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Analysis of production and emission processes of nitrous oxide at the beginning of flood irrigation by isotopomer ratios

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1. Introduction

Agricultural soil is the largest anthropogenic source of nitrous oxide (N_2O) which contributes to global warming and ozone depletion. N_2O is produced by microbial processes of nitrification as a byproduct of hydroxylamine oxidation, and denitrification as an intermediate product of nitrite reduction and is further reduced to N_2. In rice paddy soils, N_2O emissions were observed in association with water supplies and drainage practices (for midseason aeration or for rice harvest). N_2O emitted at the beginning of flood irrigation is considered to be derived from denitrification, but production and consumption processes of N_2O in the soil or transport process to soil surfaces are not fully understood.

The purpose of this study is to clarify both contribution of denitrification for N_2O emissions and transport process of N_2O in the soil at the beginning of flood irrigation by analyzing isotopomer ratios. It is suggested that isotopomer ratios of N_2O (bulk nitrogen and oxygen isotope ratios, $d^{15}N^{bulk}$ and $d^{18}O$, and intramolecular ^{15} N site preference, SP) are useful parameters that provide information about microbial metabolisms described above. We tried to figure out temporal changes of production and consumption processes of N_2O or its transport process affected by a water supply using spatial variability of soil moisture content.

2. Materials and methods

N_2O fluxes were measured by closed chamber method 7 days after the beginning of a water supply on Apr. 20, 2011 at 8 plots of paddy soils in Tsukubamirai, Ibaraki Prefecture, Japan. The soil type was a Gray lowland soil. Isotopomer ratios of soil-emitted N_2O were calculated from those of N_2O in chamber air and ambient air assuming mixing of soil-emitted gases and ambient air in chambers. To measure concentrations and analyze isotopomer ratios of N_2O in the soil, soil gases at 10 cm depth were collected by soil gas samplers with silicon tubes at 6 plots. N_2O flux was monitored every 2 h with an automated chamber system at a plot. Soil samples from 0-10 cm depth at each plot were collected and used for extraction with 10% KCl solution for analysis of the soil nutrient content. The water filled pore space (WFPS) was calculated from the volumetric water content and porosity.

3. Results and discussion

High N_2O emissions (80-217 mcgN/m^2/h) were observed at plots where groundwater level was 1 cm depth. On the other hand, low N_2O emissions (6-60 mcgN/m^2/h) and high N_2O concentrations of soil gases (134-160ppm) were observed at plots where water depth were 1-5 cm. Isotopomer ratios of N_2O emitted from soil surfaces were close to the values of N_2O in the soil, although they indicated relatively higher values than those of N_2O in the soil at a plot where water depth was 5 cm. Isotopomer ratios of N_2O at plots where groundwater level was 1 cm depth showed values near the range of the reported values of N_2O which produced by denitrification in pure culture. On the other hand, isotopomer ratios of N_2O at water depth were 1-5 cm were relatively higher than those of N_2O at plots where groundwater level was 1 cm depth. It was thought to be due to consumption of a part of N_2O by denitrification which is associated with elevations of isotopomer ratios of residual N_2O by isotopic fractionation. N_2O concentrations and isotopomer ratios in the soil were near the values of N_2O in ambient air at the plots where WFPS were low.

Therefore, it was considered that N_2O was produced by denitrification at shallow depth with the increase of WFPS, and emitted to air by the effects of both upward advection by increasing ground water levels and molecular diffusion. N_2O emissions became low and N_2O accumulated in the soil when soil surfaces were covered with water. It was assumed to be due to low diffusion coefficient of dissolved N_2O. In addition, it was thought that a part of N_2O was consumed by reduction to N_2 under anaerobic conditions and residual N_2O accumulated in the soil.

Keywords: Nitrous oxide, Denitrification, Isotopomer