MANURE APPLICATION TECHNOLOGY AND IMPACT ON NITROGEN DYNAMICS

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Abstract

A field study was carried out near Elora, Ontario to assess the impact of manure application timing and method on ammonia volatilization and nitrogen availability to the crop. A novel method was developed and calibrated for quantifying ammonia volatilization using passive dosimeter tubes, which promises to provide an economical alternative to other methods. Ammonia loss was negligible from injected manure treatments, and when manure was incorporated immediately it had smaller losses than when it was incorporated 1, 3 or 5 days following application, or applied using an aeration tool. There were no significant yield differences between treatments, which was attributed to low demand for additional nitrogen in the 2005 growing season. There was a general trend across sample dates of greater soil mineral N and plant nitrogen uptake for injection treatments and manure application times closer to the growing season.

Introduction

Currently, Canada produces 783,000 tonnes of nitrogen per year in livestock manure. When properly managed, this manure could provide Canadian agriculture with over 32% of our nitrogen needs (Statistics Canada, 1996). Unfortunately, due to nitrogen's high mobility in soil, and its potential to readily volatilize, apparent nutrient use efficiency is relatively low. Research needs to be conducted to study the impact of different management practices on nitrogen loss.

Manure nitrogen contains two forms of nitrogen, ammoniacal nitrogen and organic nitrogen (Beauchamp, 1983). Since the ammoniacal nitrogen is in the mineral form it can be immediately lost by volatilization, plant uptake, or (following nitrification) leaching. In contrast, the organic fraction needs to undergo mineralization first before it is susceptible to these losses. Since this is a microbial process the rate at which this happens depends on many factors, including soil temperature, and carbon to nitrogen ratio. This organic fraction can take years before it becomes fully available to the crop (Beauchamp, 1983). The ratio between ammoniacal and organic nitrogen is highly dependent on the manure source; therefore, nitrogen dynamics after manure application is significantly affected by the type of manure used (Reid et al., 2006). The average ammoniacal N content of Ontario manure samples was 66% for liquid hog manure, but only 12% for solid beef and 6% for solid broiler manure.

Ammonia Losses

Ammonia loss from livestock manure was studied as early as 1839 (Sprengel, 1839). Research continued, and by 1918 a study suggested that practices involving immediate incorporation of the

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manure after application would substantially reduce ammonia volatilization (Blanck, 1918). The introduction of mineral N fertilizers in the 1950's resulted in a worldwide decrease in research on nitrogen conservation from manures that lasted over three decades (Bussink and Oenema, 1998). It was not until the 1980's that nitrogen lost to the atmosphere was understood as an environmental issue and the interest of researching practices to reduce losses increased (Roelofs et al., 1985). Recent increases in the price of nitrogen fertilizer have added an economic dimension to this interest in conserving manure nitrogen.

The application of livestock manure on arable land can result in anywhere from no loss to a complete loss of the ammoniacal nitrogen applied (Huijsmas et al., 2003). This large range of emissions is due to the multiple factors that can affect the quantity lost including climatic conditions (temperature and precipitation), and application method. This study was intended to assess the effect manure application method and timing has on ammonia emissions, and on the subsequent availability of manure nitrogen to succeeding crops.

Methodology

The experiment was conducted over two growing seasons. The first year site was located at the Elora Research Station, University of Guelph, Elora, Ontario. The location of the second year site was at a cooperators field, 4 km northeast of the Elora Research Station. Both fields are classified as London Loam (Grey-Brown Luvisol)(Hoffman and Matthews, 1963). The sites were conventionally tilled and previously cropped to barley (*Hordeum vulgare L.*). Soil samples, ammonia emission testing, plant analysis and yield measurements were obtained and evaluated in each year of the study.

Liquid swine manure for both years was sourced from a commercial swine finishing operation near the experimental sites. This manure was stored in an outside tank, and was agitated for 45 minutes prior to being loaded on a transfer tank. There were three different application timings, and 8 different application methods, as shown in Table 1.

Table 1: Timing and application method treatments

Application Timing	Application Method
1. Summer (September 24th, 2004, September 1st, 2005)	1. Aerator (strips in front of Phillips aerator teeth)
	2. Deep Injection (30-35 cm deep with DMI injectors)
2. Fall (November 17th, 2004 and November 18th, 2005)	3. Shallow Injection (18-25 cm deep, vibrashank teeth)
	4. Surface Applied, no incorporation
3. Spring (May 18th, 2005 and April 28th, 2006)	5. Surface Applied, immediate incorporation
	6. Surface Applied, incorporation 1 day after application
	7. Surface Applied, incorporation 3 days after application
	8. Surface Applied, incorporation 5 days after application

Manure was applied to provide a target rate of 150 kg of total N per hectare. Manure properties and actual application rates are shown in Table 2. In addition, separate plots received sidedress rates of UAN solution from 0 to 250 kg N ha^{-1}, in 50 kg increments, as well as a deep injected sidedress manure treatment. All plots received broadcast applications of 200 kg ha^{-1} of P_2O_5 as triple super phosphate, and 200 kg ha^{-1} of K_2O as muriate of potash, which were high enough rates to bring P and K up to non-limiting levels. Soil pH and magnesium were already at non-limiting levels.

Table 2: Properties of manure applied to Elora plots in year 1.

Application Time	Dry Matter (%)	Total N (%)	NH_4-N (%)	Total P (%)	Total K (%)	Applied (kg N ha^{-1})
Summer	2.51	0.38	0.27	0.07	0.23	140
Fall	4.14	0.39	0.28	0.12	0.20	148
Spring	4.23	0.41	0.23	0.14	0.21	155
Sidedress	4.50	0.48	0.30	0.15	0.25	178

All the plots were conventionally tilled in both years of the study, and the entire site was planted to Pioneer 39K37 at a planting density of 80,000 seeds per hectare with 75 cm row spacing. No planter fertilizer was used at either site. Weed control at both sites was with a pre-emerge application of Callisto (mesotrione) and Primextra (s-metolachlor + benoxacor + atrazine).

Measuring ammonia emissions

Conventional methods of measuring ammonia emissions are either unsuited for small plot research, because they require a large fetch area, or involve a chamber that only measures a small part of the plot area and may change the conditions affecting ammonia loss inside the chamber relative to the rest of the plot. Many of these methods also involve equipment that is expensive or involves a large amount of time for laboratory analysis.

A possible alternative is to use a Gastec passive dosimeter tube (Gastec Corporation, 6431 Fakaya Ayase – City 252, Japan). They were developed to monitor ammonia concentrations in the workplace, and are relatively low in cost and labour. The ammonia, which passively enters the tube, reacts with sulphuric acid to create ammonium sulphate. The reaction results in a colour change, and therefore eliminates the need for laboratory analysis.

A calibration curve was developed that relates passive dosimeter tube readings, which are measured in ppm, into kg of N ha^{-1} volatilized. This was accomplished by placing the passive dosimeter tubes 15 cm above an alkaline solution (pH = 10.2) on a stir plate to which different rates of ammonium chloride were added. Daily readings of the passive dosimeter tubes were recorded until emissions ceased. The calibration curve derived from this experiment had an R^2 of 0.9056, and was described by the following equation:

$$\text{Kg N ha}^{-1} = 0.2809 * (\text{cumulative passive dosimeter tube reading})$$

where the passive dosimeter tube reading is in ppm.

A second experiment in the field compared the readings from the passive dosimeter tubes, 15 cm above the soil surface, inside a chamber with a perforated plastic cover to adjacent tubes outside of the chambers. Liquid swine manure had been surface applied to barley stubble at the rate of

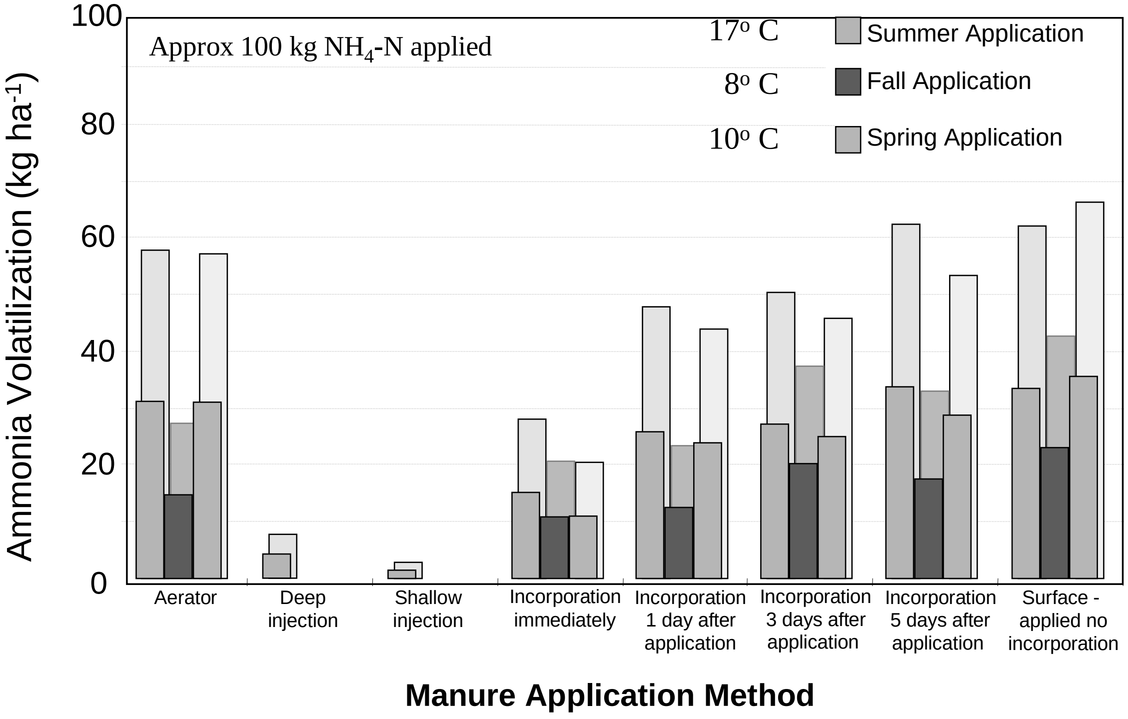
150 kg of N ha^{-1}. Results indicated that the measured ammonia values are greater with the chamber relative to the non-chamber treatment, with a mean difference between the two methods of 59.7%. This difference may be attributed to the perforated plastic lid, which could have limited the release of ammonia to the atmosphere leading to increased concentrations within the chamber. Conversely, the method without the chamber would have permitted eddies to dilute the ammonia concentration in the air thus leading to lower than actual values. Therefore, the actual volatilization value most likely lies between the chamber and non-chamber measurements. There was also greater variability in the values when the chamber was used, most likely because the small surface area covered by the chamber increased the influence of spatial variability in manure application. It is important to note that even though the chamber increases the variability, that chamber allows for small plot reading to occur while preventing contamination from neighbouring plot emissions. Further studies should investigate the effect different chamber dimensions and different lid materials have, as this may reduce the variability observed by this measurement method.

Results and Discussion

Ammonia Loss

Ammonia emissions from the first year site at the Elora Research Station are shown in Figure 1.

Figure 1. Total Ammonia Emissions from the ERS Site



* Solid colours represent lower mean limit and faded colours represent upper mean limit

The solid bars in front indicate the losses measured outside the chamber, while the shaded bars behind them indicate the losses measured within the chambers. As noted earlier, the actual loss will be between the two figures, and most likely nearer the top of the range. The ammonia losses were lower for the fall application time than for the summer or spring applications, most likely due to the lower temperatures at that time. Among the application methods, both of the injection systems showed low to negligible ammonia losses. The manure incorporated immediately after application had lower ammonia losses than any surface application with delayed incorporation, and than the aerator treatment.

The ammonia emission data for the second year of the study (not shown) followed a similar pattern, but with much lower total ammonia losses. This can be attributed to lower air temperatures following application (particularly for the fall and spring applications), and precipitation soon after application that carried some of the manure N into the soil where it was protected from volatile loss.

Figure 2. Impact of air temperature on ammonia loss at ERS site.

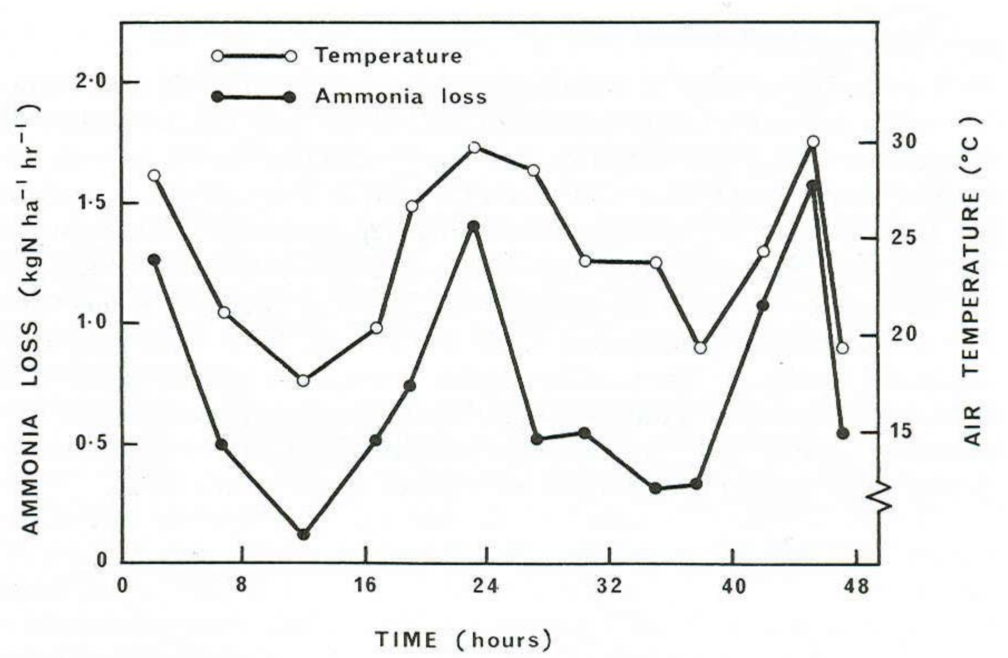


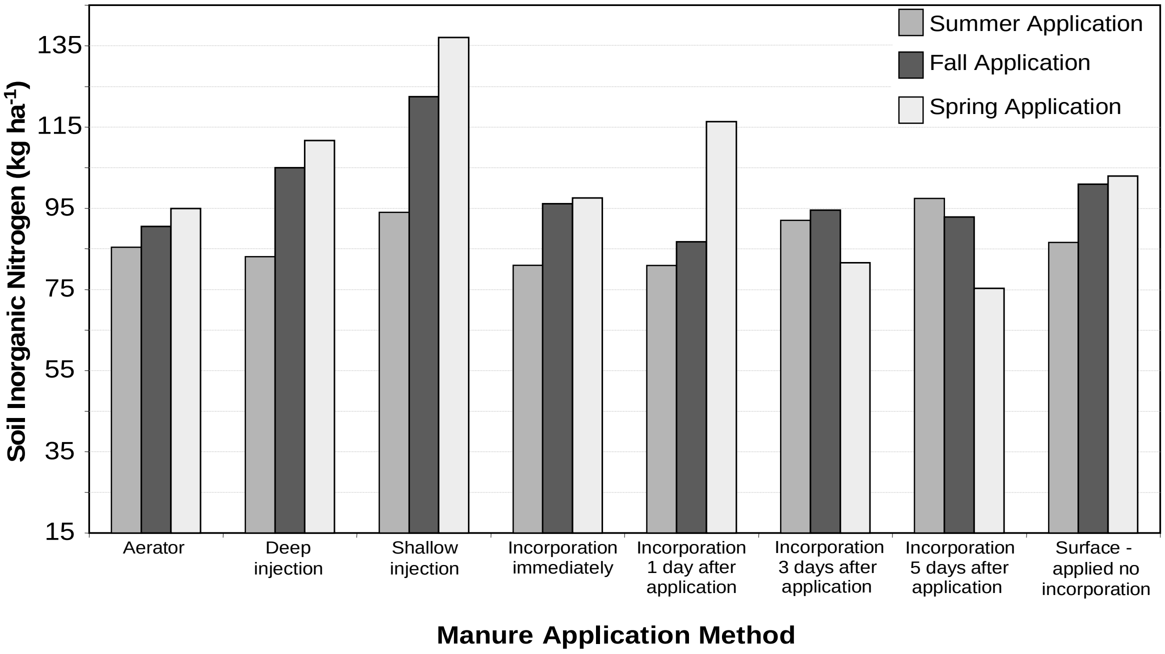
Figure 2 clearly shows the impact of air temperature on the rate of ammonia loss from the soil surface.

Soil Nitrogen

The impact of application timing and method on soil mineral N content is shown in Figure 3. In general, the highest mineral N contents resulted from the spring manure application timing, with the exception of the three and five day incorporation treatments. The differences between treatments were much more evident with the spring application timing than with the summer or fall timings. It is likely that losses due to immobilization, denitrification and leaching are a greater factor in N availability as the length of time to crop uptake increases. The highest soil mineral N contents from the spring application were from the injected treatments, which is consistent with the smaller ammonia losses for these treatments.

Figure 3. 2005 Spring Soil Inorganic Nitrogen Content

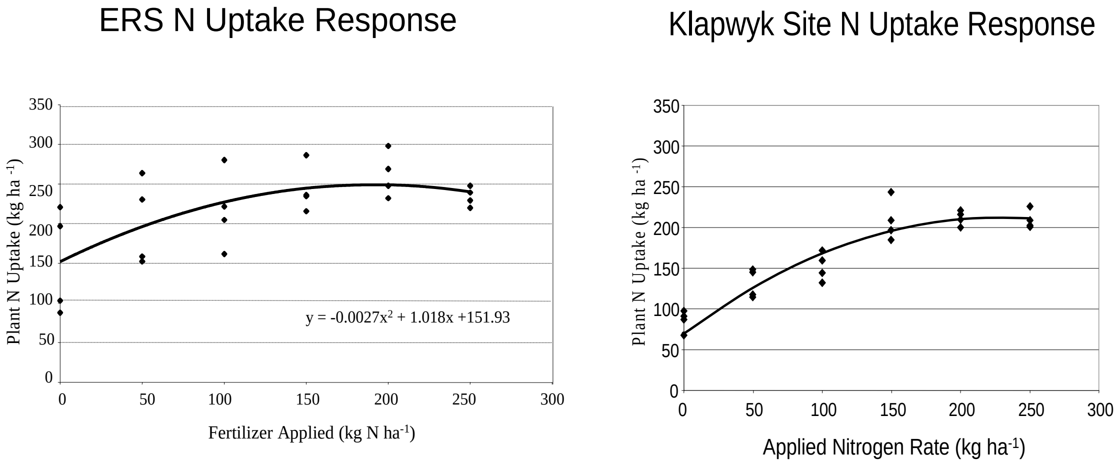
Spring = (May 24th – June 28th)



Nitrogen Uptake and Nutrient Use Efficiency

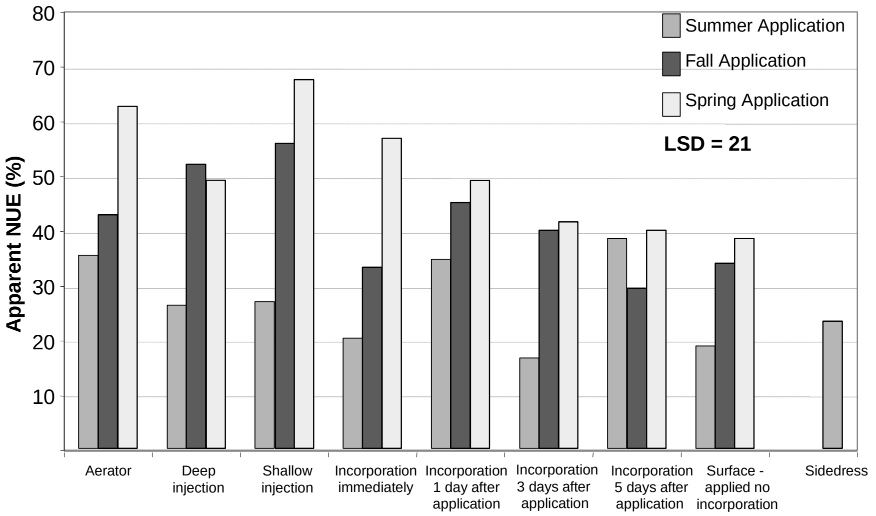
Nitrogen uptake curves were derived from the plots fertilized with sidedress UAN. As shown in Figure 4, these showed a quadratic relationship to applied N.

Figure 4. N uptake response in Years 1 and 2



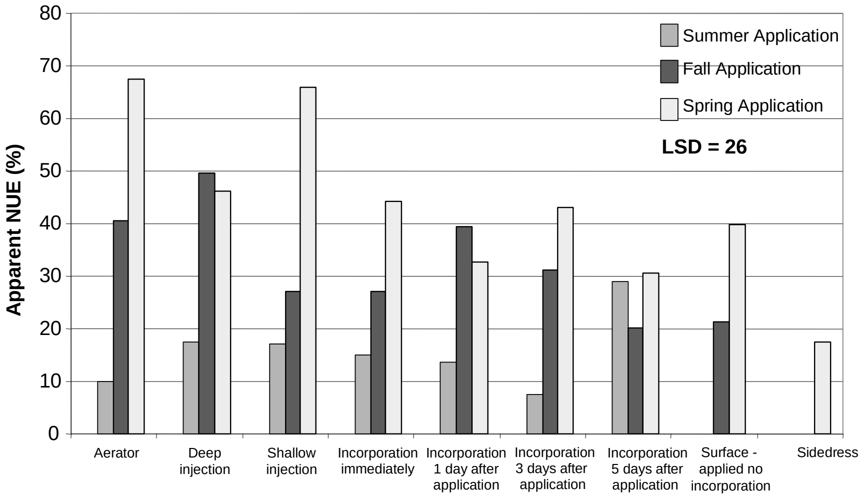
This data was compared to the total nitrogen uptake measured in the manured plots, and an apparent Nutrient Use Efficiency was calculated for each treatment, as shown in Figure 5 (Year 1 at the Elora Research Station) and Figure 6 (Year 2 at the cooperators farm).

Figure 5. ERS Apparent NUE



The apparent NUE was greatest for the spring applied manure, which is consistent with the effect of manure application timing on soil mineral N. It is important to recognize that this particular manure had roughly two-thirds of the total N in the ammonium form, which would be immediately available for crop uptake. The same pattern may not hold for other manure types, particularly for solid cattle manures with a very low proportion of ammoniacal N. The low apparent NUE for the sidedress application can be attributed to the relatively high rate of N applied (much above crop requirements), and the root pruning that may have occurred from an aggressive sidedress unit.

Figure 6. Klapwyk Site Apparent NUE



Similar to the impact on soil mineral N contents, the effect of treatment on plant N uptake and apparent NUE was greater as the timing of manure application got closer to the time of plant uptake. It appears that, in this study, the ammonium N that was retained from the summer application timing was lost by other pathways before crop uptake could occur. The injection methods generally had higher apparent NUE than any of the surface applied methods. What is surprising, particularly given how little impact the aerator had on ammonia loss, is how high the apparent NUE is for the aerator treatment in both years of the study.

Conclusions

The passive dosimeter tubes appear to be a viable, cost effective and reproducible method to monitor ammonia emissions; however, more research should be conducted to increase the accuracy of the measured emissions.

Application of manure containing a high proportion of ammoniacal N close to the growing season has great potential to increase the efficiency of nitrogen use. Injection of liquid manure can greatly reduce or eliminate the loss of ammonia to the air, which can increase the availability of manure N to the following crop. Broadcast manure should be incorporated as soon after application as possible. Application methods, and the retention of ammoniacal N in the soil, have little impact on N uptake by the succeeding crop when there is a long time period between manure application and the growing season. The ammonium N that is retained in a fall application only increases the amount of N that can be lost through leaching or denitrification.

Continuing research is required to validate the amount of ammonia loss from different manure types and on different soils so that prediction of available N from manure can be improved.

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