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Ammonia emission from a permanent grassland on volcanic soil after the treatment with dairy slurry and urea

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HIGHLIGHTS

- Volatilization of NH_3 is the most important pathway of N loss in local grasslands.
- Total N losses ranged from c. 1.8% to 26.0% for urea applied in winter and fall.
- Total N losses ranged from c. 3.1% to 20.5% for slurry applied in winter and summer.
- The use of urease inhibitor showed a 71% reduction in N loss across all seasons.

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ABSTRACT

Ammonia (NH_3) is an air pollutant largely emitted from agricultural activities including the application of livestock manures and fertilizers to grassland. This gas has been linked with important negative impacts on natural ecosystems. In southern Chile, the use of inorganic and organic fertilizers (e.g. slurries) has increased in cattle production systems over recent years, heightening the risk of N losses to the wider environment. The objectives of this study were to evaluate on permanent grasslands on a volcanic ash soil in southern Chile: 1) the N loss due to NH_3 volatilization following surface application of dairy slurry and urea fertilizer; and 2) the effect of a urease inhibitor on NH_3 emissions from urea fertilizer application. Small plot field experiments were conducted over spring, fall, winter and summer seasons, using a system of wind tunnels to measure ammonia emissions. Ammonia losses ranged from 1.8 (winter) to 26.0% (fall) and 3.1 (winter) to 20.5% (summer) of total N applied for urea and slurry, respectively. Based on the readily available N applied (ammoniacal N for dairy slurry and urea N for urea fertilizer), losses from dairy slurry were much greater, at 16.1 and 82.0%, for winter and summer, respectively. The use of a urease inhibitor proved to be an effective option to minimize the N loss due NH_3 volatilization from urea fertilizer, with an average reduction of 71% across all seasons. The results of this and other recent studies regarding N losses suggest that ammonia volatilization is the main pathway of N loss from grassland systems in southern Chile on volcanic ash soils when urea and slurry are used as an N source. The use of good management practices, such as the inclusion of a urease inhibitor with urea fertilizer could have a beneficial impact on reducing N losses due NH_3 volatilization and the environmental and economic impact of these emissions.

1. Introduction

Agriculture is the main source of ammonia (NH_3) emissions to the atmosphere, accounting for more than 90% of the total NH_3 emissions in Europe (Erisman et al., 2008) and more than 50% of the global NH_3 emissions (Bouwman et al., 1997). In agricultural systems, NH_3 emissions derive mainly from livestock excreta and subsequent manure management and from field-applied N fertilizers (Beusen et al., 2008). Volatilized NH_3 can be the cause of important environmental impacts such as soil acidification and eutrophication with subsequent loss of biodiversity, the formation of acid fine particulates with impacts on human health, and secondary emissions of nitrous oxide, following deposition (Erisman et al., 2008; Asman et al., 1998).

Dairy production systems in southern Chile are predominantly grazing based, with mineral and organic fertilizations all year

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round. Dairy slurry is usually used as a source of nutrients in local grasslands, either alone or as a complement to inorganic fertilizers (Salazar et al., 2003). Cattle production is estimated to contribute >85% of total agricultural NH_3 emissions for this area (Martínez-Lagos et al., 2010). Nitrogen fertilization to grasslands has increased in the last decade in southern Chile, in order to achieve higher milk yields and stocking rates (Alfaro and Salazar, 2005).

Throughout the world, urea is the predominant source of inorganic N used in agriculture accounting for 50% of the total world fertilizer N consumption (Sanz-Cobena et al., 2008). In order to reduce nutrient losses, there is an interest in the development and use of stabilized N fertilizers associated with urease inhibitors. The inhibitor delays the hydrolysis of urea to ammonium nitrogen, allowing the urea to infiltrate into the soil by diffusion or convection (Trenkel, 2010) prior to significant losses through NH_3 volatilization. The application of urea fertilizer with a urease inhibitor has proven to be very effective depending on management and environmental conditions (Sommer et al., 2004).

Internationally, there have been a number of efforts aimed at achieving NH_3 emission reductions (e.g. the Gothenburg Protocol under the Convention on Long-Range Transboundary Air Pollution of the United Nations). However in Chile there is currently no legislation to control NH_3 emissions from agricultural sources and there are few published data regarding NH_3 losses specific to Chilean soils, climate and agricultural practices (e.g. Salazar et al., 2012a; Martínez-Lagos et al., 2010; Núñez et al., 2010; Casanova and Benavides, 2009).

The objectives of this study were to evaluate on permanent grassland on a volcanic ash soil in southern Chile: 1) the N loss due to NH_3 volatilization following surface application of dairy slurry and urea fertilizer; and 2) the effect of a urease inhibitor on NH_3 emissions from urea fertilizer application.

2. Material and methods

2.1. Experimental site

The experiments were carried out on permanent grasslands, with no recent history (3 years) of N fertilization or livestock grazing, located at the National Institute of Agricultural Research, INIA-Remehue (40° 31′S, 73° 03′W, altitude 65 m). A total of seven experiments were conducted between 2009 and 2012, with a different area being used for each experiment. The soil at the site is an Andosol (IUSS, 2007) of the Osorno soil series (Typic hapludands; CIREN, 2005), with a depth greater than 1 m, organic matter (OM) content of 16.6–21.4%,water pH of 5.7–6.5, and Cation Exchange Capacity (CEC) of 48.4–65.6 cmol(+)/kg. The climate is a typical Mediterranean cold weather, with a 37 year mean annual temperature of 11.3 °C (5.8–16.8 °C) and mean annual precipitation of 1252 mm. The grasslands were predominantly perennial ryegrass (*Lolium perenne* L.).

2.2. Dairy slurry vs. urea fertilizer experiments

Comparisons between emissions from dairy slurry and urea fertilizer applications were made in spring 2009, fall 2010, winter 2010 and summer 2012. Urea was used as the fertilizer N source in the experiments because it is the most commonly used mineral fertilizer among local farmers, mainly due to it lower cost (Salazar et al., 2003). The target application rate of fertilizers was equivalent to 100 kg of total N ha^{-1}, applied in one dressing. This was at the higher end of the range of typical application rates for a single dressing to grasslands for the region which may vary between 20 and 100 kg N ha^{-1} (Salazar et al., 2003, 2007).

Three replicate plots (2 × 1 m each) with grass sward height of 5 cm were established for each treatment in a randomized block design for each experiment. In the summer 2012 experiment there were only two replicates as the effect of the urease inhibitor was evaluated in the same trial and variability between replicates had proven to be low from the previous experiments. Urea fertilizer was surface applied by hand and dairy slurry was applied using watering cans fitted with a small splash plate for slurry distribution across the plot. Dairy slurry was obtained directly from the slurry storage of the dairy unit located at INIA Remehue. A slurry sample was taken 2 weeks prior to application in order to determine the application rate to use according to the slurry N content.

During application, further slurry samples were collected for analysis. Slurry dry matter (DM) content was determined by drying sub-samples of slurries at 105 °C until constant weight (Sadzawka, 1990). Total N was determined by Kjeldahl digestion (Gerhardt model Vapodest 5) according to the methodology described by AOAC (1990). Total ammoniacal N (TAN) content was analyzed by shaking 6 g of fresh dairy slurry with 100 ml of 2 M KCl for 1 h (Keeney and Nelson, 1982) followed by automated colorimetry (SKALAR, SA 4000, Breda, The Netherlands).

2.3. Urea fertilizer vs. urea with a urease inhibitor experiments

Experiments comparing emissions from applications of urea fertilizer and urea with a urease inhibitor were carried out during spring 2010, fall 2011, winter 2011 and summer 2012. The urease inhibitor N-(n-butyl) thiophosphoric acid triamide (NBPT) was used as a commercially available coated urea product (trade name AmiNtec®). Fertilizers were surface applied by hand in one dressing, at a target rate of 100 kg of total N ha^{-1}. Three replicate plots (2 × 1 m each) with grass sward height of 5 cm were set up in a randomized block design, with the exception of the summer 2012 experiment where there were only two replicates as noted above.

In all experiments, regardless of the applied N source, meteorological data (surface temperature and actual evapotranspiration) during each experimental period were recorded using the INIA-Remehue meteorological station located 300 m from the experimental site. Soil moisture content at the time of treatment application was also determined in each experiment by drying three soil samples at 105 °C until constant weight according to Sadzawka (1990).

2.4. Ammonia emission measurements

Ammonia emissions were evaluated using a system of small wind tunnels (Lockyer, 1984). Each wind tunnel comprises two parts; 1) a transparent section formed from a polycarbonate sheet (2.0 × 1.2 × 0.002 m) which is flexed and pinned to the soil along each 2 m edge to form a tunnel covering an area of 1 m^2 (0.5 × 2 m), and 2) a circular steel duct which contains a co-axial fan to draw air through the transparent section. The fan is fitted with a speed controller and the air flow rate is measured by a vane anemometer mounted in the steel duct and coupled to an air-speed indicator. Air flow through the tunnels was controlled at a constant rate of 1 m s^{-1}. The concentrations of NH_3–N in air entering and leaving the tunnels were measured by drawing air continuously from the inlet and outlet of each tunnel through absorption flasks containing orthophosphoric acid (0.002 M).

Ammonia emission measurements were conducted for 21 days following treatment application in each experiment. Absorption flasks were changed every 24 h and, for the experiments involving slurry, an additional 2 changes during the first 24 h after application. Following exposure, samples from the flasks were diluted with deionized water and the extracts were stored at <4 °C prior to