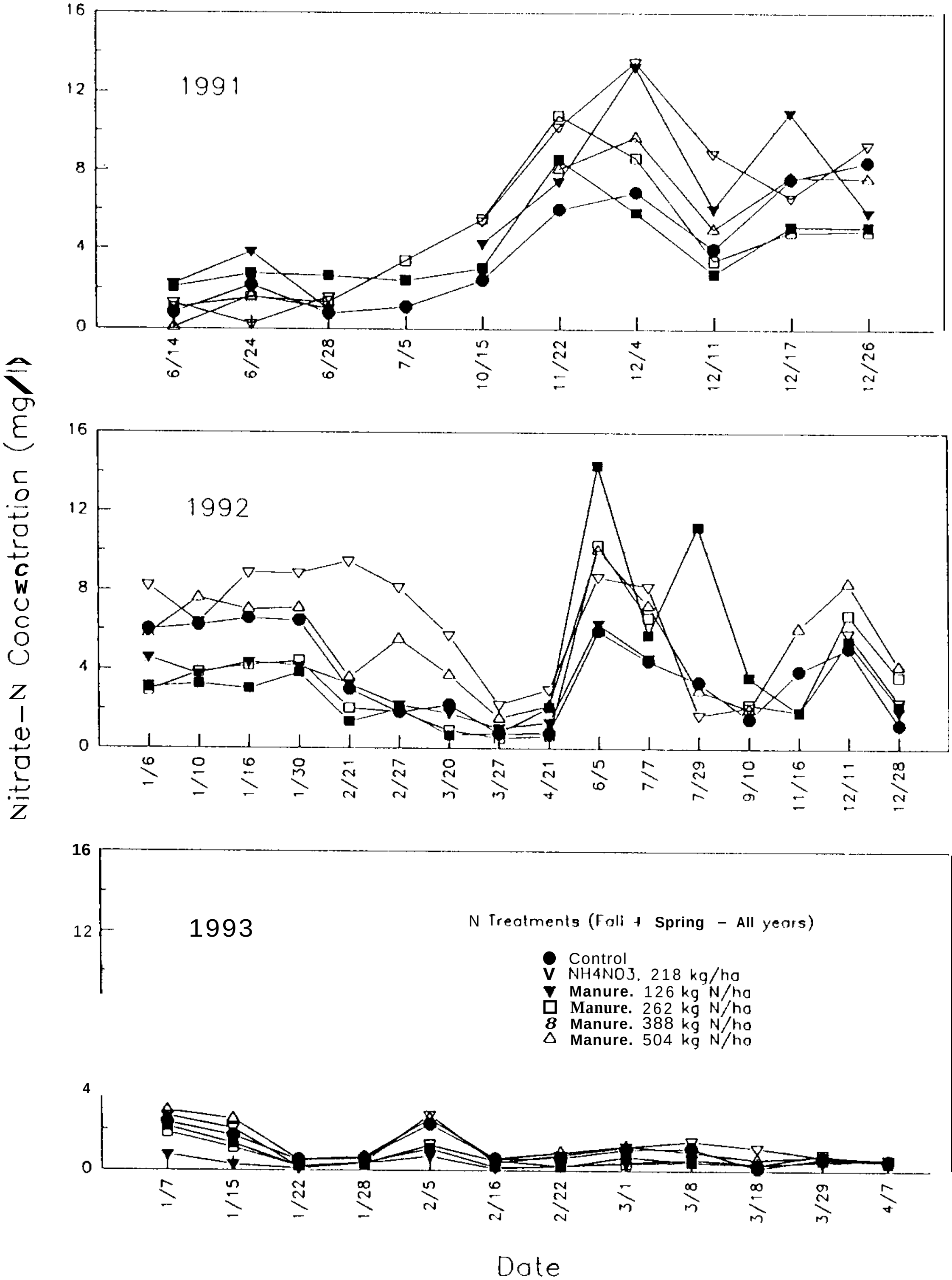

Fig. 1. Nitrate-N concentrations in leachate collected in pan lyslmeters for June 14, 1991 through April 7, 1993. Dotted line represents the 10 mg L^{-1} concentration standard for nitrate contamination of water.

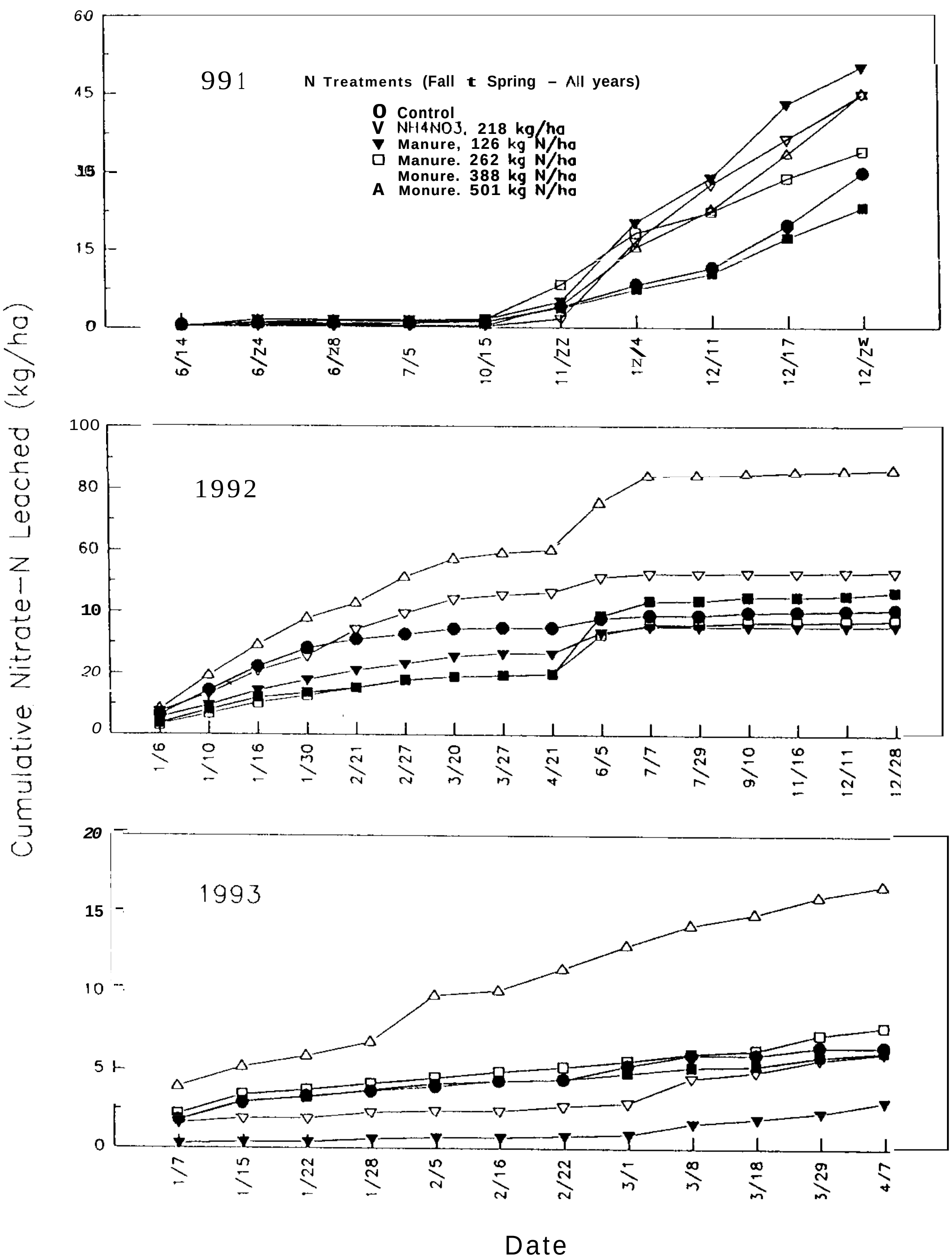

Fig. 2. Cumulative loss of nitrate-N collected in the pan lysimeters. Cumulative loss for each year is calculated from the first leaching event for that year.

Table 3. Mehlich I extractable orthophosphate as affected by manure treatment and sampling depth. August 14. 1992.

Depth	Control	NH_4NO_3	Manure N Treatment - Spring + Fall (kg N/ha) 126	262	388	504
cm		mg PO_4-P/kg				
Mulch*	292.0 d	810.0 cd	650.8 d	1211.4 cb	1675.7 b	2616.0 a
0 - 7.5	22.8	37.0	29.8	22.7	35.5	39.4
7.5 - 15	4.5	5.9	6.6	10.9	7.3	8.0
15 - 30	3.2	4.7	2.8	4.2	4.3	4.4
30 - 45	5.2	4.4	4.5	3.7	5.1	4.3

* Mulch means followed by the same letter are not different at α = 0.05 by LSD. There were no significant differences between means at the other depths.

Table 4. Total P as affected by manure treatment and sampling depth. August 14, 1992.

Depth	Control	NH_4NO_3	Manure N Treatment - Spring + Fall (kg N/ha) 126	262	388	504
cm		mg PO_4-P/kg				
Mulch*	1651 e	2364 ed	3082 cd	3883 bc	4354 b	5753 a
0 - 7.5	659	787	695	716	797	775
7.5 - 15	437	572	500	534	536	550
15 - 30	448	546	447	479	527	515
30 - 45	479	532	498	476	498	485

* Mulch means followed by the same letter are not different at α = 0.05 by LSD. There were no significant differences between means at the other depths.

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