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Temperature and moisture affect methane and nitrous oxide emission from bovine manure patches in tropical conditions

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ABSTRACT

Animal production systems are important sources of greenhouse gases (GHG), especially methane (CH_4) and nitrous oxide (N_2O). Brazilian beef production is almost exclusively (more than 90%) pasture-based. GHG emissions from faeces deposited in pastures have been extensively studied in temperate climates, but emissions under tropical conditions are unclear. The aim of this study was to examine the effects of tropical temperature and moisture conditions on GHG emission from manure. We hypothesized that periodical rainfall and high temperature on tropical climates would increase the GHG emission from faeces by maintaining an anaerobic environment within the faeces. We measured the emission of CH_4 and N_2O from cattle faeces in two different field sites in Brazil: São Paulo (subtropical) and Rondônia (tropical), as well as under controlled conditions, simulating summer conditions. Emissions of CH_4 from faeces ranged from 117 to 1007 mg C–CH_4 m^{-2} h^{-1}. In the field, summer emissions were 2.9 (São Paulo) and 2.5 (Rondônia) times higher than winter ($p < 0.05$). In controlled conditions, prolonged moisture conditions at high temperature (35 °C) resulted in higher emissions ($p < 0.05$) than the no-rewetted treatment (2831 and 1781 mgCH_4 m^{-2}, respectively). Emission factors determined were 0.02 and 0.05 kg CH_4 $head^{-1}$ $year^{-1}$ (winter and summer São Paulo, respectively) and 0.06 and 0.10 kg CH_4 $head^{-1}$ $year^{-1}$ (winter and summer Rondônia, respectively), significantly lower than the IPCC default value of 1 kg CH_4 $head^{-1}$ $year^{-1}$. CH_4 emissions from faeces were slightly higher than from others studies in temperate climates. N_2O emission from faeces was lower than the control at the Rondônia site during the summer, with net negative fluxes. We conclude that climate is a strong factor controlling GHG emission from faeces. Our study showed that in a continental-size country as Brazil, an average emission factor as proposed by the IPCC is not the best option.

1. Introduction

The Brazilian cattle herd is massive, reaching about 200 million heads. Brazil is the second largest exporter of beef, responsible for 15% of beef production worldwide (FAO, 2012). More than 90% of Brazilian beef production occurs on pasture, with a low grazing intensity (1 head ha^{-1}) (Anualpec, 2010). Extensive cattle breeding occupies 48% of arable land. Most of the slaughtered animals (60%) for beef production are 4 years old steers, with an average weight of 450 kg (Ferraz and Felicio, 2010).

Ruminant animals play an important role in greenhouse gas (GHG) emission of methane (CH_4) and nitrous oxide (N_2O) into the atmosphere. Emissions occur mainly through enteric fermentation and cattle manure (faeces and urine) deposited in pastures. Although there is extensive literature on animals and production rates of methane and nitrous oxide under temperate conditions (Saggar et al., 2004; Eckard et al., 2010), much less is known for tropical conditions. The excreta from grazing animals can give rise to "hot-spots" for GHG emission. The warm and moist conditions in cattle manure create an optimal microenvironment for the anaerobic microorganisms that produce CH_4 (Saggar et al., 2004) and N_2O (Allen et al., 1996; Flessa et al., 1996). These faeces are decomposed and subject to various factors that may influence the extent of GHG emission, such as temperature and rainfall.

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Given the large number of animals and lack of information related to GHG emission from faeces, we examined the emission of CH_4 and N_2O from faeces in Brazil, in two different regions: São Paulo (subtropical climate) and Rondônia (tropical climate). We hypothesized that periodical rainfall and high temperature in tropical climates would increase the GHG emission by maintaining an anaerobic environment within the faeces. We also hypothesized that the studied regions would have different patterns of emission because of different climate.

2. Material and methods

2.1. Field experiments

The experimental pastures were not grazed by livestock before or during the experiment and had not received any nitrogen fertilizer for five months prior to the experiment. The first experiment was carried out from 27 July to 15 August 2011 (winter) and 31 January to 29 February of 2012 (summer) at the University of São Paulo, Piracicaba, SP, Brazil (22°42′07″S; 47°37′17″W) under subtropical climatic conditions (Cwa-Köppen climatic classification). The average air temperature and total precipitation were 19 °C and 50 mm (winter); 25 °C and 139 mm (summer) (Fig. 1). The second experiment was carried out from 09 June to 10 July 2012 (winter) and 09 November to 10 December of 2012 (summer) at Agropecuária Nova Vida, Ariquemes, RO, Brazil (10°10′05″S; 62°49′27″W) under tropical climatic conditions (Aw-Köppen climatic classification). The average air temperature and total precipitation were 32 °C and 7 mm (winter); 29 °C and 250 mm (summer) (Fig. 1). Meteorological data were recorded at the nearest meteorological station (rainfall and air temperature), which was within 1 km of both field sites.

2.1.1. Set up of the field experiments

The soil from SP experiment was classified as a Nitisol (FAO, 1998), with sandy loam soil texture, while the soil from RO experiment was classified as Oxisol. Sand, clay, silt content, pH and bulk density were determined according to Embrapa (1979) and Anderson and Ingram (1989). The total soil C and N were determined by dry combustion (Nelson and Sommers, 1996), through a CN elemental analyzer (LECO @2000). Soil mineral N content was determined by extraction with 2 M KCl with a 1:2 ratio of soil and extractant (Bremmer and Keeney, 1966). Soil extracts were filtered and stored at 4 °C. Concentrations of NH_4^+ and NO_3^- in the extracts were determined by automated flow injection analysis (FIA) (Ruzicka and Hansen, 1981). Soil properties (upper 10 cm) from the start of the experiment are shown in Table 1.

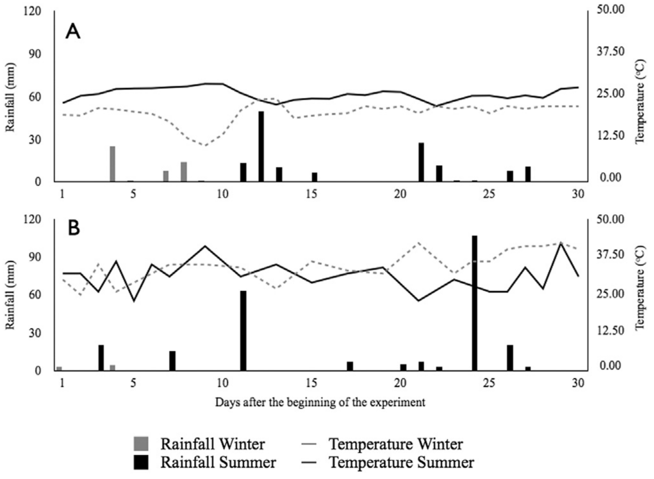

Fig. 1. Climatic data from the study sites, during two different seasons. (A) São Paulo; (B) Rondônia.

Faeces were collected from a group of 10, three year old steers (*Nellore*), with an average weight of 450 kg, directly before the start of the experiments, and thoroughly mixed before application. The steers were grazing pasture (*Brachiaria decumbens*) supplemented with mineral salts. The selected area in each site was divided in 10 plots, each 1 × 1 m and assigned to two treatments (with faeces, labelled as "WF" and a control with no faeces, labelled as "NF") with five replicates, laid out as a randomized complete block design. Plots consisted of a chamber area (0.064 m^2) and adjacent area for faeces sampling (0.05 m^2). The chambers were installed and remained in soil during 30 days. After this, chambers were removed and installed again in the same area in other season. Each dung sample was applied at the rate of 8 kg m^{-2} (2.50 kgC m^{-2}; 0.13 kg N m^{-2}; water content: 85%). These rates represent values observed in extensive systems (González-Avalos and Ruiz-Suárez, 2001; Orr et al., 2012) and by our own observations in the field.

2.1.2. Flux measurements

A closed static chamber technique (Jones et al., 2005) was used for estimating CH_4 and N_2O emission. At the field site, non-vented steel chambers (28 cm diameter, 13 cm height) were installed two days before the first sampling. The chambers were inserted to a depth of up to 3 cm to ensure an airtight seal. At the time of sampling, lids were placed on top of the chambers and a seal was achieved via water filled groove on the chamber that the lid fitted in to. There were 17 sampling occasions: daily during the first week, followed by three times a week for the next two weeks and twice in the last week of the experiment. Gas sampling was normally carried out between 09:00 and 11:00. Samples were collected at 0, 10 and 20 min after the chamber was closed. A 20-ml syringe was used to collect the gas samples from the chambers, which were then placed in pre-evacuated 13 ml headspace vials using a hypodermic needle. The glass vials had a chloro-butyl rubber septum (Chromacol). Samples were analysed for CH_4 and N_2O within 7 days after collection by gas chromatography (GC – Shimadzu 2014). Total GHG emissions from WF and NF treatments were estimated by calculating cumulative fluxes over an experimental period of 30 days in both experiments.

Adjacent to each flux chamber were assigned plots that also received the same faeces rate. Faeces were sampled on days 1, 7, 15, 22 and 30. Water filled pore space (WFPS) of the soil and moisture of the faeces were calculated gravimetrically.

2.2. Potential production of CH_4 and N_2O

We also investigated how temperature and moisture influenced the production of methane and nitrous oxide in soils incubated in laboratory. Soil (0–10 cm) was collected from the same place of São

Table 1
Soil proprieties (0–10 cm) at the beginning of the two field experiments during winter and summer.

		Sand	Clay	Silt	pH	Density	C	N	NO_3^-	NH_4^+
		%				g m^{-3}	g kg dry soil^{-1}		mg N kg dry soil^{-1}	
SP	Winter	35	30	35	5.4	1.60	28.3	2.1	8.1	3.1
	Summer	37	23	40	5.6	1.60	30.3	2.9	18.1	5.8
RO	Winter	62	30	8	4.9	1.50	25.5	2.2	2.5	5.2
	Summer	65	25	8	5.0	1.50	27.3	3.0	1.3	2.3

SP: São Paulo state; RO: Rondônia state.