

# In situ determination of NO and N<sub>2</sub>O from cow-urine applied to a pasture soil under summer conditions

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## Abstract

A field experiment was performed during summer using bovine urine at 0, 500 and 1000 kg N/ha to study the effect of urine-N rate on NO<sub>x</sub> (NO + NO<sub>2</sub>) and N<sub>2</sub>O emissions. A Templeton silt loam soil (pH 5.2) was used (Typic Immature Pallic, New Zealand soil classification). The experimental design was a randomized complete block. The main objective of the study was to obtain NO<sub>x</sub> data from pasture under bovine urine patches for New Zealand conditions. The experiment was run for 3 months with measurements of some pH, moisture, temperature and inorganic-N and gas (NO<sub>x</sub> and N<sub>2</sub>O) fluxes, taken over this time. It was found that the emission factors after 3 months for NO-N in the summer were 0.15 and 0.20% of the urine-N applied for the 500 and 1000 kg N/ha rates respectively while the respective N<sub>2</sub>O-N fluxes were 0.14 and 0.16%. Multiple regression analyses were used to predict the best regression model for NO-N flux at 500 and 1000 kg N/ha treatment. The best regression model was obtained at 1000 kg N/ha using the soil moisture and the rate of NH<sub>4</sub><sup>+</sup>-N depletion as significant variables. In contrast, the best regression model for N<sub>2</sub>O-N fluxes was obtained at 500 kg N/ha treatment using surface soil pH, logNO-N, N<sub>2</sub>O-N:NO-N ratio and soil moisture as significant variables.

## Key Words

Nitric oxide (NO), nitrous oxide (N<sub>2</sub>O), bovine urine, season, multiple regressions.

## Introduction

Anthropogenic endeavours have led to changes in the global nitrogen cycle. As a consequence gaseous emission of nitric oxide (NO), nitrogen dioxide (NO<sub>2</sub>) (hereafter referred to as NO<sub>x</sub>), and nitrous oxide (N<sub>2</sub>O) have increased. Scientific interest in these gas emissions from agricultural soils has increased due to their adverse environmental effects, both globally and locally. Nitrous oxide is a gas that contributes to greenhouse warming and also a gas that can undergo oxidation in the stratosphere to form NO<sub>x</sub> which in turn can participate in photochemical processes. These processes have adverse effects on stratospheric ozone (O<sub>3</sub>) concentrations. The emission of NO<sub>x</sub> from soils is of significance due to its potential effect on tropospheric O<sub>3</sub> formation. Increasing levels of NO<sub>x</sub> can adversely affect air quality, which has implications for the health of humans, plants and animals. The economic loss of N fertilizer as NO<sub>x</sub> gas may represent 1-10% of the N applied (Veldkamp 1997). These NO<sub>x</sub> gases are also responsible for the atmospheric acidity and nitrogen to downwind ecosystems. In soils, the microbial processes responsible for NO<sub>x</sub> and N<sub>2</sub>O gas emissions are known to be nitrification and denitrification, while abiotic production also occurs to a lesser and unknown extent (Venterea and Rolston 2000). The majority of studies on NO<sub>x</sub> gas emissions have focused on fertilizer applications with very few studies (ca. 5) examining the potential for NO<sub>x</sub> emissions from urine patches in grazed pastures. Studies that have examined NO<sub>x</sub> gas emissions from urine have used unrealistically low rates of N, for New Zealand systems, or concentrated on soils with high moisture contents where NO<sub>x</sub> gas emissions might be expected to be low. Of these, none have examined urine-N rates and/or seasonal effects on urine-N NO<sub>x</sub> fluxes. There are no in situ studies in New Zealand temperate pastures that have examined the potential for NO<sub>x</sub> emissions from bovine urine.

The main objectives of this experiment were: To obtain the NO<sub>x</sub> emission data from pastures under two rates of bovine urine, under New Zealand summer conditions; To examine the relationships between NO and the N<sub>2</sub>O fluxes and between NO fluxes and the measured soil variables from urine treated soils.

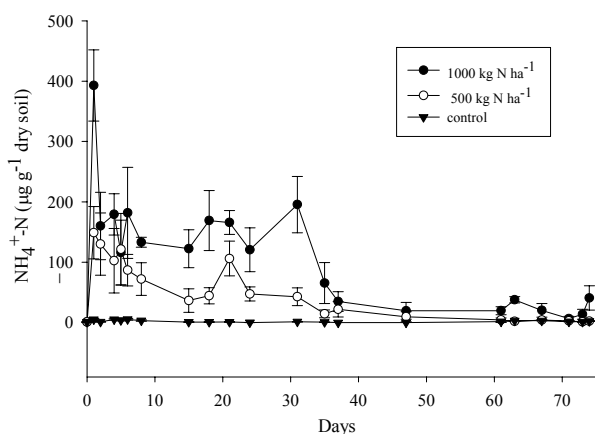
## Methods

A field experiment was conducted in which urine, collected from the Lincoln University dairy farm, with urinary-N concentration of 10.5 g N/L was applied to experimental plots. Experimental plots were either gas chamber plots (0.029 m<sup>2</sup>) or soil sampling plots (0.16 m<sup>2</sup>). The experimental design consisted of three

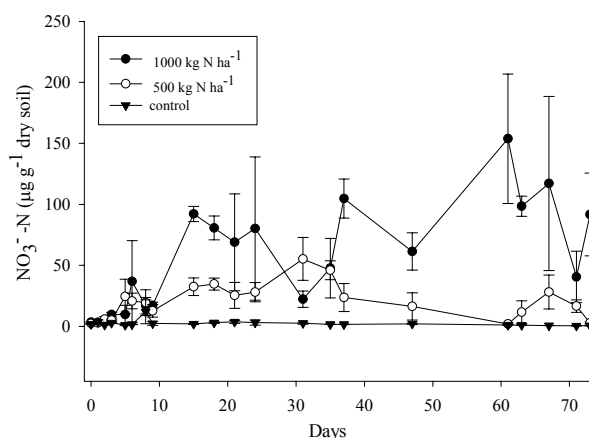
treatments (500 kg N/ha, 1000 kg N/ha and a control) replicated 3 times. Gas sampling for  $\text{NO}_x$  and  $\text{N}_2\text{O}$  was conducted periodically for nearly 3 months using chemiluminescence and gas chromatography methods respectively. The soil  $\text{NH}_4^+\text{-N}$  and  $\text{NO}_3^-\text{-N}$  concentrations were measured concurrently with the gas sampling events over a depth of 0 – 7.5 cm but the soil  $\text{NO}_2^-\text{-N}$  concentration was determined for 3 soil depths of 0-2.5, 2.5-5.0 and 5.0-7.5 cm.

## Results

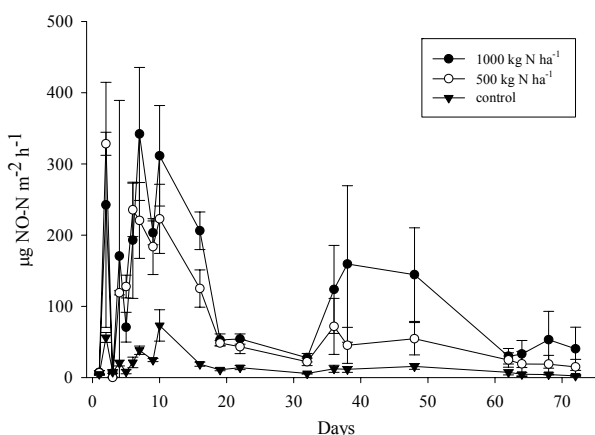
Results showed that urine-N rate significantly affected the inorganic-N concentrations. Maximum  $\text{NH}_4^+\text{-N}$  and  $\text{NO}_3^-\text{-N}$  concentrations were recorded at the highest urine-N rate (1000 kg N/ha) followed by the subsequent urine-N rate (500 kg N/ha) (Figures 1 and 2). The soil  $\text{NO}_2^-\text{-N}$  concentrations did not show any significant differences between depths due to treatments. When data from the 3 soil depths were pooled the soil  $\text{NO}_2^-\text{-N}$  concentrations were negatively correlated with soil pH ( $r = -0.22$ ,  $P < 0.01$ ). The  $\text{NH}_4^+$  depletion rate was 1.8 fold higher in the 1000 kg N/ha than the 500 kg N/ha treatment. No significant differences in terms of surface soil pH were observed in urine-N treated soils. However, the urine-N treated soils had higher soil pH values than the control treatment. Fluxes of  $\text{NO-N}$  varied over time and with urine-N rate (Figure 3). Maximum  $\text{NO-N}$  fluxes were observed at the high urine-N rate of 1000 kg N/ha treatment. Cumulative  $\text{NO-N}$  losses for the 500 and 1000 kg N/ha treatments were 0.15 and 0.20% of the applied urine-N respectively.  $\text{NO-N}$  fluxes were positively correlated with surface soil pH,  $\text{NO}_3^-\text{-N}$ ,  $\text{NH}_4^+\text{-N}$ , net ammonium depletion rates and net nitrate accumulation rates. Urine-N rate also significantly affected the  $\text{N}_2\text{O-N}$  fluxes over time (Figure 4). Maximum cumulative  $\text{N}_2\text{O-N}$  fluxes (0.16%) were recorded at 1000 kg N/ha followed by the 500 kg N/ha treatment (0.14%). When the  $\text{N}_2\text{O-N}$  flux data from all sampling dates were pooled  $\text{N}_2\text{O-N}$  fluxes were significantly correlated with surface soil pH and  $\text{NH}_4^+\text{-N}$  concentration. Soil temperature and WFPS during the experimental period ranged from 14-30°C and 17.5-35.6% respectively.



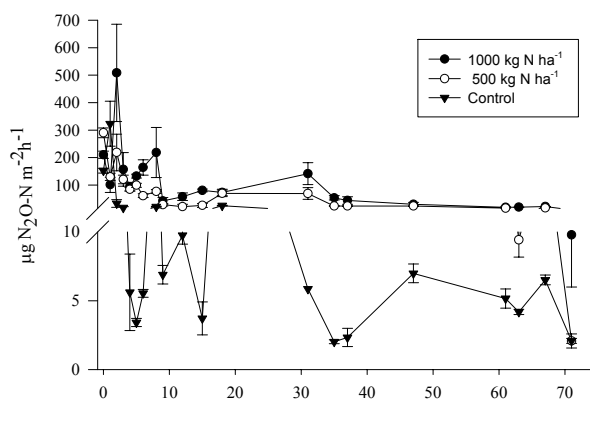
**Figure 1** Soil  $\text{NH}_4^+\text{-N}$  concentrations over time ( $n = 3$ , error bars are  $\pm$  s.e.m.).



**Figure 2.** Soil  $\text{NO}_3^-\text{-N}$  concentrations over time ( $n = 3$ , error bars are  $\pm$  s.e.m.).



**Figure 3.**  $\text{NO-N}$  fluxes over time following urine treatment application ( $n = 3$ , error bars  $\pm$  s.e.m.).



**Figure 4.** Soil  $\text{N}_2\text{O-N}$  fluxes over time following urine treatment application ( $n = 3$ , error bars  $\pm$  s.e.m.).

## Conclusion

The cumulative NO-N flux from the 500 kg N/ha treatment was very comparable with the maximum flux attained in the other field studies where bovine urine has been applied under summer conditions. No other in situ studies have been performed using 1000 kg urine-N/ha and the current study represents the first at this rate. No previous in situ urine studies have attempted to examine the relationships between the net NO-N flux, the soil NO<sub>2</sub><sup>-</sup>-N pool and soil pH. Despite the presence of NO<sub>2</sub><sup>-</sup>-N in the soil, no relationship was found between theoretical HNO<sub>2</sub> concentrations and the NO-N flux. Thus net NO-N emissions are believed to have been predominately from microbial sources. Further evidence of biological production of NO was seen with the strong relationship between logN<sub>2</sub>O-N and logNO-N emissions. The gaseous N losses observed in the present study were not significant in agronomic terms, but assist in assessing the contribution of such losses to the atmospheric budget for NO<sub>x</sub>. Further studies are required to elucidate in-situ production mechanisms of NO and the relationship to N<sub>2</sub>O in the urine patch.

## References

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