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EFFECT OF INCREASING COW URINE PATCH AREA ON AMMONIA EMISSIONS IN A PASTURE SOIL

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Abstract

Livestock urine patches are a major source of gaseous and leaching losses of nitrogen (N) to the wider environment. This is due to the high deposition rate of N (typically 400-800 kg N/ha) returned in urine on relatively small areas of pasture during grazing. A typical urination is ~2.5 L deposited on 0.25 m^2 pasture soil area. Increasing the spread of dairy cow urine patches has been shown to reduce the movement of mineral N below the rootzone, thus, reducing N leaching risk. However, there has been limited research on the effect of urine patch size on ammonia (NH_3) emissions. Therefore, the objective of this study was to quantify the effect of increasing urine patch area (i.e. decreasing urine application depth) on NH_3 emissions from cow urine applied to a pasture soil during autumn.

A field experiment was conducted on a pasture site near Palmerston North in the early autumn of 2019. The soil at the site is a Manawatu silt loam soil (Weathered Fluvial Recent soil or Dystric Fluventic Eutroichrept). Three urine application depth treatments of 10 mm, 5 mm and 2.5 mm were used, representing the depths that would result from applying 2.5 L of urine to three different patch areas: 0.25 m^2 (i.e. typical patch size), 0.5 m^2 and 1 m^2, respectively. Each treatment was replicated five times. The concentration of total N in applied urine was 4.53 g N L^{-1}. Ammonia measurements were conducted over a period of 20 days using the Dynamic Chamber method. Soil samples were also collected and analysed for soil nitrate, ammonium and pH.

Average cumulative NH_3 emissions increased with increasing urine application depth, but the relationship was not linear. When the NH_3 losses from each application depth treatment were extrapolated to the urine patch areas that they represented, then the highest losses occurred for the 1 m^2 urine patch area (2.5 mm treatment). These results showed that increasing the spread area of a specific volume of urine could increase total NH_3 emissions.

Introduction

In grazed pastures, livestock urine patches are a major source of gaseous and leaching losses of N to the wider environment from New Zealand agricultural systems (Ball and Ryden, 1984, Ledgard, 2001, Selbie et al., 2015). This has posed environmental concerns, such as acidification and eutrophication of natural ecosystems. In addition, NH_3 emissions subsequently act as an indirect source of the greenhouse gas (GHG) nitrous oxide (N_2O) (Cameron et al., 2013). It is envisaged that increasing the area of pasture covered by each urination will increase plant uptake of N, reducing the accumulation of soil nitrate (NO_3^-) and consequently the risk to the environment. Ramirez (2017) found that increasing the size of cow urine patches has the potential to reduce N leaching losses. However, there has been limited research on quantifying the effect of urine patch size on NH_3 emissions. Therefore, the objective of this study was to quantify the effect of increasing urine patch area (i.e. decreasing urine application depth) on NH_3 emissions from dairy cow urine applied to a pasture soil.

Methods

Experimental design and field trial layout

A field experiment was carried out in early autumn to determine the effect of increasing cow urine patch area on NH_3 emissions. The experiment consisted of 20 chambers that were either treated with cow urine or left untreated (control treatment). The experiment was located on a site with a Manawatu silt loam soil, a Weathered Fluvial Recent soil (NZ Classification) or Dystric Fluventic Eutroichrept (USDA Classification), which had a standard ryegrass (*Lolium perenne)* and white clover (*Trifolium repens*) mixed pasture, which included some weed species.

There were three treatments and five replicates of each treatment (Table 1). The treatments were allocated to the chambers randomly.

Table 1 Treatments for the chambers

Treatment #	Urine patch area (m^2)	Application depth (mm)	Urine N (L/patch)	Chamber area (m^2)	Volume of Urine applied (ml/chamber)	Amount of Urine N applied (mg N/chamber)
1	0.25	10	2.5	0.0177	177	802
2	0.50	5	2.5	0.0177	89	401
3	1	2.5	2.5	0.0177	44	201

Urine collection and application to chambers

Urine was collected from dairy cows during milking times at Massey University Dairy 4 Farm. The urine was refrigerated at 4˚C after collection until the start of the experiment. Before application to the chambers on 7 March, all of the urine was mixed together. The urine was applied at depths of 10 mm, 5 mm and 2.5 mm, representing the depths that would result from the deposition of 2.5 L of urine to patch areas of 0.25 m^2 (i.e. typical urine patch size), 0.5 m^2 and 1 m^2, respectively (Table 1). The concentration of total N in the applied urine was 4.53 g N/L.

Ammonia measurement

Gas sampling was conducted using the Dynamic chamber method similar to that described by Kissel et al. (1977). It comprised of a volatilisation chamber, an acid trap for trapping ammonia and a manifold that consisted of 6 air valves regulating the air flow rate inside the chambers (Figure 1). The PVC pipe chambers, with a transparent top (clear Perspex), have a diameter of 0.15 m and a height of 0.04 m. The chambers were pushed into the soil to a depth of approximately 0.01 m, leaving a headspace volume of 0.5 m^3. Each chamber has a vent on its side that connect, via tubing, to an acid trap (250 ml, 0.025 M H_2SO_4), which in turn is connected to a vacuum cleaner via a manifold (Figure 1). The air sucked from the chambers passes through the acid trap at a constant flow rate of 6 L min^{-1} (monitored daily) (Rodriguez et al., 2019). The chambers were left in place with the vacuum running continuously for approximately 4 weeks. The acid solution was sampled and replaced every day for the first 5 days, then at intervals of between 1 and 6 days, thereafter. Ammonia volatilisation was continuously measured until the NH_3 flux reached background levels. The chambers were covered with shade cloth to avoid direct sunlight and to help, along with the continuous airflow, avoid elevating the temperature inside the chambers above ambient temperature levels (Li et al., 2014) (Figure 1).

Figure 1: Ammonia sampling site and set up of the Dynamic Chamber method

Results & discussion

For the urine patch depths; 10 mm, 5 mm and 2.5 mm, there was a peak in the NH_3-N emissions (0.11, 0.06 and 0.04 g NH_3-N/chamber, respectively) on the 8th of March (Fig 2 a) i.e. the first 24 hours after application of urine. After the peak, there was a steep decrease and then gradual decrease to background levels, approximately 2 weeks after urine application. The NH_3 concentrations decreased with decreasing urine application depth, but the decrease was not linear (Fig 2 a).

When the NH_3 losses per chambers for each application depth treatment were extrapolated to the urine patch areas that they represented, the NH_3 emissions from the 1 m^2 (2.5 mm depth treatment), 0.5 m^2 (5 mm depth treatment) and 0.25 m^2 (10 mm depth treatment) urine patch areas were 2.21, 1.70 and 1.62 g NH_3-N/patch, respectively, on the 8th of March (1 day after urine application) (Fig 2 b).

The total cumulative NH_3 emissions from the 0.25, 0.5 and 1 m^2 extrapolated urine patch areas, receiving the same volume of urine, were calculated to be an average of 2.47, 2.68 and 3.54 g NH_3-N/patch, respectively (Fig 2 c), which represented 21.8, 23.6 and 31.2% of the urine N, respectively. The NH_3 losses, calculated for each urine patch area, were significantly higher for the 1 m^2 urine patch (2.5 mm depth treatment) compared to the other two treatments (Fig 2 c), which demonstrated the influence of surface area on volatilisation, even though urine concentration in the soil was lower.

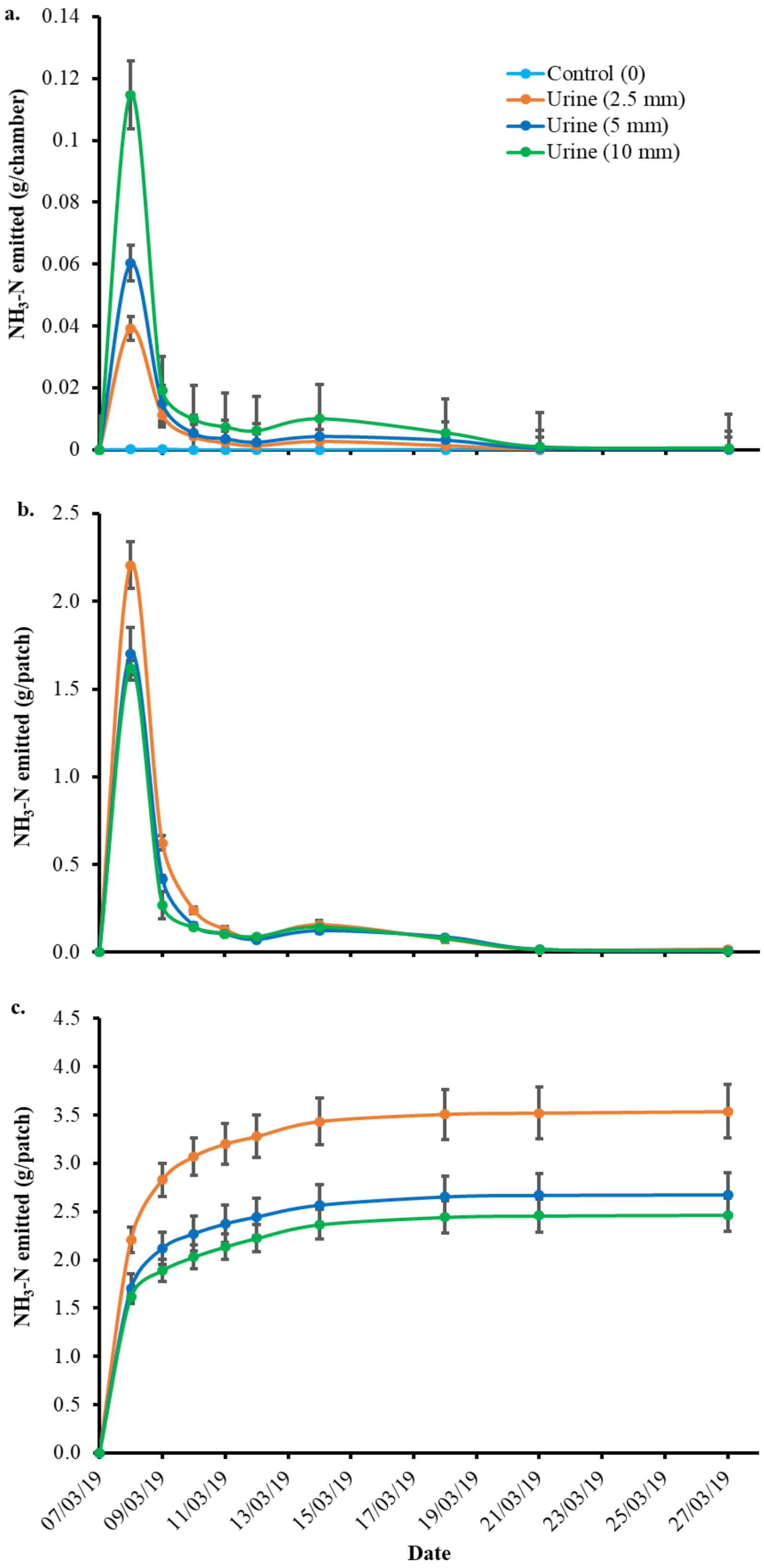

Figure 2: Ammonia losses following dairy cow urine application to pasture; a. NH_3-N emitted per chamber b. daily NH_3-N emitted per urine patch and c. cumulative NH_3-N emitted per urine patch. Error bars are standard error of the mean.

Conclusion

Increasing the spread area of a specific volume of urine has potential to increase total NH_3 emissions. While this may result in higher indirect greenhouse gas emissions, it also can further reduce the concentration of nitrate N in the soil. Lower soil nitrate concentrations during winter and early spring has the potential to reduce nitrate leaching and nitrous oxide emissions. Therefore, further research is required to assess the full impacts of the increasing urine spread area on total N losses to the wider environment.

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