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NITROUS OXIDE EMISSIONS FROM SOILS UNDER SUGARCANE FIELDS IN THE CERRADO

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SUMMARY

Soil fertilization with mineral nitrogen and organic fertilizers, such as the vinasse – a liquid waste from bio-ethanol production, is a common practice on the sugarcane produced in Brazil that can lead to increasing emissions of greenhouse gases. Nitrous oxide (N_2O) is a greenhouse gas even more harmful than the carbon dioxide (CO_2), and has longer residence time in the atmosphere. The present study has been conducted on a sugarcane irrigated experiment established at the EMBRAPA Cerrados research station, in Brazil. We hypothesized that N_2O emissions would be higher in the sugarcane fields, especially in the fertilized areas that combined mineral nitrogen (N) and vinasse (V), than in the native vegetation remnants (Cerrado); and that irrigated soils would have the highest fluxes of N_2O. First measurements were done after the application of N and vinasse in May 2014 until June 2014 as an intensive campaign, and continuous monitoring have been conducted so far. Preliminary results showed that higher emissions occurred on soils combining N and V, showing fluxes that were twice as higher than the fluxes from other treatments, and 100 times bigger than fluxes from soils with native vegetation (469±158, 62.3±6.9, and 0.8±0.1 for V+N, N and Cerrado areas, respectively). The present study is pioneer in the Cerrado region and data are important to assess the regional variations on the N_2O fluxes in Brazil, to reduce the bias on national estimations of N_2O emissions, and to find more sustainable solutions for the production of bio-ethanol from sugarcane.

KEYWORDS

Bio-ethanol; N-mineral fertilization; vinasse.

INTRODUCTION

Atmospheric concentration of nitrous oxide (N_2O) has risen from 270 during previous industrial era to lately 319 ppm (Forster et al. 2007). N_2O has about 300 greater radiative effect than the carbon dioxide (CO_2) and much longer residence time in the atmosphere (114 years). However, less information about the magnitude of emissions of N_2O is available in the literature. Brazil was already responsible for ~500 Gg of global emissions of N_2O from anthropogenic sources in 2005 (Brazil 2010). Of which, 87% came from the agricultural lands and animal waste (Cerri et al. 2009). However, because flux rates vary greatly according to the land use, soil type, climate and inputs of fertilizers, detailed data and reliable estimates are difficult to obtain. Measuring fluxes in different types of soil, climate and land management is important to mitigate for greenhouse gases emissions (GHG), to improve national and global assessments of N_2O emissions, and to pursue a more sustainable development of the market in Brazil.

The production of bioethanol from sugarcane has doubled over the past decade and already occupies 14% of the available croplands in Brazil (IBGE 2012). Thus, the central-south region of Brazil that contains great part of the Brazilian savannahs and open woodlands, the Cerrado, is expected to be highly affected by the land use changes and disturbances caused by the expansion of sugarcane fields extent (Feres et al. 2009; Myers et al., 2000). Lima (2010) registered one increment of about 100 to 300% in the production of sugarcane by Goiás, Mato Grosso and Mato Grosso do Sul for the period of 1992-2007. The region called MATOPIBA in the north of Cerrado and is the region where the deforestation is occurring in favour of new areas for sugarcane fields (Castro et al. 2010).

High N_2O are well expected to increase in sugarcane systems due to the use of fertilizers, heavy machinery and irrigation (Lisboa et al. 2011). Concerns about the negative environmental consequences are strong (Sawyer 2008), especially because land use changes (i.e., habitat losses and soil disturbances) modify of nutrient pools and water availability, affecting the dynamics of GHGs. The majority of the sugarcane fields receive high inputs of synthetic nitrogenised fertilizers (N). Additionally, the use of heavy machinery during the harvest may cause soil compaction and create soil aggregates with low oxygen conditions. Higher N availability increases denitrification when soils become hypoxic, which causes higher emissions of N_2O. Heavy rain events causing waterlogging are also reported to contribute to high peaks of N_2O (Davidson et al. 2001). Adding residues from sugarcane processing for bio-ethanol production to the sugarcane fields is a common practice in Brazil (Previtalli 2011), which can affect rates of N_2O fluxes emitted by the soil. For example, the vinasse is produced in high quantities during the bio-ethanol manufacturing and is recycled by the farmers for economic reasons. It is rich in essential nutrients for plant growth and has high contents of labile carbohydrates (Carmo et al. 2012, Previtali 2011). Studies have suggested that this practice increases the emissions of N_2O due to the interaction between N and soil carbon (Carmo et al. 2012, Cerri et al. 2013). The amount of inorganic N made available by the processes of denitrification and nitrification affects the N_2O emissions.

In the present study we aimed to assess: (1) effects of the sugarcane systems on the emissions of N_2O in the Cerrado soils? Specifically, how does the combination of the vinasse and N affect the magnitudes of N_2O emissions? (2) How does irrigation affect the emissions of N_2O when both N and vinasse are added? (3) How those emissions in the sugarcane fields differ from Cerrado native vegetation? We hypothesized that the highest emissions would occur in plots combining N and vinasse. Irrigation would increase emissions especially after long dry periods. We believed that N_2O emissions would be higher in sugarcane fields than those in native woodlands Cerrado (*Cerradão*) as reported by literature (Nobre 1994; Poth et al. 1995).

MATERIAL AND METHODS

Study area

The study was conducted at the EMBRAPA Cerrados research station, located in Planaltina-DF, 38 km from Brasília, Brazil. The climate is classified as tropical Aw *sensu* Köeppen, with dry winters and well defined wet/dry seasons. The annual temperature varies between 22 °C and 25 °C and the precipitation ranges from 800 to 2000 mm per year. Of which, 80% occurs during the rainy season, between October and February. Soils are Oxisol (U.S. classification system) or *Latossolos* (Brazilian system; Carvalho et al. 2010).

Sampling and analyses

We used the method of the static closed chambers (rectangular) for N_2O sampling (Carvalho et al. 2006, Jantalia et al. 2008, Carmo et al. 2012, Signor et al. 2013). RB867515 was the chosen sugarcane variety, which is commonly used by farmers in Brazil. 30 ml air samples were collected using 60 ml syringes at three times: immediately after sealing the chamber (0 min), at 15 and 30 min after. Samples were stored in sealed vacuumed headspace vials until be analysed in the gas chromatograph (Air Thermo Trace GC equipped with a Porapak Q column and an electrons detector). Soil temperature, soil moisture at 10 cm depth and chamber temperature were also measured concomitally. Soil samples (0-10 cm depth) were collected after each gas sampling event to assess inorganic nitrogen (nitrate and ammonium).

We chose the irrigation level of 75% of water deficit to compare with those areas without irrigation (0%). Thus, 3 replicates for each of the following treatment were established on the sugarcane field: sugarcane under N fertilization without irrigation (N 0%); vinasse only without irrigation (V 0%); nitrogen plus vinasse without irrigation (N+V 0%); nitrogen irrigated (N 75%); vinasse irrigated (V 75%); and nitrogen plus vinasse irrigated (N+V 75%). Emissions on two Cerrado remnants (*Cerradão*) were also collect at the same days for comparisons. Two static chambers (A in mid row; B in the row) were installed by replicated treatment in the sugarcane fields, totalizing 36 chambers. B chambers received direct N addition because were next to the row in those treatments using N. Three chambers per Cerrado plot were installed (=6). Ammonium nitrate was applied as N source at 120 kg ha^{-1} before the vinasse addition (at 150 m^3 ha^{-1}). Irrigation was proceeded one week after.

Fluxes were calculated using the following equation by Jantalia et al. (2008):

$$N_2O = \delta C/\delta t * M/Vm * V/A$$

Where, N_2O is reported in μg m^2 h^{-1}; δC/δt is the change in concentration of N_2O during the incubation; M is the molecular weight of N_2O and m is the molecular volume at sampling temperature; V is the chamber volume and A is the area covered by the chamber.

RESULTS AND DISCUSSION

We analysed the first week of emissions and found highest emissions in the areas that we combined the nitrogen and vinasse addition. Emissions varied from below ~1 μg m^{-2} h^{-1} in the Cerrado to ~450 μg m^{-2} h^{-1} in the combined N+V treatment in the first day of measurements (Fig. 1).

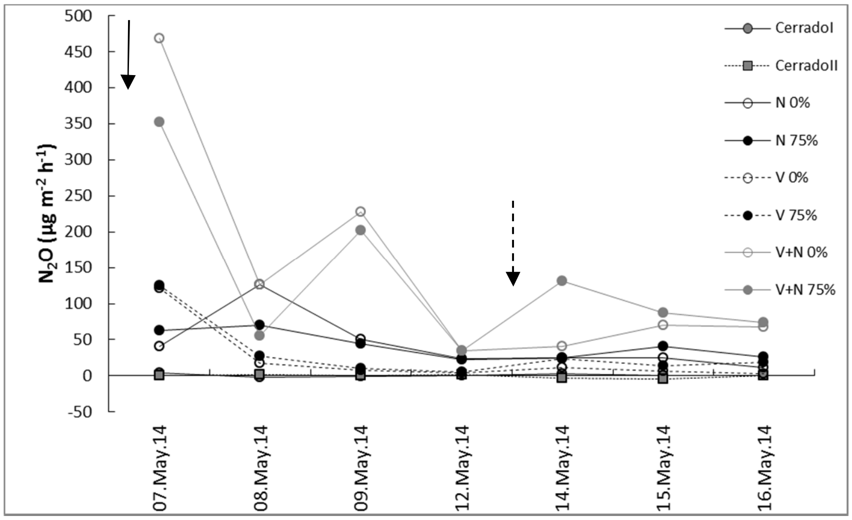

Figure 1. Nitrous oxide emissions from sugarcane fields under different fertilization and irrigation treatments and two native Cerrado areas. N= nitrogen only, V= vinasse only, N+V= nitrogen plus vinasse; 0%= no irrigation, 75%= irrigated at 75% of water deficit. Straight arrow= N and vinasse addition; Dotted arrow= Irrigation.

On average, irrigated and non-irrigated areas responded similarly to the first N addition, except for the N+V treatments, which showed stronger response in the N+V 0%. However, after the first irrigation event, one week later fertilization, all irrigated treatments showed slightly higher N_2O emissions than treatments without irrigation. The highest emissions of a dry area in the beginning of the experiment might be due to hypoxic conditions, or either that the N was not readily used by plants creating a surplus in the soils.

During the first day of experiment, chambers B that received direct N additions showed very high emissions on the N+V 0% treatment 776±186 µg m^{-2} h^{-1} for a short 2-day-peak (Fig. 1; Table 1). After irrigation, responses were very similar between chambers and treatments, with a trend of higher emissions from the V+N 75% treatment. Recent studies have shown that the fertilization has a positive effect on the N_2O emissions, which may increase fluxes from 0 to 1200 µg m^{-2} h^{-1} (Carvalho et al., 2006; 2010; Signor et al., 2013). Paredes et al. (2014) reported for an area outside Cerrado that emissions tend to increase even more (9000 µg m^{-2} h^{-1}) in a short period of time after addition of vinasse and N. As shown, rates in the Cerrado are high but still lower than in other regions in Brazil.

Table 1. Emissions of nitrous oxide (μg m^{-2} h^{-1}) ± standard deviation (n=3) for Cerrado and different treatments in the sugarcane fields. N= nitrogen only, V= vinasse only, N+V= nitrogen plus vinasse; 0%= no irrigation, 75%= irrigated at 75% of water deficit.

Date	Cerrado I*	Cerrado II*	A chambers					
			N 0%	N 75%	V 0%	V 75%	V+N 0%	V+N 75%
07.May.2014	4.5±3.9	0.83±0.9	33.98±39.6	55.64±79.8	209.05±194.9	137.09±167.1	161.75±106	502.87±195.8
08.May.2014	-1.51±2.6	3.44±5.3	29.76±23.8	57.70±59.4	13.50±11.8	16.48±15.6	37.24±11	49.89±67
09.May.2014	-0.37±5.7	-0.69±5.7	20.29±18.6	37.67±45.2	12.52±11.6	7.50±8.4	16.60±12.4	38.13±12.5
12.May.2014	0.08±2.2	0.90±3.4	13.76±16.3	15.77±11.9	8.12±6.8	3.96±3.4	16.56±5.9	26.89±16.6
14.May.2014	3.28±6.7	1.67±1.3	13.91±8.3	20.59±21.7	11.83±6.7	32.80±22	24.49±27	113.67±89
15.May.2014	-	-8.15±9.3	13.01±10.6	39.62±42.1	9.53±3.1	18.27±12.4	28.86±32.6	71.17±89.1
16.May.2014	-	-	1.84±13.6	27.87±31.6	2.79±14.4	23.00±5.7	45.57±38.5	62.05±74
			B chambers					
			N 0%	N 75%	V 0%	V 75%	V+N 0%	V+N 75%
07.May.2014			48.35±3	69.11±29.1	34.12±26.9	112.83±164	776.31±322.4	202.72±209.2
08.May.2014			223.75±340.8	82.31±46.8	21.81±16	37.18±45.2	214.19±337.6	60.36±59
09.May.2014			80.67±109.2	52.30±26.5	3.22±3.5	14.06±8.3	438.51±317.7	366.61±141.4
12.May.2014			33.69±44.6	29.88±19.6	0.23±1.7	6.88±9.6	53.69±40.1	42.87±43.1
14.May.2014			36.26±17.8	30.18±6.7	11.64±18.3	14.64±7.3	57.82±19.9	149.89±37.5
15.May.2014			36.43±26	41.26±14.8	4.75±0.9	9.89±1.9	110.50±102.5	103.43±20.6
16.May.2014			21.45±13.6	23.55±31.6	3.45±14.4	14.20±5.7	90.78±38.5	85.06±74

*=average of 3 chambers; A=chamber without direct N addition; B=chamber with direct N addition; A and B=average of chambers.

CONCLUSIONS

Our preliminary results confirmed the hypothesis of higher emissions of nitrous oxide from the soils that received both mineral nitrogen and vinasse. Irrigated areas are likely to emit higher N_2O fluxes, but those responses are not linear. Cerrado areas are unlikely to represent net source of N_2O to the atmosphere. We believe the precipitation and temperature dynamics across seasons may change the soil responses regarding N_2O, and our long monitoring plans are important to answer those questions.

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