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Edaphoclimatic factors and interactions with nitrous oxide emissions in integrated production systems

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Introduction

The worldwide increase in the concentration of greenhouse gases (GHGs) has caused climate changes that have not been observed since 800,000 years ago. As a result, the heating of the Earth's surface has been higher in the last three decades than recorded until 1950 (IPCC 2013). N2O is considered a very active gas in the process of global warming due to its high ability to absorb infrared radiation and is a stable gas in the atmosphere, contributing approximately with 6% of the radiative potential of GHGs, and has a half-life of 120 years. Its global warming potential (GWP) is 310 times higher compared to CO_2 and its concentration in the atmosphere has increased in recent decades, reaching $324,2 \pm 0,1$ ppb. This increase has been attributed to increased amounts of nitrogen fertilizers used in agriculture, conversion of forest areas for agriculture, increased fires, intensification of livestock, etc. (Bustamante et al. 2012). Thus, agriculture is the main activity responsible for N_2O emissions to the atmosphere as a result of oxidation of organic matter and complex microbial processes associated with management practices on ecosystems. Integrated production systems can be considered a strategy to reduce soil N_2O emissions in the Brazilian Cerrado (Carvalho et al., 2014).

Material and Methods

The study was conducted in the experimental field of Embrapa Cerrados, located in Planaltina, DF (15º35`30″ S, 14º42`30″W and altitude 1007 m) from February 2012 to April 2014. The treatments consisted of four areas with different land use: a cultivated area with Eucalyptus urograndis in alley cropping, spaced 2 x 2 m between plants and 22 m between rows (ICLF); a cultivated area at full sunlight in absence of tree species (ICL); and two adjacent areas used as a reference: a native Cerrado and low productivity pasture. The ICL and ICLF areas consisted of experimental plots with 1.2 ha in a complete randomized block design with three replications. In March 2012, after soybean harvest, seeds of *B. brizantha* cv. BRS Piatã were broadcasted immediately before sowing the sorghum to establish the intercropping system in the off-season growth. After harvesting the sorghum (July 2012), the pasture of *B. brizantha* was left to establish for the entrance of the livestock (cattle).

Soil N_2O sampling period was from February/2012 to February/2014. Three static chambers were placed in each plot, totaling 24 chambers in the integrated systems experiment (ICL and ICLF). For each reference area (native Cerrado and continuous pasture) three chambers were installed. Each chamber consisted of a rectangular hollow metal frame (38 cm wide, 58 cm long, 6 cm in height) that was inserted 5 cm into the soil and a top polyethylene tray that was coupled and sealed to the base during gas sampling. The top of the tray contained a triple Luer valve for fastening the sampling syringes, thus allowing the removal of the gases at the time of sampling. The samples were collected and immediately transferred to 20 ml glass pre-evacuated vials (-80kPa). Gas sampling frequency was carried out, on average, three to four consecutive days a week during the rainy season, weekly during short period of drought during the rainy season, and biweekly during the dry season. In the rainy season, samples were collected 5 following days after nitrogen fertilizer applications. The analysis of N_2O concentrations were performed at the Laboratory of Gas Chromatography of the Embrapa Cerrados, using a gas chromatograph.

In addition to the gas sampling, soil samples were also collected at each gas sampling to determine the gravimetric water content, the concentration of mineral forms of nitrogen in the soil (N-NO_3^- and N-NH_4^+), carbon and nitrogen microbial biomass and total carbon and nitrogen. Soil samples, composed of three sub-samples were collected at each plot at depths of 0-5 cm and 5-10 cm. The gravimetric soil water content was determined after drying soil samples at 105 ºC for 48 h. Based on these results and the bulk density, the percentage of WFPS was calculated, using the following formula: WFPS (%) = (gravimetric moisture (%) x bulk density) / total soil porosity x 100; Where: total soil porosity = [1- (bulk density / 2.65)], with 2.65 [g cm^{-3}] is the density of the particles assumed soil. Nitrate (N-NO_3^-) and ammonium (N-NH_4^+) were analyzed following Embrapa (1997). Nitrogen microbial biomass (MBN) was determined with the method of chloroform fumigation-extraction and carbon microbial biomass (MBC) was determined according to Vance et al. (1987) and Wardle (1994). Basal respiration (BR) was estimated by measuring CO_2 released from pre-incubated soil samples for a period of seven days. Total organic carbon (TOC) and total nitrogen (TN) were analyzed according to Embrapa (1997).

Pearson's correlation and multiple linear regression were used to correlate the cumulative emissions of N_2O and the edaphoclimatic factors and soil properties.

Results and Conclusions

The dynamics of N_2O emissions can be attributed to differences between the integrated systems, continuous pasture and native Cerrado, due to their environmental conditions. Thus, the covariables (NO_3^-, NH_4^+, WFPS and rainfall) correlate with the N_2O fluxes with values less than 0.45, but highly significant (Table 1). In addition, all correlations were positive, reinforcing the relationship and direct influence that these covariables present with N_2O fluxes. Among these factors, the WFPS was the most significant. Generally, high flows coincide with periods after precipitation, which was also observed by Ussiri and Lal (2013), thereby providing the elevation of the WFPS. During this study there was good distribution of rainfall in the rainy season (October to April) with daily rainfall records higher than 40 mm. N_2O emissions can be positively correlated with the availability of inorganic N as observed in his study (Table 1). The N-NO_3^- content showed higher correlation with N_2O emissions than the N-NH_4^+ levels. Nitrification is the NH3 oxidation process for NH_4^+ or NO_3^- to under aerobic conditions, whereas denitrification is the process in which NO_3^- is reduced again to N_2O and/or N_2 under anaerobic conditions (Signor and Cerri 2013). The Cerrado soils are very aerated, providing conditions for nitrification, so that the processing reactions of NH_4^+ to NO_3^- occur more frequently. When the rainfall amounts elevate the soil WFPS above 60%, the denitrification becomes more intense, consuming NO_3^- in the soil and promoting more intense emission of N_2O (Cameron et al. 2013).

MBC and BR were significantly correlated with the emissions of N_2O, whereas CBM showed a positive correlation and the BR, a negative correlation (Table 2). BR is a biological process resulting in the release of CO_2 by microorganisms and parts of plants in soil, becoming more intense in conditions of increased O_2 concentration in the soil (Moreira and Siqueira 2006). In this study, the largest BR values occurred in the dry season, a time when the lower humidity values were observed in the soil. Under these conditions, soil macropores are mostly filled with air, thus facilitating the diffusion of O_2, and the micropores are partially filled with water, promoting the diffusion of soluble substrates. On the other hand, N_2O emissions are mainly stimulated by increasing the availability of water in the soil, since the main process for the production of N_2O in the surface denitrification (Baggs and Phillipot 2010), justifying the negative relationship obtained between BR and N_2O emissions.

The significant correlation between MBC and N_2O can be associated with the relationship between the microbial biomass and the quantity and quality of the biomass produced, the reflected vegetable waste decomposition process in the integrated systems evaluated.

Table 1. Pearson correlation coefficients representing the relationship between N_2O emissions and soil and climate variables.

Variables	Total	Dry Season	Rainy season w/N	Rainy Season wo/N
NO_3^- 0-5 cm	0,203***	0,074**	0,159***	0,086***
NO_3^- 5-10 cm	0,226***	0,050*	0,217***	0,052*
NH_4^+ 0-5 cm	0,144***	0,109***	0,056*	0,069***
NH_4^+ 5-10 cm	0,058***	0,124***	-0,029^{ns}	0,015^{ns}
WFPS 0-5 cm	0,336***	0,266***	0,412***	0,212***
WFPS 5-10 cm	0,277***	0,237***	0,313***	0,145***
Rainfall Precipitation	0,073***	0,184***	0,070**	-0,003^{ns}

^{ns}Not significant. ***, ** and * Significant at 1, 5 and 10% probability, respectively.

Table 2. Linear correlation between N2O emissions and microbiological attributes in Cerrado soil in ICL, ICLF, native Cerrado and low productivity grassland.

	MBC	MBN	BR	TOC	TN
N_2O	0,453*	0,249	-0,474*	0,006	-0,218

* Significant at 5% probability.

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