AMMONIA VOLATILIZATION FROM MANURE IN CROPPING SYSTEMS FOR ETHANOL PRODUCTION

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Abstract. Effect of tillage on ammonia (NH_3) volatilized from fresh and composted farmyard manure (FYM) used for fertilizing barley (*Hordeum vulgare* L.), was determined at two sites near Melfort, Sasktchewan in 1993. Ammonia losses were markedly higher in plots under zero tillage than under conventional tillage, as well as in plots which received a high rate (90 t ha^{-1}) of FYM versus a lower rate (22 t ha^{-1}). In conservation tillage cropping systems in which FYM is not incorporated into soil, the amount of NH_3 volatilized is not very large when FYM-N rates are comparable to crop requirements.

INTRODUCTION

Historically, organic manures, despite their low nutrient analyses, have been important for maintaining soil fertility and tilth. The Rothamsted long-term experiments, established 150 years ago, proved that crop yields are sustainable when farmyard manure (FYM) is applied to soil on an annual basis (Jenkinson 1991). However, there are environmental concerns regarding nutrient losses from FYM, particularly nitrogen (N). A principal pathway of N loss is via ammonia (NH_3) volatilization, which contributes to poor efficiency of use of N in FYM.

Under conservation tillage, reductions in NH_3 volatilization associated with incorporation may not be feasible. Reported losses of NH_3 from FYM that is not incorporated into soil are highly variable, ranging from 0 to 35% of applied N (Hargrove 1988; Schilke-Gartley and Sims 1993). Greatest losses occur immediately following field application. Manure properties, soil chemical properties, environmental, and management factors influence the magnitude of loss (Hargrove 1988). Manure source, form, and N content influences the amount of NH_3 volatilized. Approximately half of FYM-N from cows is in urea or ammonia form, mostly from urine, which is susceptible to NH_3 volatilization (Van Horn 1992). The main soil chemical properties affecting NH_3 volatilization are pH, cation exchange capacity (C.E.C), and urease activity. However, environmental factors such as temperature, soil water content, and windspeed at the soil surface are overriding factors in determining the extent of these losses. Higher losses are generally associated with periods of rapid soil drying of wet (at or near field capacity) soils. Management factors, such as FYM application rate and method, and amount and distribution of crop residues, also influence NH_3 loss.

With increased interest in production of cereal crops for ethanol feedstocks and the close association between ethanol plants and feedlots, information is required on the agronomic and environmental impacts of using FYM as a nutrient source for cereal crop production in conservation tillage systems. Therefore, information on NH_3 volatilization is required as part of an impact assessment. This paper reports on the results of a study which examined the effect of tillage on NH_3 atmospheric emissions from fresh and composted FYM under cropped conditions at two sites near Melfort, Saskatchewan in 1993.

MATERIALS AND METHODS

This study is one component of a project to determine the effect of tillage and rate and frequency of application of fresh and composted FYM in a cereal/oilseed rotation, on soil and environmental quality, soil physical properties, weed populations, and grain and biomass dry matter for ethanol production. The goal of this project is to minimize inputs required to achieve maximum sustainable yield of cereal crops. The experiment was established in 1993 at the Agriculture Canada Research Station at Melfort in the Black Chernozemic soil zone, a site 25 km southeast of Melfort in the Gray Chernozemic soil zone, and at the Agriculture Canada Experimental Farm at Scott, Saskatchewan in the Dark Brown Chernozemic soil zone. The experiments were arranged in a factorial split-split-plot design with four replicates per treatment. Plot size was 2.7 by 10 m. Main plots were tillage treatments: (1) conventional tillage (CT) with two preseeding tillage operations to incorporate crop residues and FYM; and (2) zero tillage (ZT), with preseeding herbicide burnoff and direct seeding into standing stubble and FYM. Split-plot treatments consisted of solid FYM (fresh and composted) applied annually at a rate of 22 t h^{-1} and once every four years at a rate of 90 t h^{-1}. Fresh FYM was applied on a wet weight basis; composted FYM was applied at a rate to provide an equivalent N content on a dry matter basis. The N content of fresh and composted FYM was 1.55 and 1.80% of dry matter, respectively. Therefore, 70 and 280 kg N ha^{-1} were supplied by the two rates of FYM. An additional spit-plot treatment was inorganic N and P fertilizer applied at soil test recommended rates. Split-split-plots comprised the two phases of a cereal-oilseed rotation. Ammonia volatilization was measured only in cereal ('Leduc' barley [*Hordium vulgare* L.]) plots at the Black and Gray soil sites.

Manure was uniformly spread on the plots at the Gray soil site on June 9 and at the Black soil site on June 16 in 1993. For the CT treatment, FYM was incorporated into soil by two passes of a rotovator. Thereafter, the soil was harrowed and packed. Plots were seeded on June 10 at the Gray soil site and on June 17 at the Black soil site. Immediately after seeding, NH_3 collectors were placed in the plots (2 per plot). Description of the collectors and of the extraction procedures are detailed in Marshall and Debell (1980) and Al-Kanani and Mackenzie (1992). The collectors, which have an internal diameter of 10 cm and a height of 8 cm, were positioned with the bottom about 2 cm below the soil surface. Ammonia volatilized from the area inside the collector was captured on a polyurethane pad containing 12 mL of a mixture of 1.0 M sulfuric acid-glycerol solution (2:1, v v^{-1}). Ammonia volatilization was measured over a 70-day period, by which time NH_3 emissions from manure were not detected. Pads were exchanged after the first day and thereafter every two days (weather permitting) during the first week. During subsequent weeks, pads were left in the field for 2 days. On collection dates, the exposed pads were brought to the laboratory where NH_4 was extracted by 2 M KCL and analyzed using a Technicon Autoanalyzer.

All data was expressed as NH_3 loss as a percentage of applied N. Curves were fitted to the data by non-linear regression procedures. An exponential decay model was used to describe the kinetics of NH_3 loss over time.

RESULTS AND DISCUSSION

Over the duration of the experiment, weather conditions at Melfort were much cooler and wetter than normal (Figure 1). Monthly mean air temperatures for June, July, and August were 86, 87, and 96% of the long-term average, respectively. Total monthly precipitation for these three months were 167, 245, and 84% of normal. Ammonia-N loss, expressed as a percentage of applied FYM-N, varyed markedly between FYM type and tillage treatment at both the Black and Gray soil sites (Figures 2 and 3). Volatilization from composted FYM was negligible. As expected, NH_3 losses were higher for fresh FYM. Even though NH_3 losses were very low for composted manure relative to fresh manure, the loss of N during

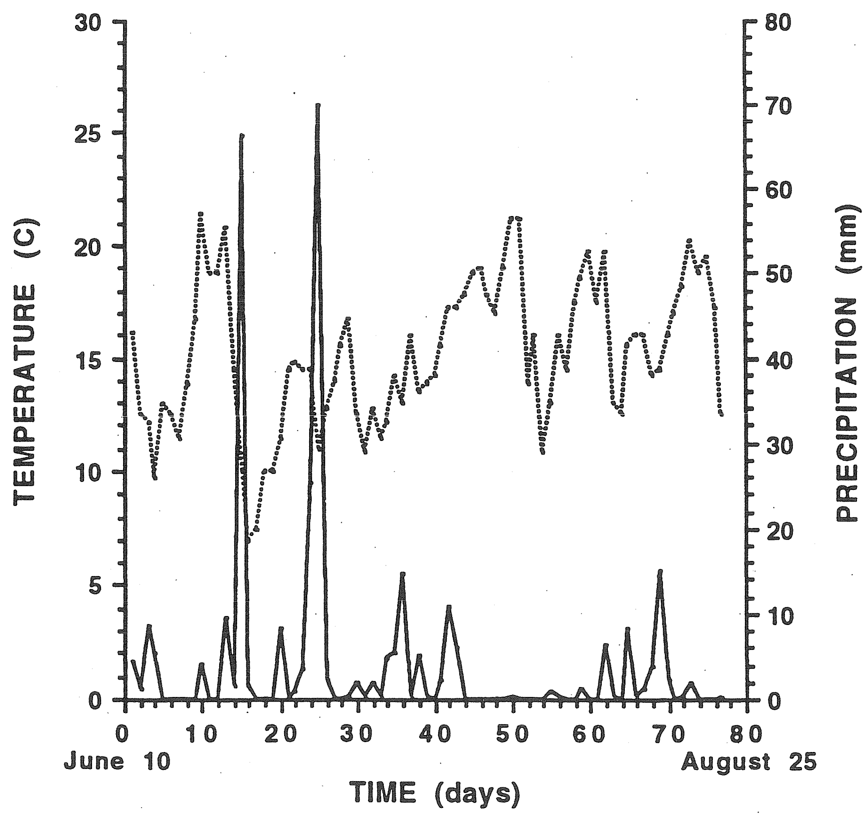

Figure 1. Daily mean air temperature (dotted line) and precipitation (solid line) from June 10 to August 25 in 1993 at Melfort, Saskatchewan.

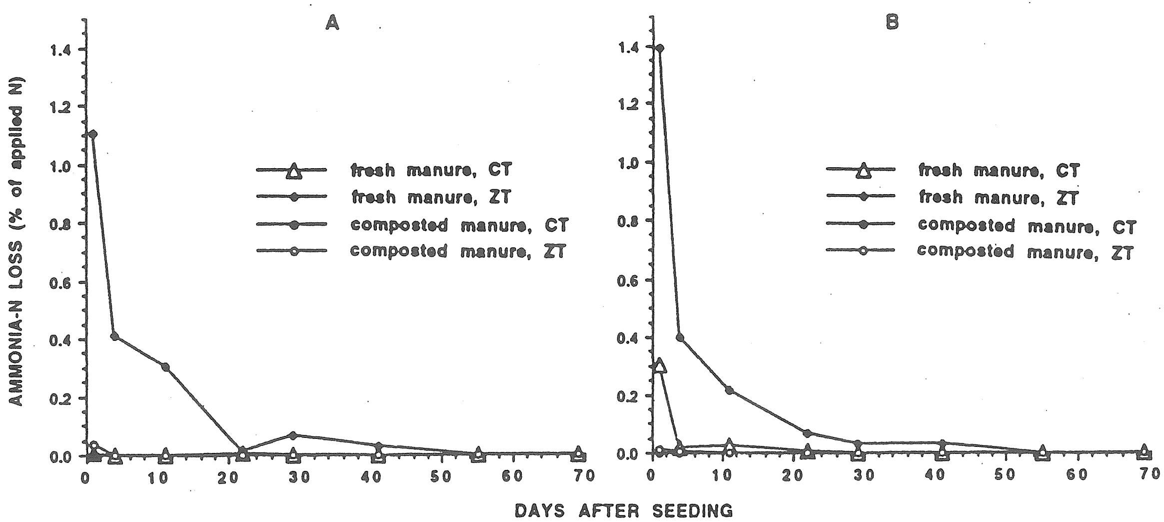

Figure 2. Loss of ammonia from fresh and composted manure, applied on June 17 in 1993 at a rate of 22 (A) and 90 t ha^{-1} (B) to a Black silty clay soil, under conventional (CT) and zero tillage (ZT) at Melfort, Saskatchewan.

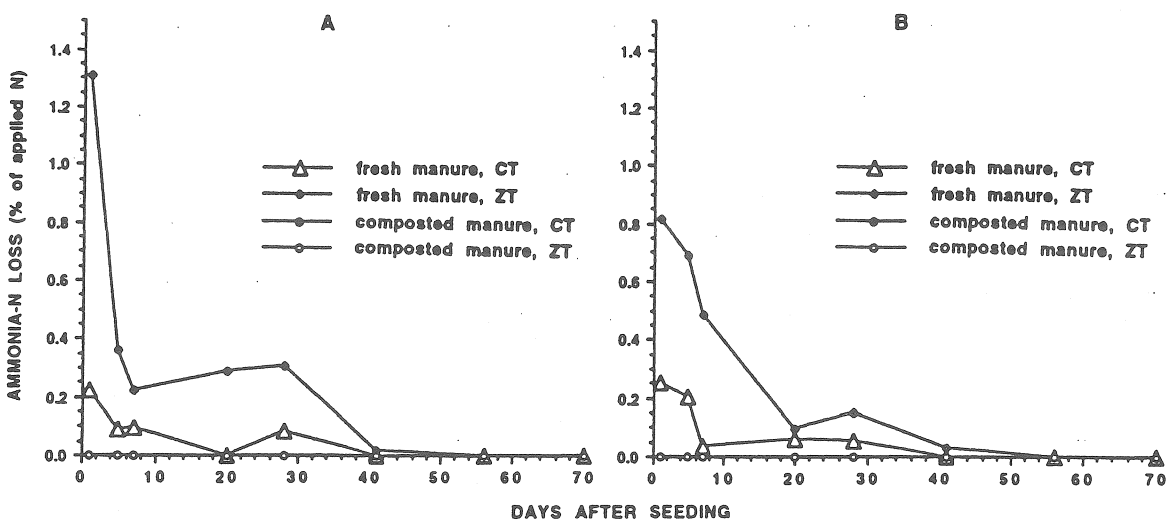

Figure 3. Loss of ammonia from fresh and composted manure, applied on June 10 in 1993 at a rate of 22 (A) and 90 t ha^{-1} (B) to a Gray-wooded loam soil, under conventional (CT) and zero tillage (ZT) near Melfort, Saskatchewan.

composting and low plant availability of remaining N are serious disadvantages relative to fresh manure. Emissions from fresh FYM in CT plots were significantly reduced compared with volatilization from corresponding ZT plots. In the latter, volatilization was detected 6 weeks after seeding. Ammonia losses from CT plots were slightly greater at the Gray soil site than at the Black soil site. A possible explanation is less effective incorporation of FYM at the Gray soil site because of dry and cloddy soil conditions at the time of application. In addition, the lower C.E.C. of the Gray loam soil compared with the Black clay soil, may result in greater volatilization from FYM in the Gray soil.

First-order half-lives ($t_{1/2}$), defined as the time required for volatilization to be reduced to half of the initial daily amount, were calculated from the exponential decay regression curves (Table 1). The relative $t_{1/2}$'s for the treatments differed with location. For ZT treatments at the Black soil site, the $t_{1/2}$ for the high rate of fresh FYM was less than the lower rate. However, the opposite was noted at the Gray soil site. Although the $t_{1/2}$ for the lower rate of fresh FYM in CT plots at the Gray soil site was greater than the corresponding rate for the ZT treatment, the converse was true for the high rate. Generally, the rate of NH_3 loss was less rapid at the Gray soil site than at the Black soil site. Because the experiments at these two sites were established a week apart, weather conditions may have influenced these differences in relative $t_{1/2}$'s between locations. Further measurements in 1994 may help to better correlate volatilization losses to prevailing weather conditions.

The estimated cumulative NH_3 loss (Figures 4 and 5) over the 10-week period at Melfort indicated that about 6% of added fresh FYM-N volatilized from ZT plots at both rates of FYM. This amounts to 4 and 17 kg N ha^{-1} lost to the atmosphere from 22 and 90 t ha^{-1} FYM, respectively. This illustrates the importance of

Table 1. Parameter estimates (standard errors in parentheses) and half-lives for the regression curves for ammonia-N loss from fresh FYM over time under conventional and zero tillage near Melfort, Saskatchewan in 1993.

Treatment[z]	a[y]	b	R^2 [x]	$t_{1/2}$
Black soil				(d^{-1})
CT, 22 (t ha^{-1} FYM)	-	-	-	-
ZT, 22	1.31(0.45)	-0.22(0.15)	0.31	3.2
CT, 90	0.76(1.06)	-0.91(1.35)	0.29	0.8
ZT, 90	2.01(0.22)	-0.38(0.06)	0.86	1.8
Gray soil				
CT, 22 (t ha^{-1} FYM)	0.24(0.08)	-0.14(0.08)	0.32	4.9
ZT, 22	1.76(0.57)	-0.30(0.16)	0.28	2.3
CT, 90	0.28(0.05)	-0.13(0.05)	0.53	5.2
ZT, 90	0.90(0.13)	-0.08(0.02)	0.72	8.6

[z]CT = conventional tillage, ZT = zero tillage.

[y]Exponential function equation: $y = a\,e^{bt}$ where a = intercept, ab = initial slope, y = NH_3-N loss as a percentage of FYM-N applied and t = time (days).

[x]All coefficients of determination are significant at the 1% level.

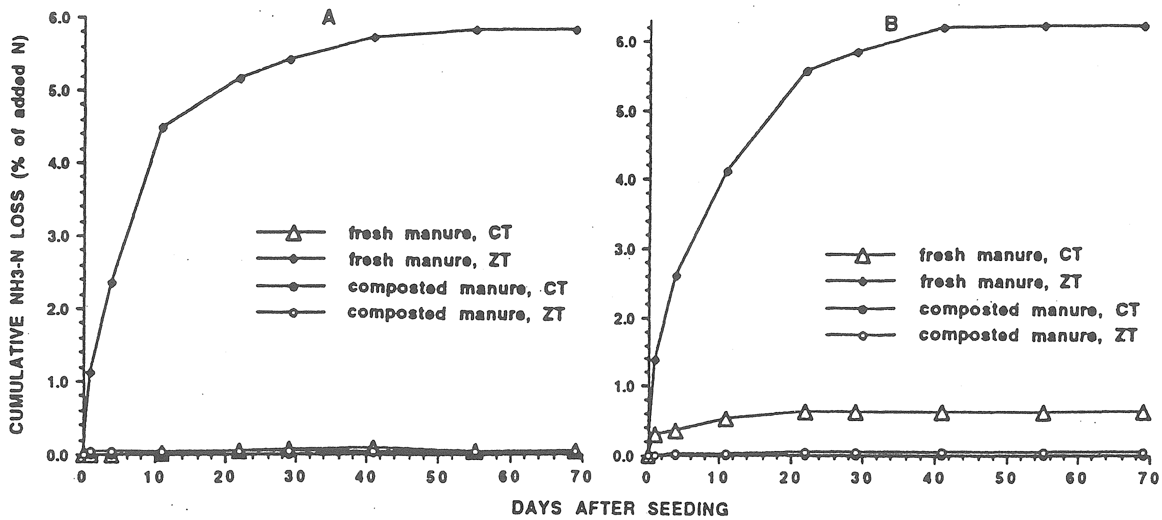

Figure 4. Cumulative loss of ammonia from fresh and composted manure, applied on June 17 in 1993 at a rate of 22 (A) and 90 t ha^{-1} (B) to a Black silty clay soil, under conventional (CT) and zero tillage (ZT) at Melfort, Saskatchewan.

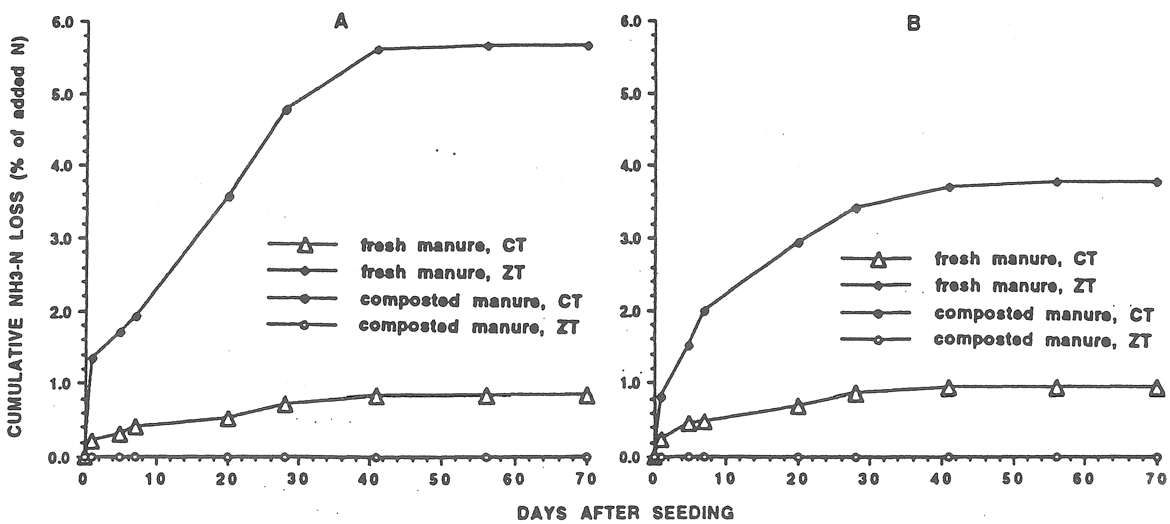

Figure 5. Cumulative loss of ammonia from fresh and composted manure, applied on June 10 in 1993 at a rate of 22 (A) and 90 t ha^{-1} (B) to a Gray-wooded loam soil, under conventional (CT) and zero tillage (ZT) near Melfort, Saskatchewan.

applying agronomically sensible rates of FYM in relation to crop requirements. Proportionally more NH_3 was lost from FYM applied at the high rate in CT plots at the Black soil site than the lower rate, which may indicate less effective incorporation of the high rate of FYM or greater concentration of ammoniacal-N in soil solution that is subject to volatilization. However, this loss represents less than 1% of applied N. At the Gray soil site, a similar amount of NH_3 was lost from ZT plots that received the lower rate of fresh FYM compared with the same treatment at the Black soil site, but less loss than expected occurred in ZT plots with the higher rate of FYM. Emissions were similar for both rates of FYM in CT plots at the Gray soil site, totalling approximately 1% of applied N. Because the collectors interfered with seeding operations, they were placed in the field immediately after seeding but about a day after manure application. Therefore, these results are slightly conservative estimates of NH_3 loss to the atmosphere.

CONCLUSIONS

When fresh FYM is not incorporated into the soil after application, as in a conservation tillage cropping system, NH_3 losses are not very large provided that the rates applied do not greatly exceed crop N requirements. Therefore, FYM testing for N analysis is very important. When applied FYM-N greatly exceeds crop requirements, significant gaseous losses can occur unless it is incorporated immediately after application. There also may be greater risk of nitrate-N leaching and denitrification. Therefore for more efficient use of FYM-N in conservation tillage systems, it is advantageous to apply an agronomically sensible FYM rate in relation to current crop requirements rather than applying a high rate to supply nutrients for current and future years' crops.

ACKNOWLEDGMENTS

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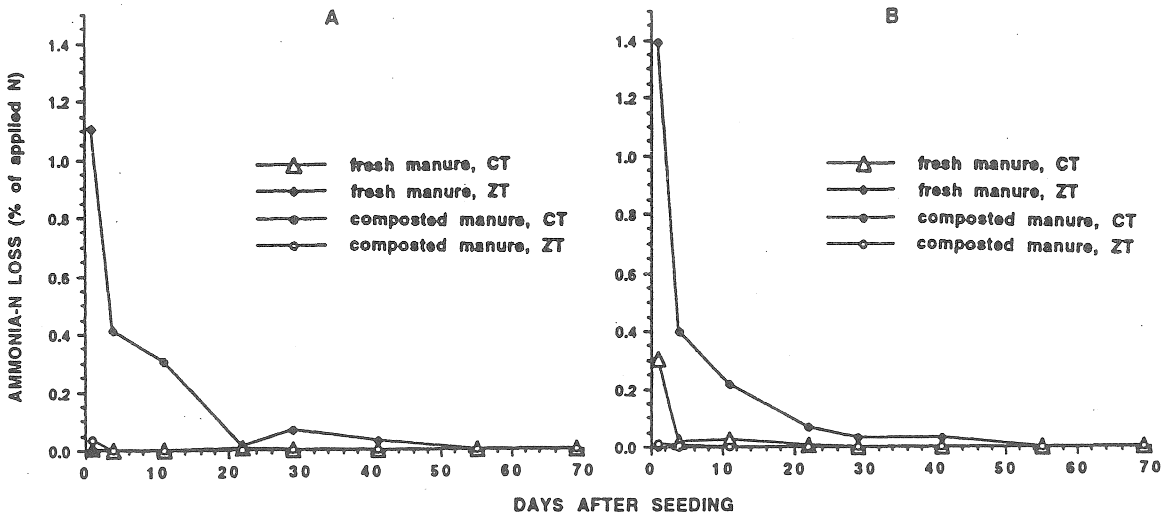

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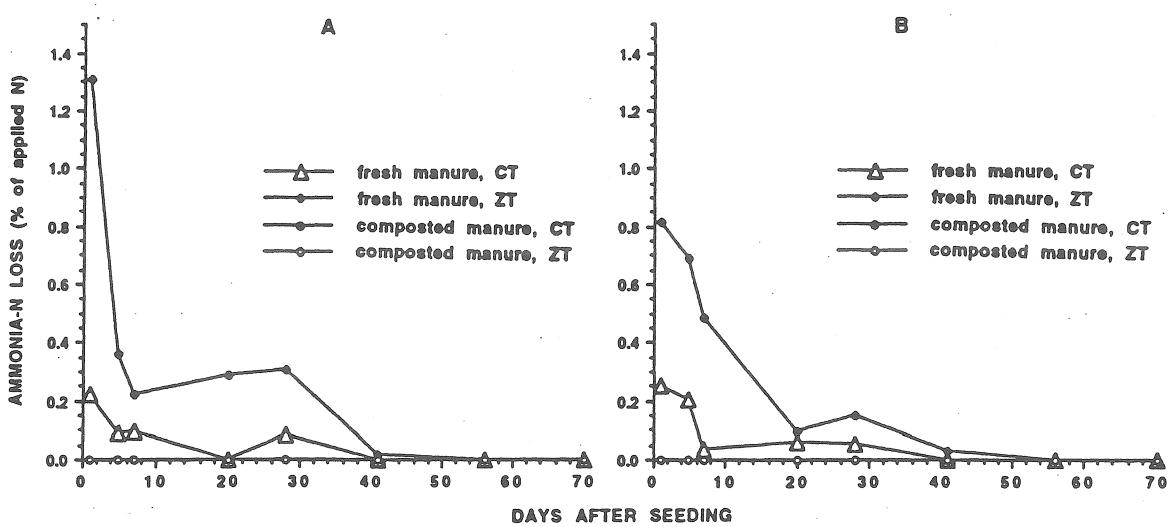

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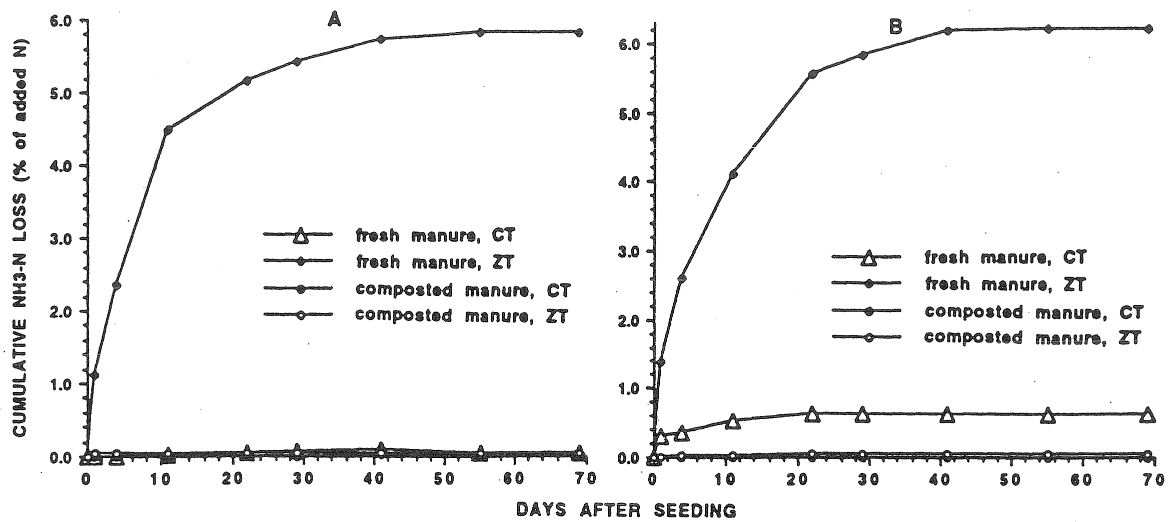

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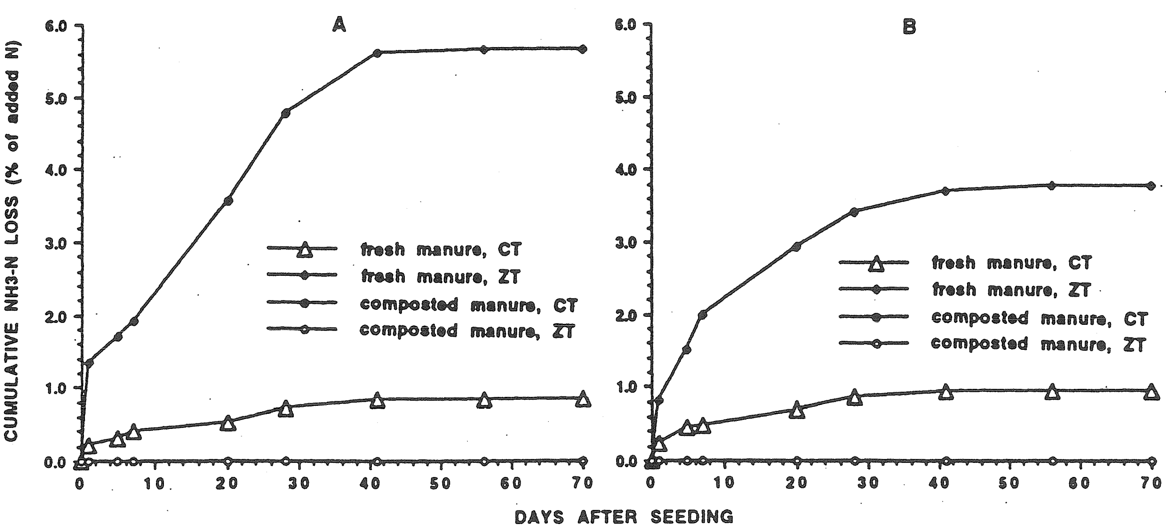

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