WATER QUALITY IN NO-TILLAGE SYSTEMS FOLLOWING LONG-TERM MANURE APPLICATIONS

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INTRODUCTION

Land disposal of animal waste can lead to the deterioration of ground and surface water quality if nutrients in the waste are not managed appropriately. Typically, manure applications are based on N requirements of the crop, and this N is credited towards the inorganic fertilizer N applied. This practice results in a phosphorus application exceeding the crop requirement and a subsequent build-up of soil phosphorus. This could potentially result in surface water degradation from phosphorus laden runoff waters from agricultural land. For these reasons, it is necessary to simultaneously evaluate the effect of manure applications on both nitrogen (N) and phosphorus loadings to ground and surface waters in order to make environmentally sound nutrient management recommendations.

Tennessee ranks 14th in the nation in numbers of total cattle and dairy cattle. As of January 1990, Tennessee had approximately 2.3 million head of cattle, including 195,000 head of dairy cows. Sound nutrient management of the animal waste produced is necessary for the protection of local and regional ground and surface waters. In the central portion of the state, the soils have developed on phosphatic limestone bedrock. These soils have a greater potential for macropore flow under both saturated and non-saturated conditions. Macropore flow results in the rapid flux of water through the profile and may result in increased solute transport if contaminants are dissolved in the flowing solution. Furthermore, to reduce soil erosion, no-till is becoming a more common cultivation practice. However, this reduced-tillage practice also increases the presence of macropores in the upper soil profile and, likewise, the chance of rapid solute transport through the profile (Adreini and Steenhuis, 1990; Tyler and Thomas, 1977).

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Land application of manures may also result in the accumulation of mineralizable N over a number of years. Kelsoe et al. (1991) and Simmons and Baker (1990) observed no differences in corn yield or N mineralization in soils receiving manure for 50 years after manure application had ceased for 3 years. Other researchers have also observed a reduced response to N fertilization and increased N mineralization with long-term applications of manure (Campbell et al., 1986; Xie and MacKenzie, 1986). Additionally, Addiscott (1988) demonstrated that much of the N leached during the winter was from the organic N sink and not residual fertilizer N applied the previous spring. Other researchers have demonstrated the contribution of organic N to the pool of leachable NO_3-N (Letey et al., 1977; Macdonald et al., 1990; Pratt et al., 1976).

For these reasons, it is necessary to evaluate the effects of manure applications on water quality in karst topography regions where no-till practices are common. Field work was initiated at the Lewisburg Dairy Station to meet the following objectives: 1) to evaluate the potential impacts of liquid dairy manure applications in no-till silage and haylage rotations on surface and subsurface water quality and 2) to evaluate initial and residual availability of N and P from dairy manures as a function of rate and frequency of application.

MATERIALS AND METHODS

Field plots were established at the University of Tennessee Dairy Experiment Station in Lewisburg, TN in April 1992. The site is located in the valley and ridge province in Tennessee on a Huntington silt loam (fine, silty, mixed mesic Fluventic Hapludalf) with a slope less than 2%. The soil is over a fractured phosphatic limestone bedrock. The depth to bedrock varies from 1 to 2 m. The site has received manure applications periodically for at least 35 years.

Total annual N treatments include three rates of liquid dairy manure (126, 252, and 504 kg N ha^{-1}), one NH_4NO_3 rate (218 kg N ha^{-1}), and a control (0 kg N ha^{-1}). These rates are split into spring and fall applications. Spring N treatments are 84, 168, and 336 kg N ha^{-1} as manure, 168 kg N ha^{-1} as NH_4NO_3, and the control. Fall treatments are 42, 84, and 168 kg N ha^{-1} as manure, 50 kg N ha^{-1} as NH_4NO_3, and the control. The application rates cover the deficient to excessive N range; however, the high application rate is not uncommon for dairy operators in this area. All treatments are replicated three times and arranged in a randomized complete block design. Each plot is 7.3 x 13.7 m and is cropped to no-till corn silage/winter wheat 1-year rotation. Tension-free pan lysimeters (60 x 75 cm) were installed at the lower end of each plot at a depth of 90 cm as described by Tyler and Thomas (1977) and Tyler et al. (1992). The lysimeters were installed at the end of April 1992 prior to the first manure applications. Tensiometers were installed in the control plots at 7.5, 22.5, 37.5, 52.5, 67.5, and 82.5 cm to monitor soil water potential.

A manure sample was collected the day before application and analyzed for N to calculate the volumes to apply for each treatment. Manure was transported to the field using a 1500 L tank and pumped to the plots through a hose using a submersible sewage pump. An agitator was used in the tank to keep the slurry mixed during the application. The volume applied was determined from a calibrated stick in the tank. Manure samples were also collected from each plot during the application and later analyzed for dry matter, total N, P, and K, and NH_4-N. Manure analyses for the spring and fall applications are shown in Table 1.

Table 1. Manure analyses, Lewisburg, TN, 1992.

	Dry matter	Total N	NH_4-N	P	K
	(%)				
Spring	8.46	0.43	0.27	0.085	0.38
Fall	2.80	0.11	0.05	0.028	0.11

No-tillage corn was planted in 91 cm rows during the first week of May. Plant populations averaged 44,000 plants ha^{-1}. Corn grain and silage were harvested from each plot. A 3-m length of row was harvested from each plot for both grain and silage yield data. Subsamples were taken for moisture and N, P, and K analyses. Soil profile samples were taken immediately following harvest. Samples were taken from 0-15, 15-30, 30-45, 45-60, 60-90, and 90-120 cm. Three cores/plot were taken and composited for laboratory analyses. Soils were analyzed for NH_4-N and NO_3-N using a KCl extraction. Fall applications of manure were applied after the soil had been sampled. Winter wheat was planted within a month.

RESULTS AND DISCUSSION

Corn grain and silage yields are shown in Table 2. Although the NH_4NO_3 treatment had the highest silage and grain yield, no significant difference was detected among yields. This is attributed to high amounts of mineralized N from previous manure applications in this field. Furthermore, because of low rainfall in the spring, plant populations in the plots were highly variable, which resulted in highly variable yield data.

Leachate was collected from the pan lysimeters after each storm event beginning on 5 June 1992. Average concentrations for NO_3-N and ortho-P are shown in Figure 1 and 2, respectively. Ammonium was not detected in the leachates and, therefore, is not shown. Both nitrate and ortho-P were detected in the leachate during this sampling period, and nitrate concentrations exceeded 10 mg L^{-1} throughout most of this sampling period. Nitrate concentrations in the leachate were highest where 168 kg N ha^{-1} as NH_4NO_3 and 336 kg N ha^{-1} as manure were applied. Nitrate concentrations from the control plot ranged from 10 mg L^{-1} to 30 mg L^{-1} during this sampling period, whereas concentrations from the high manure treatment ranged from approximately 23 mg L^{-1} to 40 mg L^{-1}. Ortho-P was generally only detected where manure had been applied and was greatest at the highest application rate.

Cumulative NO_3 leached (kg NO_3-N ha^{-1}) is shown in Figure 3. Nitrate loss was the greatest from the inorganic N treatment. During the corn growing season, approximately 140 kg N ha^{-1} was leached where 168 kg N ha^{-1} as NH_4NO_3 had been applied. Approximately 60 kg N ha^{-1} leached from the control plot. Total NO_3-N leached during this time period (5 June 1992 to 1 December 1992) ranged from approximately 100 to 200 kg N ha^{-1} among the treatments. These high levels are partly attributed to residual N from previous manure applications and are expected to diminish over time. The nitrate leached from the control plot over time will serve as a measure of this effect.

Table 2. Corn yield and N concentration, Fall 1992, Lewisburg, TN.

Nitrogen Source	Spring 1992 N Rate (kg N ha^{-1})	Silage Yld. (Mg ha^{-1})	Silage N Conc.(%)	Grain Yield (Mg ha^{-1})	Grain N Conc. (%)
Control	0	21.8	1.10	10.12	1.48
Manure	84	22.1	1.13	9.49	1.63
	168	20.5	1.08	8.79	1.47
	336	20.9	1.16	7.47	1.59
NH_4NO_3	168	23.0	1.22	10.22	1.52

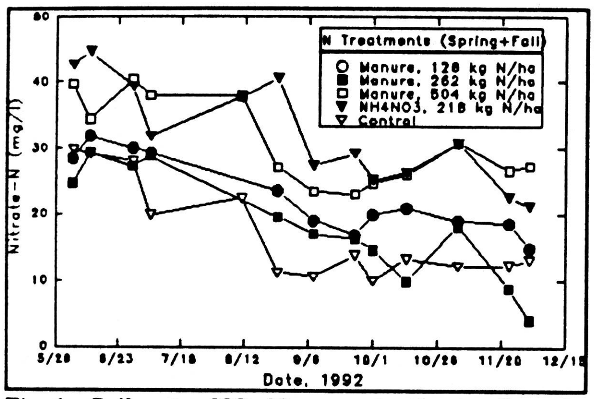

Fig. 1. Soil water NO_3-N concentrations collected in pan lysimeters from June through December 1992, Lewisburg, TN.

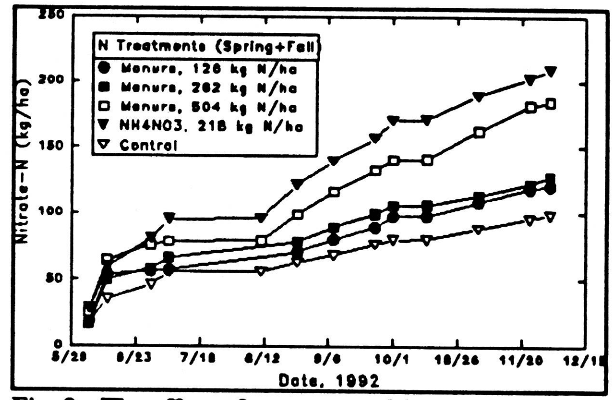

Fig. 3. The effect of manure and NH_4NO_3 applications on cumulative NO_3-N loss in leachate, Lewisburg, TN 1992.

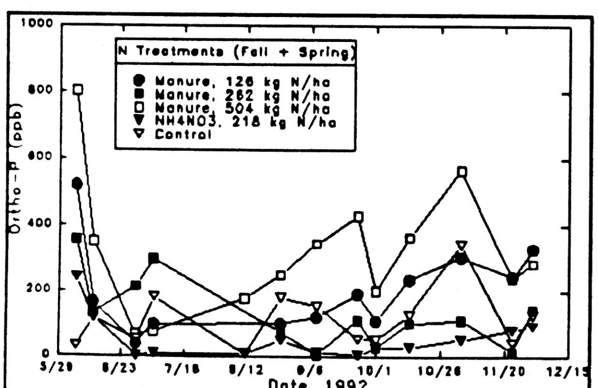

Fig. 2. Soil water ortho-P concentrations collected in pan lysimeters from June through December 1992, Lewisburg, TN.

The soil profile NO_3-N for Fall 1992 is shown in Figure 4. The increase in soil nitrate at the lower depths where NH_4NO_3 was applied is consistent with the higher amounts of NO_3 leached from this treatment. However, significant differences among the treatments were not detected.

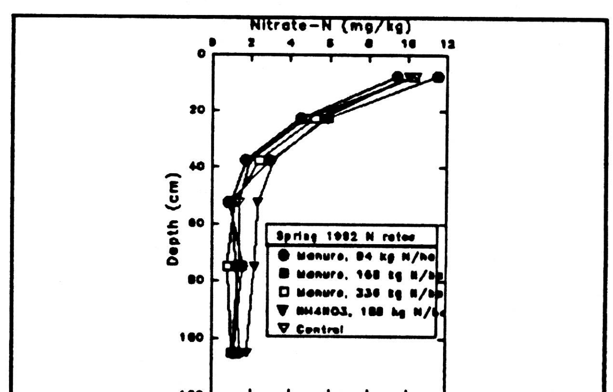

Fig. 4. The effect of manure and NH_4NO_3 applications on fall soil profile NO_3-N concentrations, Lewisburg, TN, 1992.

Although definitive conclusions should not be drawn after one site year of data, continuous applications of manure appear to have elevated nitrate concentrations in the leachate, leaving the vadose zone at this site. At a similar experimental site in Martin, Tennessee, which had not received previous manure applications (see Mullen et al., this proceedings), nitrate concentrations were not as high the first year of the study and a statistically significant response in corn yield to N applications was observed. Both these comparisons suggest that the build-up of organic N in the soil profile from long-term manure applications is a significant source of N to the corn crop and is susceptible to nitrate leaching. However, recommendations for nutrient management on previously manured sites cannot be made until more site years have been completed.

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