IMPACTS OF SHORT-TERM MANURE APPLICATIONS ON SILAGE YIELDS, WATER QUALITY AND SOIL N AND P CONCENTRATIONS

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Handling and disposal of animal manure is a significant concern in the management of a concentrated livestock operation such as a dairy farm. Manure nutrients must be properly managed to prevent excess fertilization and to minimize off-site water quality deterioration. Manure is usually disposed of by land application and farmers often apply additional fertilizers to supply crop nutrient requirements (White and Safley, 1984). Without careful management, this practice can result in the application of excessive nutrients that can lead to off-site water quality problems. These problems can include the leaching of excess nitrate nitrogen below the root zone or runoff of N and P into surface waters (Ritter, 1988).

Because of concerns over soil erosion and animal manure management, it is important to determine environmentally sound levels of manure applications within conservation tillage systems. Research is underway in Tennessee to provide information for the prudent utilization of dairy manure 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.

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 experiment is on a Loring silt loam (fine, silty, mixed, mesic Typic Fragiudalf) with average slopes of 4 to 6 percent. Prior to establishment of this experiment, the site had not received applications of animal manures for at least 10 years. Tension-free pan lysimeters (24 x 30 in.) were installed in May of 1991 at the lower end of each plot at a depth of 36 in. as previously described (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 are four rates of liquid dairy manure (112, 225, 338, and 450 lb N acre^{-1}), NH_4NO_3 (195 lb N acre^{-1}) and a control (0 lb N acre^{-1}). These rates are split into spring and fall applications. Spring N treatments were 75, 150, 225, or 300 lb N acre^{-1} as manure, 150 lb N acre^{-1} as NH_4NO_3, and the control. Fall nitrogen treatments were 38, 75, 112, and 150 lb N acre^{-1} as manure, 45 lb N acre^{-1} as NH_4NO_3, and the control. Inorganic P and K were applied only to the

NH_4NO_3 fertilizer plots at soil test recommendation rates. Treatments were replicated three times. The plots are arranged in a completely randomized design. All plots are 25 x 30 ft. (0.017 acres). The cropping sequence is no-till silage corn in the spring and a ryegrass/clover mix in the fall for forage; a common rotation for this area.

Total manure N 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 is determined by monitoring a calibrated dipstick in the tank. Analyses for all applications are shown in Table 1.

No-till corn for silage was planted on May 15, 1991 and April 28, 1992 in 38 in. rows. Corn silage was harvested on August 2, 1991 and August 25, 1992. Soil samples have also been taken on 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 fall. Samples were taken from the 0-3, 3-6, 6-12, 12-18, 18-24, 24-30, and 30-36 in depths. The soil was extracted with 2 M KCl and the extract was then analyzed for NH_4-N and NO_3-N. Available soil P was determined in Melich I extracts.

RESULTS AND DISCUSSION

Table 2 reports manure N rates, silage 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 yield 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 75 lb manure-N acre^{-1} were significantly lower than the high manure-N rate and the inorganic N treatment. Based on two years of data, applying manure at rates above approximately 225 lb manure-N acre^{-1} does not appear warranted. This rate is consistent with UT guidelines for silage corn (120 lb N acre^{-1}), assuming that half of the manure N is available the first year. Differences among rates may also continue to diminish with continued manuring over time. Simmons and coworkers (1992) observed that corn grain and silage yields were not different between a control and the 300 lb manure N acre^{-1} treatment on soils receiving manure periodically for at least 35 years.

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 112 and 225 lb manure-N acre^{-1} treatments. These peaks coincided with 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 338 lb treatment. In the late fall flush of leachate, the nitrate concentrations from all treatments were less than 10 mg L^{-1}. Much more of the soil N was evidently taken up by the corn in 1992. Concentrations of nitrate have remained below four mg L^{-1} for all treatments during 1993.

Although there are few differences between treatments for nitrate concentrations, differences in total nitrogen loss from the plots are apparent (Fig. 2). Differences in leachate volume have resulted in relatively high losses of nitrogen from the high manure treatment. Losses in 1991 were approximately 40 lb $acre^{-1}$ for the NH_4NO_3 and high manure rate. The highest loss for 1991 (approximately 45 lb $acre^{-1}$) occurred in the low manure treatment. In 1992, cumulative nitrate-N losses averaged 77 lb $acre^{-1}$ from the high manure rate (450 lb manure-N $acre^{-1}$), 47 lb $acre^{-1}$ with NH_4NO_3, and 42 lb $acre^{-1}$ for the 338 lb manure-N $acre^{-1}$ treatment. All other treatments, lost less than 40 lb NO_3-N $acre^{-1}$. In 1993, losses from the high manure rate (15 lb NO_3-N $acre^{-1}$) were more than twice as high as the other treatments through April 7.

The higher manure rates may be contributing to higher infiltration rates, resulting in increased leachate volumes collected. Infiltration rates need to be examined in these plots to elucidate the mechanism. Soil sampling to a depth of 36 in. showed no difference in soil nitrate concentrations (data not shown). Nitrate concentrations from all plots are below eight mg kg^{-1} at a depth of 6 in. or deeper. The low, uniform nitrate concentrations at depth indicate that preferential flow is probably the most important mechanism for nitrate loss in these soils. This observation agrees with data from an experiment in central Tennessee where very high concentrations of nitrate are collected in leachates under heavily manured soils, but soil nitrate concentrations are less than four mg kg^{-1} at the 36 inch depth (Simmons et al., 1993).

In addition to concerns about nitrogen, accumulation of phosphorus in manured soils may also be a problem. Leachate concentrations of orthophosphate have remained low in this experiment. Concentrations have remained below 300 $\mu g\ L^{-1}$ from all treatments (data not shown). Runoff of excess P can result in eutrophication in surface waters. Melich I extractable phosphate was also measured (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 - 3 in. 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 are also increasing significantly as manure rate increases (Table 4). Again, there were no differences between treatments in the soil fraction. Continued increases in soil P concentrations will be monitored in conjunction with impacts on both runoff and leachate $H_2PO_4^-$ concentrations.

CONCLUSIONS

Data from the past two years shows that high rates of manure will result in silage yields approaching or exceeding those from inorganic N applications. However, high rates of manure nitrogen may result in high leaching losses of nitrate-N. The 225 lb manure-N/acre application is consistent with the University of Tennessee N application guidelines for silage corn assuming that approximately one-half of the manure-N will be available in the first year. Based on two years data, it appears that the 225 lb/acre rate of manure-N will give acceptable yields while minimizing losses of N from the root zone. Losses of P from these plots via leaching has been minimal. However, the high concentrations of available and total P in the mulch layer could present a runoff hazard on sloping land.

LITERATURE CITATIONS

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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 silage yields and N concentrations, 1991-92, Martin, TN. Silage yields expressed on a dry matter basis.

Nitrogen Source	Spring Nitrogen Rate (lb N/ac)	1991 Silage Yield (ton/ac)	1991 Silage N (%)	1992 Silage Yield (ton/ac)	1992 Silage N (%)
Control	0	2.6 c*	0.54 a	3.3 c	0.63 c
Manure	75	2.8 bc	0.61 a	5.1 b	0.73 bc
	150	3.1 abc	0.61 a	5.9 ab	0.73 bc
	225	3.7 abc	0.58 a	5.9 ab	0.78 bc
	300	4.0 ab	0.59 a	6.7 a	0.88 ab
NH_4NO_3	150	4.3 a	0.61 a	5.6 ab	1.02 a

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

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 (lb N/ac)			
			112	225	338	450
in	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 - 3	22.8	37.0	29.8	22.7	35.5	39.4
3 - 6	4.5	5.9	6.6	10.9	7.3	8.0
6 - 12	3.2	4.7	2.8	4.2	4.3	4.4
12 - 18	5.2	4.4	4.5	3.7	5.1	4.3

* Mulch means followed by the same letter are not different at $\alpha = 0.05$ 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 (lb N/ac)			
			112	225	338	450
in	mg PO_4-P/kg					
Mulch*	1651 e	2364 ed	3082 cd	3883 bc	4354 b	5753 a
0 - 3	659	787	695	716	797	775
3 - 6	437	572	500	534	536	550
6 - 12	448	546	447	479	527	515
12 - 18	479	532	498	476	498	485

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

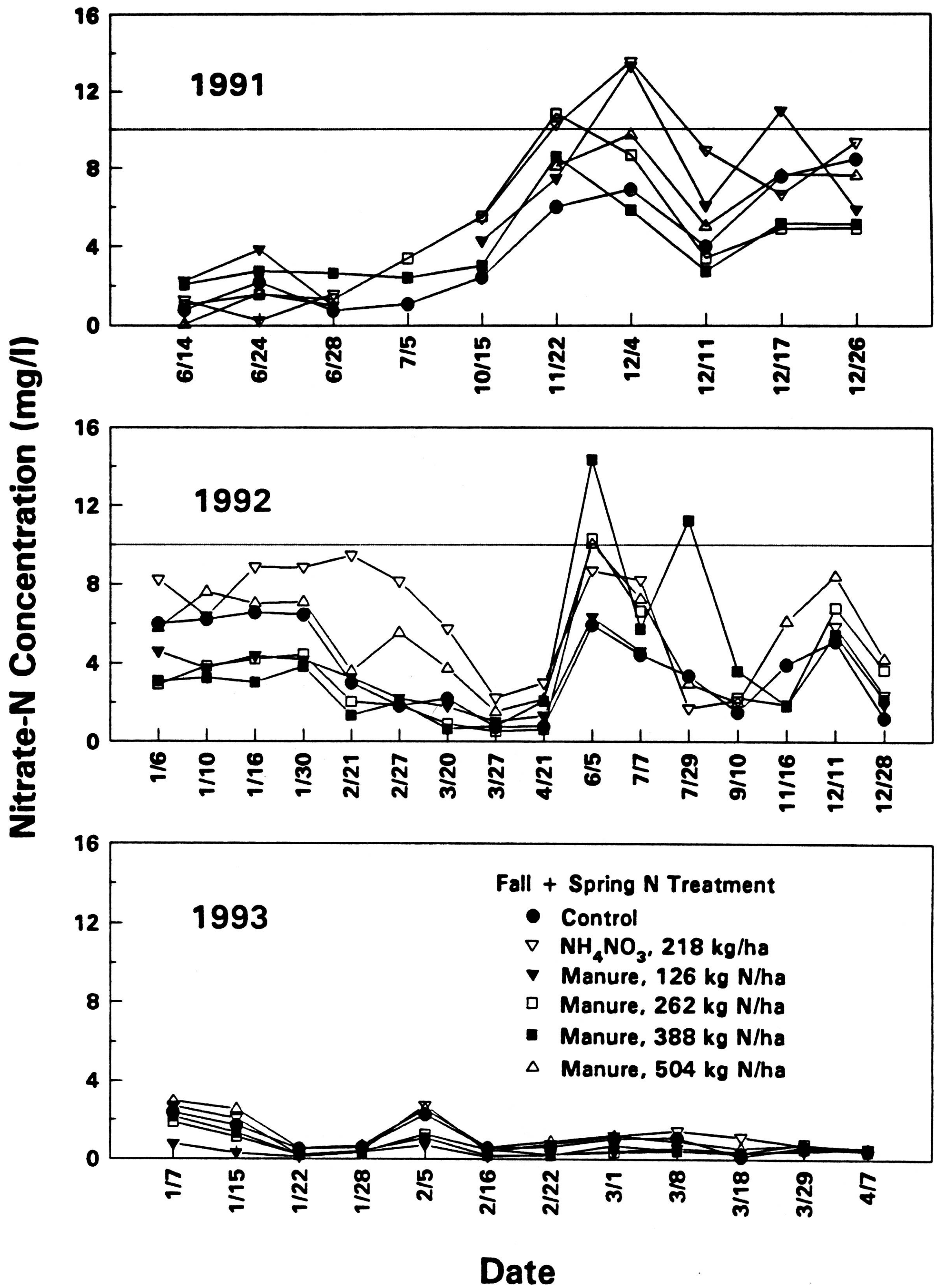

Fig. 1. Nitrate-N concentrations in leachate collected in pan lysimeters for June 14, 1991 through April 7, 1993. Dotted line represents the 10 mg L^{-1} concentration standard for nitrate contamination of water.

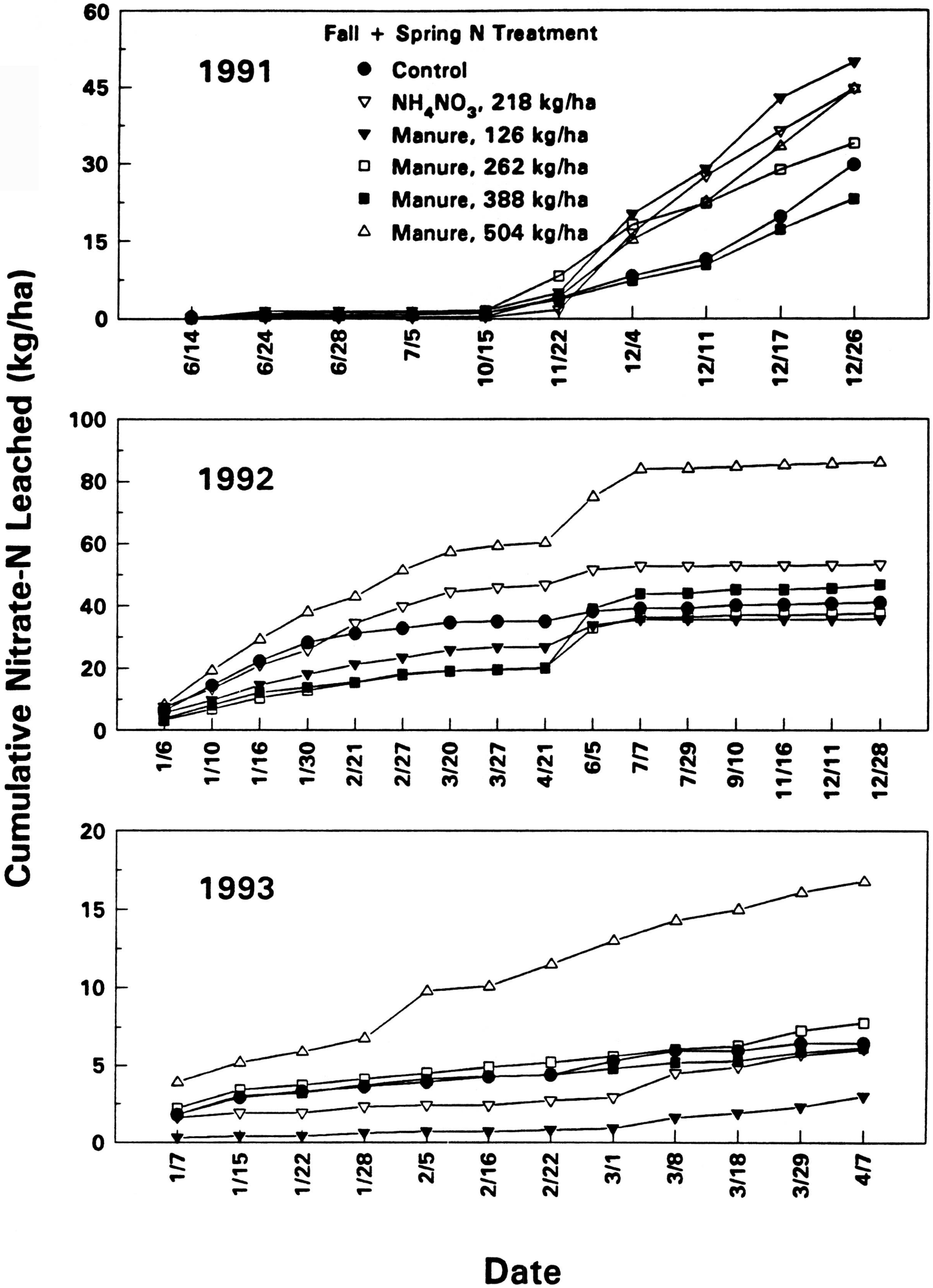

Fig. 2. Cumulative nitrate-N losses from lysimeter plots for 1991 through 1993. Accumulations are calculated from the first leaching event of each year.