An experiment to study N_2O emissions from beans crop in Brazil

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Abstract

Emissions of nitrous oxide (N_2O) by a beans culture (*Phaseulos vulgaris*) using organic and inorganic fertilizers were measured during a crop season. The experiment was performed in an experimental field of the "Departamento de Ciências Agrárias da Universidade de Taubaté – UNITAU" (23°01'S, 45°30'W) from July 2 to October 11, 2001. The parcels had 16 m^2, and they were separated by 5 m from each other. Three parcels were fertilized with ammonium sulphate and three with sewer silt, each one with 2 g N m^{-2}. A non fertilized parcel was used as a control. The N_2O flux determinations were made using the static chamber technique with a superficial area of 0.25 m^2. The quantitative determination of the N_2O concentration was done with the gas chromatography technique in conjunction with an electron capture detector (ECD). The fluxes were relatively low, ranging from 3.5 to 78.1 μg N_2O m^{-2} h^{-1} for parcels fertilized with ammonium sulphate, and from 3.5 to 68.8 μg N_2O m^{-2} h^{-1} for parcels fertilized with sewer silt. The control parcel had a lower flux, between 1.6 and 17.6 μg N_2O m^{-2} h^{-1}. The percentage of nitrogen emitted from the fertilization applied was 1.1% for both treatments, revealing no difference between the fertilizers used. Although the parcels do not show apparent differences, there were some non homogeneities in the soils, causing most of the observed variability.

Introduction

Nitrous oxide (N_2O) is one of the most important gases of the greenhouse effect, since in the low atmosphere it absorbs efficiently in bands of the infrared radiation emitted by the Earth (Cicerone, 1987; Isaksen & Stordal, 1986). Since N_2O has a long tropospheric lifetime of about 120 years, it can be transported into the stratosphere, where it is involved with the main chemical loss process of stratospheric ozone. Global average concentration increased steadily from about 275 parts per billion in volume (ppbv) in pre-industrial times to 316 ppbv at the end of 1999 (Hall et al., 2002).

Nitrous oxide is emitted into the atmosphere from natural and anthropogenic sources including the oceans, soil, combustion, biomass burning, use of fertilizer, land conversion, catalytic converters for automobiles, and various industrial processes. The biological production of N_2O results from the aerobic process of nitrification and from the anaerobic process of denitrification. Man is having an indirect effect on the nitrogen budget through the chemical conversion of atmospheric nitrogen into ammonium nitrate, the bulk of which is used as fertilizer (Shepherd et al., 1991). This N_2O emitted into the atmosphere is a significant incremental source of this trace gas, which was not accompanied by a corresponding increase in its sinks. The dominant sink is the reaction with O'D to produce NO, which is related with the destruction of the ozone layer in the stratosphere (Dobbie et al., 1999). Another sink is the soil, but it is small and has not been satisfactorily quantified. Several works have demonstrated the effect of the fertilizers on N_2O emissions; however, the estimates have associated large uncertainties due to a lack of information based in annual and seasonal variations, and the effects of the type of soil, crop, and agricultural management (Eichner, 1990, Dobbie et. al., 1999, Veldkanp and Keller, 1997, Kaiser et al., 1998).

Beans are an important cultivation in Brazil, constituting one of the five most important grain cultivations, with a harvest of more than 3 million tons in 2000 (IBGE, 2000). The bean culture was chosen due to its easy manipulation and because this cultivation is made during the whole year. The amount of agricultural fertilizers with nitrogen added in Brazil grew in recent years, with an increase from $10x10^6$ tons in 1996 to $18x10^6$ tons in 2000 (ANDA, 2001), mainly as ammonium sulphate and urea. The objective of this work is to study the N_2O emission from an experimental bean culture (*Phaseulos vulgaris*), which was subjected to two types of fertilization: ammonium sulfate and sewer silt.

Method

The project was developed in the experimental field of the "Departamento de Ciências Agrárias da Universidade de Taubaté – UNITAU" (23°01´S, 45°30´W), in a site with a medium texture yellow-red sandy clay soil. The experiment was conducted from July 2 to October 11, 2001, corresponding to the transition from winter to spring. In this period the meteorological conditions were stable most of the days, with a few days with nebulosity and rain. The environmental temperature ranged from about 20 °C to more than 32 °C.

The cropland was divided in 24 parcels of 16 m^2 each, which were separated from each other by 5 m lines. To study the nitrous oxide emission, the experiment was randomized with four repetitions for 6 treatments, for which were chosen the ammonium sulphate, an inorganic fertilizer and the sewer silt, an organic fertilizer. The ammonium sulphate was chosen because it is the most used by producers in the national scale. It presents an average of 20% nitrogen (N) and 24% of sulfur (S). It is highly stable, and does not absorb humidity. The sewer silt, which has been studied by UNITAU as a potential fertilizer, is a waste discarded by the state sanitation company "Companhia de Saneamento Básico do Estado de São Paulo - Sabesp". The analysis of the sewer silt at the UNITAU laboratory showed the following characteristics: 4.36% of total nitrogen; 0.02% of nitric nitrogen; 0.10% of ammonium and 4.24% of organic nitrogen.

From the soil analysis and the culture demand, the fertilizations setups were: 153 g for each parcel fertilized with ammonium sulphate (2 g N m^{-2}), and 734 g for the parcels fertilized with sewer silt (2 g N m^{-2}). The seeding occurred on July 2, 2001 (Julian day 183), at 2:00 PM, in a sunny day with local temperature of 26 ^{o}C. The first fertilization was performed during seeding with 1/3 of the total amount. On August 4 (day 216), an additional 1/3 was added as cover fertilization, and on September 20 (day 263), the last cover fertilization was made. Since during the first days the rain was insufficient, it was necessary to irrigate the parcels, once or twice a week, depending upon the water demand of the crop.

To evaluate the nitrous oxide flux emitted by cultivated soils the static chamber method (Christensen, 1983) was employed. The transparent acrylic chambers used in the experiment had cubic shape with 50 cm width and a volume of 125 l. The chambers were placed over the soil following a thin channel previously opened in the soil. To prevent the greenhouse effect inside the chambers, thin aluminum sheets were fixed in the faces that were receiving direct solar radiation. Air inside the chambers was extracted with a portable air pump, and it was injected into special stainless steel cylinders with a volume of 800 ml. These cylinders have an internal polishing which prevents adherence or chemical reactions of the sample gases with their walls.

Four equal-sized chambers were employed to determine fluxes from the parcels studied: three of them were placed over parcels with one type of fertilization, and the fourth one over the non fertilized parcel (control). There were two periods of sampling, one beginning at 10:40 LT (local time), and the second beginning at 13:00 LT. One air sampling was taken at time 0 minute (environmental air) and two more samplings were taken from each chamber after 30 and 60 minutes. After the second sampling (t=60 min.), the chambers were taken away up to the next sampling period, which took place around 13:00 LT. The chambers that were placed over parcels with one type of fertilizer in the morning, were placed on parcels with other type of fertilizer in the afternoon, and the same sampling procedures were followed. Samples were taken once a week with a total of 13 campaigns (except September 9), from the planting day until the leaves started to get dry, which occurred in October. The last measurement was made on October 11 (day 284).

N_2O concentration was obtained using the gas chromatography technique with an electron capture detector (ECD). The analyses were performed using a stainless steel column filled with Porapak-q polymer having a diameter of 1/8" and lengh of 3 m and a constant working temperature of 63 °C, while the detector was kept at a constant temperature of 350 ^{o}C. For calibration, a primary standard of nitrous oxide from the National Oceanic and Atmospheric Administration (NOAA) was used during the analyses, with a concentration of 311.0 ± 3.3 ppbv. The relative precision for each sample analyzed was 1.0% or less.

The N_2O flux was determined by the temporal variation of its mixing ratio inside the chamber, for a given time interval, following Schiller and Hastie (1994). To consider a flux as valid, two criteria were employed. The first of them is that the square of the correlation coefficient (r^2) must be larger than 0.90. This criterion has been employed by other researchers in the study of gas emissions to the atmosphere (Sass et al. 1992; Khalil et al., 1998). It is based on the assumption that the N_2O flux does not change over the time of the experiment. The second criterion is that the concentration determined by regression in *t = 0* must be close to the environmental air value, in order to eliminate cases where there may have been a perturbation during the placement of the chambers over the soil. From a total of 234 samples, 104 fluxes of nitrous oxide were determined; of these fluxes 12 had r^2 values lower than 0.90, which showed a disturbed increase of the concentration inside chambers. These fluxes were eliminated from the following analyses.

Results

Nitrous oxide fluxes obtained in three parcels fertilized with sewer silt, and the average flux for the control parcel (without fertilization) are presented in Figure 1. Arrows indicate the days of fertilization. In the first days after the seeding (day 183) the rain was insufficient (see Figure 1), so that the irrigation was necessary almost every day, with nitrous oxide fluxes ranging from 3.5 and 68.8 µg N_2O m^{-2} h^{-1}. Despite the irrigation and some days with rain, the soil was dry in many days of the experiment, so that the parcels 1 and 3 presented a delayed germination in comparison with the control parcel. On day 206 all parcels showed an increase in emission, with the parcel 3 having the largest peak (68.8 µg N_2O m^{-2} h^{-1}) of this treatment. The increase of nitrous oxide emission on day 206 must be related with the soil moisture, since there was rain two days before the sampling day, and the soil was wet during the sampling period. The increase of the emission associated with rain events was reported by Palm et al. (2002) in cropping rotation systems, with maize, soybean and peanuts. Dobbie et al. (1999) observed the highest emissions following the fertilizer application in small grain cereals, and in broccoli crops, particularly when associated with rainfall events. Fluxes obtained on day 255 showed the smallest values for all parcels. This occurred due to a failure in the irrigation system in the day before, which left the soil very dry. During the experiment period, the nitrous oxide emission by the unfertilized parcel (control) was between 1.6 and 17.6 µg N_2O m^{-2} h^{-1}.

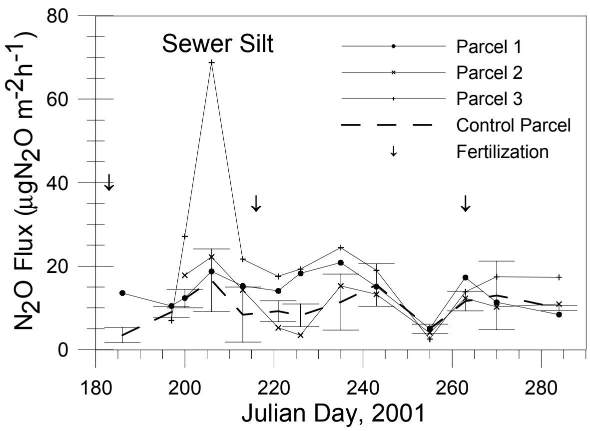


Figure 1. N_2O emission (μg N_2O m^{-2} h^{-1}) from beans crop obtained in three parcels fertilized with sewer silt, and the non fertilized parcel (control). The arrows show the days of fertilization.

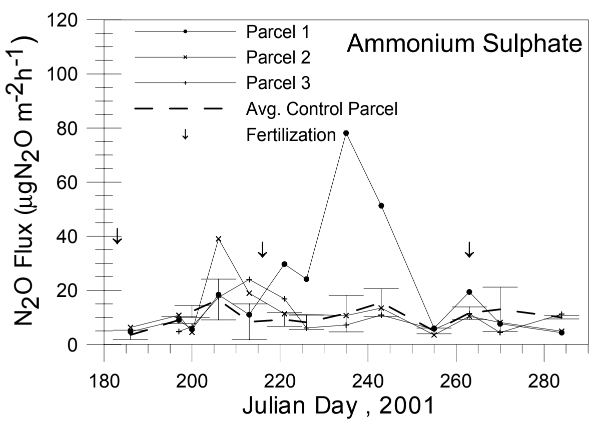
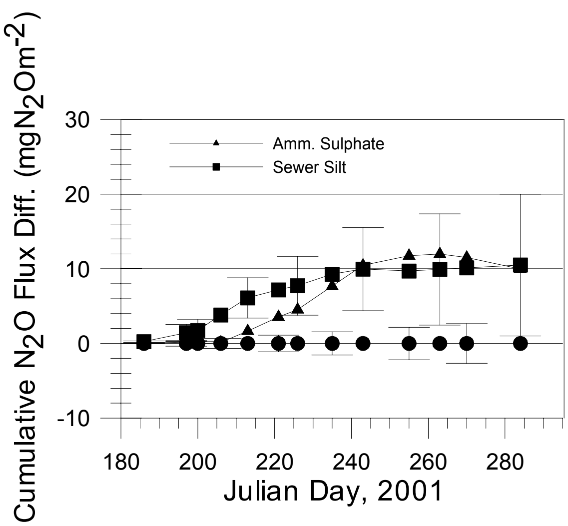


Figure 2. N_2O emission (μg N_2O m^{-2} h^{-1}) from beans crop obtained in three parcels fertilized with ammonium sulphate, and the non fertilized parcel (control). The arrows show the days of fertilization.

The fluxes of nitrous oxide from parcels fertilized with ammonium sulphate are presented in Figure 2. For the parcels with this treatment, the germination occurred about one week after the control parcel, and the growth was more uniform, with an emission of nitrous oxide between 3.5 and 78.1 μg N_2O m^{-2} h^{-1}. Differently from the sewer silt, in this treatment the highest flux occurred on day 235 in parcel 1, about the middle of the crop period with a value of 78.1 μg N_2O m^{-2} h^{-1}. Again, the highest emission was related with a rain event which occurred two days before the sampling, turning the soil wet, which can increase the microbiologic activity in the soil, thus increasing the nitrous oxide emission. A smaller peak was observed on day 206 (parcel 2), as was observed in parcels fertilized with sewer silt. Other small peaks were observed on day 213 (parcel 3), and days 221 and 263 (parcel 1). The lower emission on day 255 was due an irrigation failure. These events showed that the nitrous oxide emission is very sensitive to soil moisture and soil homogeneity of the parcels, such as pointed out by Shepherd at al. (1991) and Clayton et al. (1994) in studies of fertilized soils. The emission can be function of many factors, such as soil moisture, soil temperature, and soil water-filled pore space, which were not considered in the experiments (Eichner, 1990, Shepherd et al., 1991; Veldkamp and Keller, 1997, Dobbie et al., 1999).

The cumulative difference (fertilized minus control parcel) of N_2O loss from the average emission for each treatment over the whole period was calculated by linear interpolation between samplings and is presented in Figure 3. In the first weeks, all treatments presented a similar emission pattern, with the fertilized parcels detaching from the control parcel after July 25 (day 206). The fertilization did not cause a direct effect in the emission. This effect could be related to the distribution of the fertilization in three fractions, which could attenuate the effect, revealing that other factors were contributing to the emission. At the end of the crop period, both types of fertilized parcels had almost the same loss of nitrous oxide, with a cumulative emission of 34.6 ± 11.7 mg N_2O m^{-2} for ammonium sulphate, 35.2 ± 9.5 mg N_2O m^{-2} for sewer silt, and 24.7 ± 3.1 mg N_2O m_{-2} for the control parcel, resulting a total loss about 1.4 times higher than



the one of the control parcel.

Figure 3. Cumulative N2O flux difference between the fertilized parcels and control parcel (μg N_2O m^{-2} h^{-1}). For clearness of the figure, the standard deviations were plotted only for some points.

The percentage of nitrogen loss obtained for parcels fertilized were 1.10% for ammonium sulphate, and 1,12 for sewer silt, with individual parcels ranging between 0.70% and 1.65%. These values are within the range obtained by Galbally (1992) and Eichner (1990). These authors concluded that the N_2O emission may vary between 0.001% and 6.8%, depending on the fertilizer. But it is lower than that obtained by Shepherd et al. (1991), which determined a conversion of 5%, in average, of nitrogen from fertilization. The nitrous oxide emission averages for both treatments were very similar, so that there is no difference between these two types of fertilizers. Studies reported by Eichner (1990), using the same fertilizer ranging from 176 to 528 kg N ha^{-1} in different crop systems, showed an emission of 1.8% to 15.3% of nitrogen from the applied fertilization. This high variability reveals the need of new research of N_2O emissions to better understand this component of the global budget.

Conclusions

Emission of nitrous oxide was studied in an experimental field in Brazil during the dry period using two types of fertilizers: sewer silt and ammonium sulphate. A non fertilized parcel was used as a control, whose emission ranged from 1.6 to 17.6 μg N_2O $m^{-2}h^{-1}$. For the parcels fertilized with sewer silt the emission was between 3.5 and 68.8 μg N_2O $m^{-2}h^{-1}$, while for the parcels fertilized with ammonium sulphate, the emission ranged from 3.5 to 78.1 μg N_2O $m\text{-}^{2}h^{-1}$. The ratio of total emission of nitrogen to fertilization applied was 1.1% for both treatments. The relatively low emissions observed were probably related with the relative dry condition during the crop and to some non homogeneity of the soil in the parcels. Although these values of emissions were in the lower range in comparison with earlier studies, they show the importance of agriculture as a source of nitrous oxide to the atmosphere.

Acknowledgments

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