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Nitrous oxide emission factors for urine and dung patches in a subtropical Brazilian pastureland

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ABSTRACT

Cattle urine and dung (faeces) patches are nitrous oxide (N_2O) sources in pasturelands with impacts in the global N_2O budget, but specific information about those emissions are still missing for Brazilian subtropical and tropical regions. We conducted a sequence of 3 field-trials (summer, winter and spring, 90 days each) to evaluate the N_2O emission and emission factor (EF) after the deposition of 3 volumes of cattle urine or 3 weights of dung (½, 1 and 1½ time the mean urination volume or defecation weight of Friesian cows) on a free-drained Cambisol of a subtropical pastureland of Brazil. The N_2O emission peaks (3198 $\mu g\ N_2O\text{-}N\ m^{-2}\ h^{-1}$ after urine in summer was the highest) occurred on average 17 ± 9 days after application (DAA), both for urine and dung, and dropped to the background levels 41 ± 10 DAA of urine and 49 ± 10 DAA of dung. The highest contents of NH_4^+-N in soil (200–250 mg N kg^{-1}) occurred one day after urine application and 10–14 days later for dung (100–200 mg N kg^{-1}). Nitrate peaks occurred from 23 to 26 DAA in urine patches (∼40–50 mg N kg^{-1}) and 19–50 DAA in dung patches (∼40–50 mg N kg^{-1}). The N_2O emission peaks for urine coincided with soil NH_4^+-N peak in winter but with soil NO_3^--N peak in spring. For dung, the emission peak seemed to be more associated with soil NO_3^--N than to NH_4^+-N, either in winter or spring (inorganic-N was not assessed in summer). It was not possible to conclude whether nitrification or denitrification was the dominant process in N_2O production, but it seemed that both played relevant roles. The EF for urine, averaged across the seasons, diminished with increments in urine volume, from 0.33% in ½ volume to 0.19% in 1½ volume, possibly because urine percolated deeper into the soil and proportionally less N remained available for N_2O production in the top layer. The EF for dung was 0.19%, 0.12% and 0.14% for ½, 1 and 1½ weight, respectively, showing no clear trend with increment in dung weight. The lowest EFs for urine and dung occurred in winter, possibly because of lowest temperatures and soil water-filled pore space. The average EF for dung (0.15%) was lower than that of urine (0.26%), because urea-N of urine is more readily available for the hydrolysis than organic N forms of dung. This result suggests that these two excreta should be addressed separately in national greenhouse gases inventories or communications. Our results suggest that the default 2% EF proposed in IPCC Guidelines for cattle excreta are overestimated for subtropical Brazil.

1. Introduction

Nitrous oxide (N_2O) has radiative forcing properties that make it a potent greenhouse gas with a global warming potential of about 300 times greater than that of carbon dioxide (CO_2) (IPCC, 2007). It is also the most important ozone-depleting agent, being the primary source of stratospheric NO_x that catalytically destroys ozone (Ravishankara et al., 2009). Since pre-industrial time up to 2005,

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atmospheric N_2O concentration increased by 18% (270–319 ppb) and agriculture played a significant role in that increase. Agricultural N_2O emission is responsible for 60% of global N_2O emission, mainly due to application of fertilizer-N and deposition of animal excreta onto pasturelands; and it is projected to increase by 35–60% until 2030 (Smith et al., 2007). In Brazil, where about 175 million hectares support 205 million cattle (IBGE, 2009), 40% of the estimated national N_2O emission would be derived from urine and dung (faeces) excreted onto pastureland soils (Brazil, 2010).

Much of the nitrogen (N) ingested by cattle as feed (80–95%) is returned to soil as urine or dung (Haynes and Williams, 1993; Bolan et al., 2004). Considering that equivalent rates of 800 and 2000 kg N ha^{-1} are applied in urine patches and dung pats, respectively (Oenema et al., 1997), and that this N can be hydrolyzed to ammonium (NH_4^+) and subsequently nitrified to nitrate (NO_3^-), urine and dung patches have been regarded as important localized N_2O sources in pasturelands, capable of impacting the N_2O global budget (Mosier et al., 1998). When NO_3^- undergoes denitrification, the N is reduced to the gaseous forms of nitric oxide (NO), N_2O or dinitrogen (N_2). Nitrous oxide may also be produced by nitrifier denitrification, where the intermediate nitrite (NO_2^-) may be reduced to NO, N_2O or N_2 instead of being oxidized to NO_3^- (Wrage et al., 2001).

The N_2O emission factor (EF) for a given N source is the percentage of the applied N that is emitted as N_2O, and so it allows comparison between studies carried out under different agronomic and environmental conditions. According to the IPCC, the default EF for cattle excreta deposited by grazing animals onto pastures is 2% (no distinction between urine and dung), with an uncertainty range from 0.7% to 6% (IPCC, 2006). If information about N_2O emission is available for a country, specific EFs can be used in national inventories or communications. For example, New Zealand uses a country-specific EF of 1% for urine and considers a separate and lower one for dung (0.25%) (New_Zealand, 2012). In Australia, the country-specific EF for urine is 0.4% and a higher one (0.5%) is for dung (Australia, 2012). However, such specific information is lacking for subtropical and tropical conditions of South America. Moreover, the default EF of IPCC is based on studies carried out primarily in temperate conditions and may not be appropriate for tropical and subtropical regions. Despite Brazil holding the second largest cattle herd of the world, it does not have specific N_2O EFs for cattle urine and dung yet. In the second and most recent Brazilian Communication of greenhouse gases (Brazil, 2010), estimates of N_2O emissions from animal excreta in pastureland were based on the IPCC 2% default EF (Alves, 2010). However, most of the subtropical Brazilian pasturelands are in well drained soils, where N_2O production is not so favourable because of better aeration conditions. Thus, we hypothesized that the EFs for urine and dung are lower than the default 2%.

Despite differences in N contents and forms between dung and urine, the 2% default EF is applied indistinguishably for both excreta types (IPCC, 2006). However, studies have found that N_2O EF for dung is generally lower than that for urine (Flessa et al., 1996; Yamulki et al., 1998; van der Weerden et al., 2011). Moreover, van der Weerden et al. (2011) recently recommended the disaggregation of urine and dung EFs for national greenhouse gases inventories (in the specific case, for New Zealand), but stated that further research needs to be undertaken on the subject. We hypothesized that, under subtropical Brazil conditions, the EF is lower for cattle dung than for urine, because dung N is not as readily available to N_2O production as urea-N of urine; and this difference should be considered in national inventories or communications.

The N_2O emission patterns after dung or urine application may differ considerably by season, and studies have highlighted the importance of considering this factor in dung and urine N_2O emission studies (Allen et al., 1996; Yamulki et al., 1998; van Groenigen et al., 2005b). In some temperate regions, higher N_2O emissions from excreta patches have been reported to occur in winter (Allen et al., 1996; Luo et al., 2008), mainly due to the wet conditions of the season in those regions. In subtropical Brazil, seasons are distinguishable mainly by temperature, a climatic factor shown to influence N_2O emissions in pasturelands (Uchida et al., 2011). We hypothesized that because of lower temperatures in winter, the EF for urine and dung would be lower in winter than for spring or summer under subtropical conditions.

Nitrous oxide emission and EF might also be affected by the volume of urine and the weight of dung voided by animals. With higher urination volume, preferential flows may occur through the soil and carry the urea-N deeper (Haynes and Williams, 1993) and so reduce the availability of N for N_2O production. We hypothesized that the higher the urination volume, the more N is leached into soil, the less N is available to N_2O production and the lower the EF is. For dung, we hypothesized that the larger the dung weight, the bigger the pat, the longer it remains moist, the more favourable the conditions are for N_2O production and the higher the EF is.

This study aimed at assessing N_2O emissions from cattle urine and dung patches in a subtropical pastureland of Brazil to evaluate (i) how appropriate the default 2% EF is for the region; (ii) how excreta type (urine vs. dung) affect the emission and if EF is different between them; (iii) how seasons affect emission patterns; and (iv) how the volume of urine and the weight of dung voided by animals affect emission and EF.

2. Materials and methods

2.1. Site description

The study was conducted on cattle pastureland comprising mainly *Paspalum paniculatum* L., *Axonopus compressus* (Sw.) P. Beauv and *Pennisetum clandestinum* Hochst. ex Chiov., at Canguiri Experimental Farm (dairy sector), near Curitiba-PR, Brazil (25°23′55″S; 49°07′29″W; 912 m altitude). The clayey Cambisol has a 10% slope and contains 439 g kg^{-1} of clay, pH of 4.9 and 25 g kg^{-1} of organic carbon in the 0–20 cm layer, and is free drained. The humid mesothermic subtropical climate (Cfb, Köppen) has a mean precipitation of 1408 mm per year (around 75 mm in August and 165 in January) and a mean monthly temperature varying from 12.2 °C in June to 19.9 in February (Brasil, 1992). Frosts are frequent in winter.

2.2. Experimental design and excreta characteristics

We measured N_2O fluxes during 3 separate 90-day trials which included summer (January 17th–April 17th), winter (June 3rd–September 1st) and spring (September 16th–December 15th) seasons of 2011 (South Hemisphere). Although the trial periods did not coincide exactly with regular seasons, we decided to name them according to the predominant season each trial encompassed.

Three volumes of urine and 3 weights of dung were applied over the soil in microplots delimitated by circular metal bases of 32.5-cm internal diameter (area = 0.083 m^2) inserted 2.5 cm into the soil. Bases remained inserted during the entire period of sampling in each season. A treatment of soil without excreta was used as control. No fertilizer-N had been used in the area during the last 2 years. When herbage reached 20-cm high, it was cut to 10-cm high and removed from the area during the course of the trials, simulating grazing.

Urine volumes were equivalent to half ($U_{0.5}$), full ($U_{1.0}$) and one and a half times ($U_{1.5}$) the mean volume of 20 urine samples of Friesian milking cows (live weight ~500 kg) fed on diets based on grazing (adjacent pasture with the same botanical composition of