# IMPACT OF AMMONIA REDUCTION MANAGEMENT PRACTICES IN LAND APPLIED MANURE ON NITROGEN LOSSES and NITROGEN USE EFFICIENCY

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## ABSTRACT

Dairy manure is a valuable nitrogen (N) source in crop production, but N losses through volatilization and leaching diminish its nutrient value and pose environmental risks. Proper manure management practices can enhance nitrogen use efficiency (NUE) and mitigate these environmental concerns. This ongoing two-year field study evaluates different manure application methods and assesses their tradeoffs regarding N leaching and NUE. The study involves six experimental treatments, each applying 94 $m^3$ $ha^{-1}$ of liquid dairy manure through different methods: injection, incorporation, surface broadcast, and two treatments with urease inhibitor-one injected and one surface broadcast. Additionally, there are control plots with no manure application. Ammonia emissions are measured through a closed stainless chamber using FTIR technology and daily fluxes are calculated while cumulative N leached during the growing season is determined using resin cartridges. Preliminary results suggests that ammonia emissions tend to be lower with manure injection especially when the manure is treated with urease inhibitor compared to when manure is surface applied. In contrast, the results show that manure injection and incorporation resulted in the greatest significant $NO_3^-$-N leaching with averages of 104 kg $ha^{-1}$ and 108 kg $ha^{-1}$ respectively, in comparison to surface manure application (79 kg $ha^{-1}$). These findings highlight how the implementation of manure application strategies to mitigate $NH_3$ emissions influences other N transformations, dynamics and loss pathways which is critical towards making informed agronomic decisions that optimize crop productivity while ensuring environmental conservation

## INTRODUCTION

Dairy manure is a major plant nutrient source, especially nitrogen (N) in crop production, most notably in the agricultural regions of the Midwest US. Dairy cows can excrete between 50-130 kg of N annually through manure and urine (Powell et al., 2011; Nennich et al. 2006). The excreted N contains different proportions of both the organic and inorganic N fractions. Inorganic N is readily available for plant and microbial absorption and contains larger amounts of ammonium ($NH_4^+$-N) and ammonia ($NH_3$) (Aguirre-Villegas et al 2017). The organic N fraction undergoes microbial mineralization under conducive environmental conditions converting it into inorganic forms that can readily be utilized by plants (Cusick et al., 2006). Urinary N is primarily present as urea and can rapidly hydrolyze in the presence and activity of urease enzyme produced by microbes often present in the manure or even in the soil (Ketterings et al., 2005; Wyer et al., 2022; Cordero et al., 2019). This degradation process results in production of $NH_3$ and carbon dioxide ($CO_2$) emissions. The $NH_3$ in aqueous solution is present as both volatile $NH_3$ and nonvolatile $NH_4^+$-N (Moraes et al., 2017).

Over the past few decades, there has been a discernible rise in atmospheric $NH_3$ concentrations. In the United States, between 2008 to 2018, atmospheric $NH_3$ concentrations have increased by more than 40% and this has been attributed to both natural and anthropogenic sources such as agricultural production (Toro et al., 2024). With increasing demand for animal products, livestock production is seen as a primary driver of the rising $NH_3$ emissions. It accounts for approximately 60% of the national emissions while the usage of synthetic fertilizers contributes an additional 20% (Schultz et al., 2019). $NH_3$ and nitrous oxide ($N_2O$) are the major gaseous N losses from manure that are of key concern (Rotz 2004; Aguirre-Villegas et al., 2017). The loss of N from manure not only diminishes its fertilizer value affecting crop yields, but also poses a potential threat across various ecosystems in the environment.

Research indicates that N losses as emissions are typically higher during land manure applications, often falling between 30% to 53% (Aguirre-Villegas et al., 2017; Powell et al., 2011). Different manure management practices may minimize $NH_3$ losses to the atmosphere but may increase the risk of nitrate leaching that still poses a risk of environmental degradation. It becomes crucial to conduct research that fully addresses these tradeoffs to optimize manure nutrients to enhance nitrogen use efficiency and promote crop productivity while balancing environmental impacts.

## MATERIALS AND METHODS

### Experimental Design

Two years field experiments were conducted at the University of Wisconsin-Madison, Arlington Agricultural Research Station located in Columbia County, Wisconsin from 2024 and 2025. The predominant soil classification at the station is a Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudolls). The experiemental set-up was a randomized complete block design comprising of six treatments and four replications; manure injection at 15 cm depth (INJ), manure incorporation in less than 1-hour of application (INC), manure with urease inhibitor and then injected at 15 cm (IHB_inj), manure with urease inhibitor and then surface applied (IHB_s), manure surface broadcast (SURF), and plots with no manure application as the control (NoM). Each experiemental plot measured 9 m wide by 76 m long.

Manure was sourced from the University of Wisconsin-Madison Emmons Blaine Dairy Cattle farm located at the Research Station. Manure was uniformly applied across the plots at a target rate of 94 $m^3$/ha. Surface manure was applied using a splash plate on a raised Jamesway coulter injector. For incorporation, manure was surface-applied and immediately mixed to 15 cm with a chisel plow. Injection treatments used a Jamesway coulter injector with five units mounted on a toolbar, placing manure at 15 cm depth. Following manure application, corn silage was planted.

### Measurement of Nitrogen Leaching and Ammonia Volatilization

Nitrogen leaching was determined cumulatively at a depth of 90 cm using ion exchange resin cartridges also referred to as Self -Integrating Accumulators (SIA) developed by the German company TerrAquat (Bischoff, 2007). Three resin catridges were buried in the soil in each experimental plot prior to manure application and these were retrieved after 6-months. The resin catridges were divided intro three layers from the top *i.e* upper layer (5 cm), mid layer (1 cm), and lower layer (4 cm). The lowest layer will be discarded as it acts as a buffer for any upward solute movement due to diffusion and capillary rise (Bischoff et al., 2007). The first layer was used to determine the accumulated N leaching flux while the second layer was utilized as an internal blank whose results were subtracted from the first layer (Bischoff et al, 2007).

The 6-month inorganic N cumulative leaching flux will be calculated as kg of N per hectare using the equation as shown below (Wey et al, 2021).

$$\text{Nitrogen flux } (kg\ N\ ha^{-1}) = \frac{C\ x\ V\ x\ M_{layer}}{M_{subsample} * A}\ x\ 10^{-2}$$

C: measured N concentration (mg N $L^{-1}$)

V: volume of the extracting solution (0.04 L)

$M_{layer}$: weight of the resin-sand mixture layer (g)

$M_{subsample}$: weight of resin-sand mixture extracted (10 g)

A: area of the resin cartridge (0.0079 $m^2$)

Ammonia emissions were measured using an FTIR follwoung a chamber based methodology outlined in the USDA-ARS GRACEnet protocol (Parkin and Venterea, 2010). Measurements were taken immediately after manure application and in the subsequent hours; 0, 3, 24, 28, 48, 52 and 96 hours after manure application.

**Soil Sampling and analysis**

Soil samples were collected at depths of 0-15, 15-30, and 30-60 cm using a 2-cm soil probe from each experimental plot prior to the start of the experiment and monthly following the application of dairy manure and planting of corn silage. These soil samples were extracted using 2M KCl and were analyzed for inorganic N concentration.

## PRELIMINARY RESULTS AND DISCUSSION

**Cumulative ammonia emissions**

Ammonia volatilization was greatest in the surface manure application reaching a cumulative average of 8.5 kg of ammonia within the 96 hours of manure application compairing all experimental treatments (Figure 1). The addition of urease inhibitor during manure surface application led to almost a 50% decrease in the ammnonia volatilization compared to surface application without urease ihnihibitor. In general, manure injection led to the lowest ammonia emissions in comparisons with all the treatments that received manure although there was no significant differences of adding urease inhibitor during manure injection.

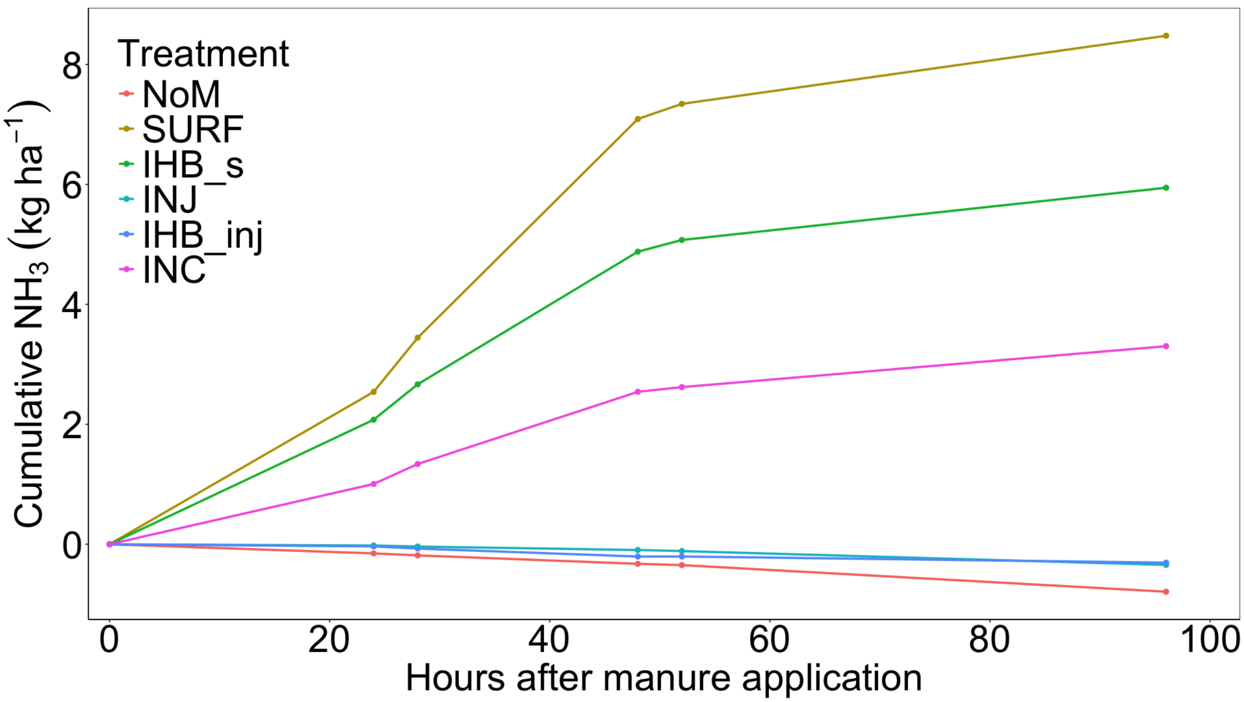


Figure 1: Mean cumulative ammonia volatilization with 96 hours of manure application

**Potential Nitrogen Leached**

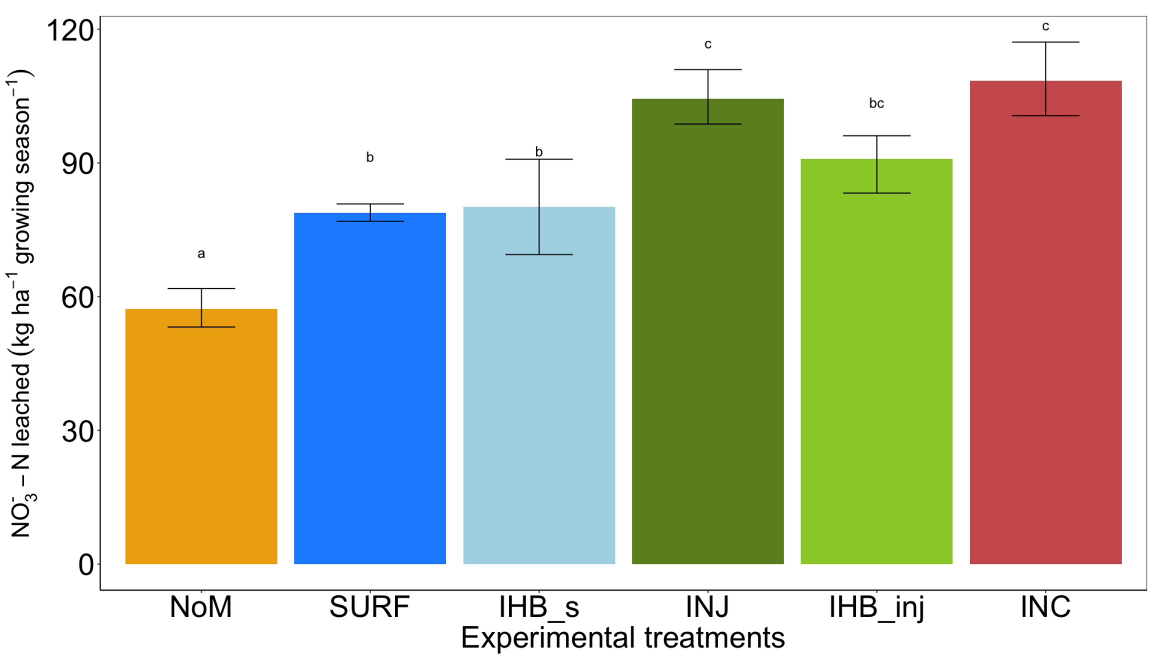


Figure 2: Cumulative N leached during 6-months following manure application

Surface manure applications with or without urease inhbitor resulted into significant decrease in nitrate leaching compared to manure incorporation and injection with or without the urease inhibitor (Figure 2). On average manure incorporation led to the greatest nitrate leaching of 108.4 kg ha$^{-1}$ although this was not statistically different from manure injection with or without urease inhibitor. These findings suggest that treatments with greater ammonia volatilization may result in lower nitrate leaching possibly because of a reduced soil N pool, whereas those that minimize ammonia losses may be associated with greater N leaching.

**Corn silage yield**

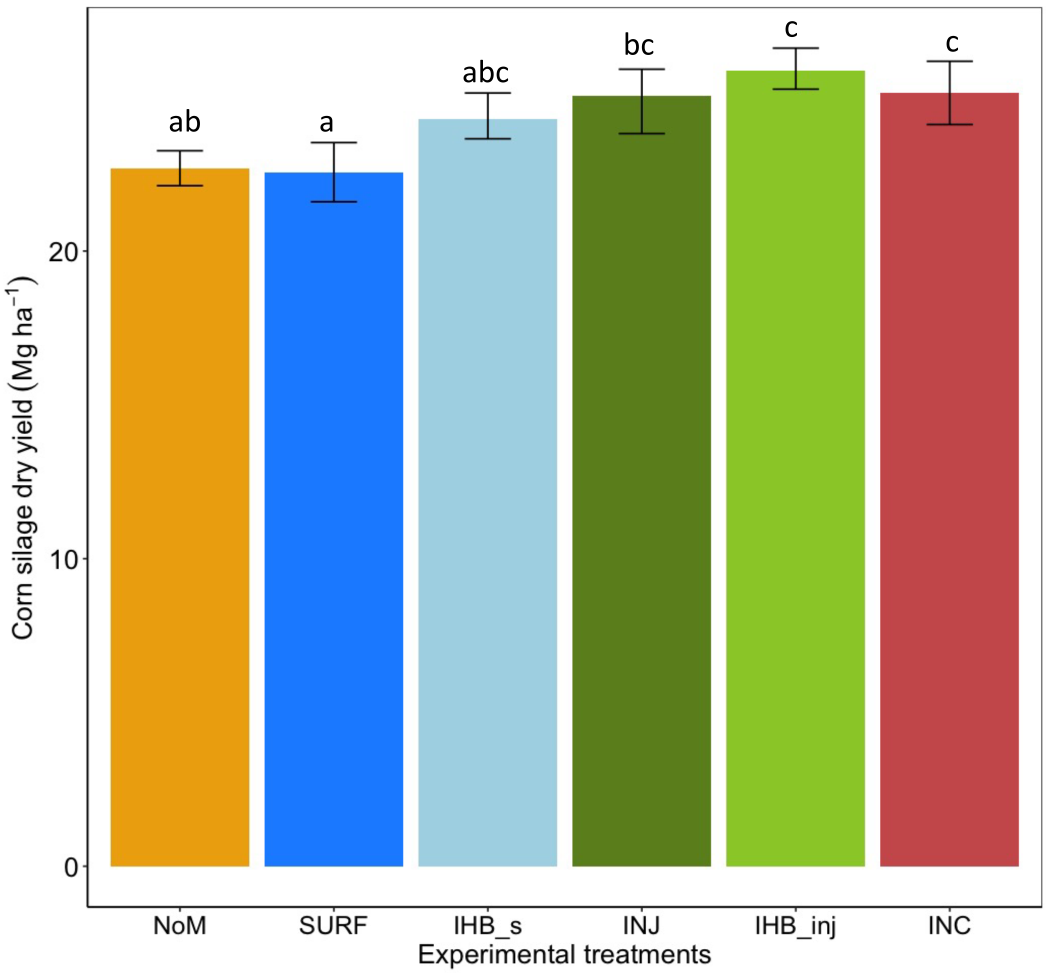


Figure 3: Average corn silage dry yield across the experiemental plots

The greatest corn silage yield (25.9 Mg Ha$^{-1}$) was obtained under the manure inejction with urease inhibitor although this was not statistically different from manure injection without inhibitor and manure incopration (Figure 3). Although both the manure injection and inhibitor had resulted into the greatest nitrate leaching, they still maintained a higher yield compared to the manure surface application treatment.

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