Available online at www.sciencedirect.com
ScienceDirect
Atmospheric Environment 42 (2008) 3882–3887
ATMOSPHERIC ENVIRONMENT
www.elsevier.com/locate/atmosenv

Short communication

Effects of rare-earth fertilizers on the emission of nitrous oxide from agricultural soils in China

Zhangwei Wang, Xiaoshan Zhang*, Yujing Mu

Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Received 22 July 2007; received in revised form 10 January 2008; accepted 10 January 2008

Abstract

Rare-earth fertilizers have long been used in agriculture in China. The consequences of these applications are of more recent concern. In our study, an experiment was carried out to identify the effects of applying rare-earth fertilizers on emission of nitrous oxide from paddy and dryland soils in northern China. Normal dosage of rare-earth fertilizers only, normal dosage of urea only, normal dosage of urea plus rare-earth fertilizers, and a normal urea application plus a 10-fold increase in the dosage of rare-earth fertilizers were applied to the soils in pots, prepared for our experiment. A static closed-chamber technique was used to measure nitrous oxide emission flux from the soil in the pots before and after fertilization during the experiment. The results show that the application of only rare-earth fertilizers did not have any visible effect on the emission of nitrous oxide from both paddy and dryland soils. Applying a normal dosage rare-earth fertilizers plus urea led to greater emission of nitrous oxide from the soils than only applying the normal dosage of urea. When a 10-fold increase of rare-earth fertilizers dosage was added to a normal dosage of urea, the emission of nitrous oxide from the soils increased even further. We speculate that the application of rare-earth fertilizers leads to an increase of available NH_4^+-N from urea hydrolysis and activate bacteria and enzymes in nitrification and de-nitrification.

Keywords: Rare-earth fertilizer; Nitrous oxide emission; Agricultural soils

1. Introduction

Nitrous oxide (N_2O) is a greenhouse gas (Wang and Sze, 1980) and involved in the destruction of stratospheric ozone (Crutzen, 1970). Long-term global measurements of atmospheric N_2O show an annual growth rate of 0.3%. During the 1990s, the concentration of N_2O was about 311 ppbv in the atmosphere (Bouwman, 1990; Battle et al., 1996). Agricultural soils are significant sources of N_2O (Iserman, 1994; Harrison et al., 1995). The emission of N_2O from the application of nitrogen fertilizer to agricultural soils is currently estimated to be 2–3 Tg yr^{-1} N_2O-N (1 Tg = 10^{12} g), which accounts for about 21–46% of total emission from global anthropogenic sources (FAO and IAEA, 1992). Therefore, the emission of N_2O from agricultural soils has generated considerable attention.

Rare-earth elements (REEs) are members of Group IIIA in the periodic table and all have similar physical and chemical properties. Fertilizers containing REEs (REE fertilizers) have been applied as microelement fertilizers in agriculture since the 1980s. Subsequently, physiological effects of REE fertilizers have been reported in such

*Corresponding author. Tel./fax: +86 10 62849369.
E-mail address: zhangxsh@rcees.ac.cn (X. Zhang).

1352-2310/$ - see front matter
doi:10.1016/j.atmosenv.2008.01.018

instances as the improvement of membrane stabilization and hormone effectiveness, growth response to coleoptile segments, better nitrogen fixation efficiency and reduction in water loss by plants (Guo, 1998; Brown et al., 1990). Currently, compound fertilizers such as urea, organic compounds and carbon ammonium mixed with REEs are widely used by Chinese farmers (Guo, 1998; Huo and Xiao, 1998). It is estimated that application of REE fertilizers in China covered approximately $3.7 \times 10^6\,hm^2$ in 1993 and $1.6–2.0 \times 10^7\,hm^2$ in 1995 (Peng and Wang, 1995). Other studies also pointed out that exterior rare earth has an effect on the activities of microbes and enzymes and therefore affected nitrogen transformation in soils (Chu et al., 2000a, 2001; Xu and Wang, 2001; Ozaki et al., 2006). N_2O is primarily emitted into the atmosphere as a result of microbiological activities through the nitrogen cycle in soils (Bouwman, 1990). Consequently, the application of REE fertilizers to agricultural soils might also affect the process of N_2O generation and further increases the uncertainty of emission estimates of N_2O from agricultural soils. In this study we carried out an experiment to test the effect of applying rare-earth fertilizers on N_2O emission from agricultural soils in northern China.

2. Materials and methods

2.1. Soil and REE fertilizers

Two types of agricultural soil from the north of Beijing (39°60′N, 116°30′E) were used in this experiment. On one of these soils rice had been cultivated for more than 20 years (hereafter called paddy soil) and on the other wheat had been grown for about 15 years (hereafter called dryland soil). Both soils are typically luvic cinnamon soils found in the temperate monsoon climate of the region. Soil from the first 20 cm of the surface layer was collected. The basic characteristics of soils were analyzed according to the methods described by Kim (1995) and are presented in Table 1. The REE fertilizers used in this study was supplied by the Research Center for Agriculture Application of Rare Earth Elements in China. The concentration of REE fertilizers is $212.4\,mg\,L^{-1}$, identified as a rare-earth oxide. Individual rare-earth oxide components, as percentages, are listed in Table 2.

2.2. Experiment

Both types of soils that we had collected were thoroughly mixed and then 20 kg (fresh weight) soil was placed in pots for treatment. Five treatments were prepared for both paddy and dryland soils. All treatment soils were stabilized for 2 weeks before REE fertilizers and urea were applied. According to the information from the Research Center for Agriculture Application of Rare Earth Elements in China, the recommended dosage of REE fertilizers for agricultural soil ranged between 0.7 and $3.6\,kg\,h\,m^{-2}$. In our study the normal dosage of 1.35 kg REE fertilizers per hm^2, corresponding to 0.6 mg REE fertilizers per kg experimental soil ($0.6\,mg_{RE}\,kg^{-1}$), was used. We also applied a 10-fold dosage of REE fertilizers ($6.0\,mg_{RE}\,kg^{-1}$) to investigate the consequences of excessive application of REE fertilizers. The application dosage of urea was 0.15 g per kg of soil ($0.15\,g_{urea}\,kg^{-1}$) following the recommendation of the fertilization manual (Pang, 1994), which corresponds to 3.0 g urea per treatment.

A pre-treatment test was conducted to investigate the intrinsic difference in experimental pots of N_2O emission from the paddy soil and dryland soil. Each treatment applied 3 g urea, and five replicates were set for each of the soils.

Table 2
Components of REE fertilizers

Component	La_2O_3	CeO_2	Pr_6O_{11}	Nd_2O_3	Sm_2O_3	Others
Percentage	28.0	50.8	5.2	15.8	0.1	<0.1

Table 1
Characteristics of experimental soils

Soil	Total N ($g\,kg^{-1}$)	Total P ($g\,kg^{-1}$)	Organic matter ($g\,kg^{-1}$)	$pH_{(soil:H_2O=1:5)}$
Paddy soil	11.1	5.6	21.3	7.40
Dryland soil	9.8	8.6	14.5	7.25