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Factors controlling episodic soil CO₂ and N₂O emissions from managed grassland and corn field in southern Hokkaido, Japan

(北海道南部の草地、飼料畑土壌からの突発的CO₂およびN₂O排出の制御因子)

Nitrous oxide (N₂O) and carbon dioxide (CO₂) emissions from soil were highly variable in time caused by the complex set of environmental variables such as soil temperature and moisture, soil organic matter (SOM) content, O₂ status as well as nutrient availability. Gas fluxes at hot moment frequently accounts for larger proportion of greenhouse gas (GHG) budgets. Temporal heterogeneity is accentuated in agricultural relative to non-managed landscapes. Land management causes physical and biogeochemical disturbance of extreme magnitude and in pulsed events. Episodic high CO₂ and N₂O fluxes have been reported after events including drying-rewetting, rainfall, freezing-thawing, fertilizer and manure additions, harvest and tillage. Therefore understanding the temporal variability of CO₂ and N₂O fluxes is key importance to reliably estimate these gases fluxes and to develop mitigation strategies. In this study, episodic N₂O and CO₂ fluxes at hot moments in managed grassland and cornfield was evaluated by box plot method, and the effects of nutrient management and soil properties associated with tillage including bulk density, soil moisture content, aggregate size on CO₂, N₂O and NO emissions were studied by laboratory incubation, and then to identify key factors affecting the episodic CO₂ and N₂O emission.

1. Evaluation of N₂O and CO₂ hot moments in managed grassland and cornfield

Soil N₂O and CO₂ fluxes from managed grassland and cornfield in Shizunai and Shin-Hidaka, Hokkaido, Japan were monitored by closed chamber at plots applied with fertilizer (F), manure plus fertilizer (MF), and no-fertilizer (CT). The N₂O and CO₂ fluxes at hot moments were analyzed by box plot method. The characteristics of N₂O and CO₂ hot moments were generally similar in two sites but varied between grassland

and cornfield. Threshold of N₂O peak event was higher in cornfield than in grassland due to higher rates of fertilization and mineralization. Events of temperature > 20 °C, rainfall, harvest, fertilizer and manure applications significantly promoting N₂O hot moment in grassland, while only rainfall event significantly induced N₂O hot moment in cornfield. More sensitive response of N₂O hot moment to fertilizers addition event in grassland can be attributed to the much lower NO₃⁻ contents. Greater magnitude of N₂O hot moment in cornfield after rainfall event was caused by more sufficient N supply for denitrification. Except the contribution of N₂O hot moment in cornfield of Shin-Hidaka ranged from 5.9%~19.4%, N₂O hot moment accounted for more than one-third of the annual total emissions in F and MF plots. The CO₂ flux was strongly controlled by soil temperatures, and much less episodic than N₂O flux. Therefore mitigating episodic N₂O flux would greatly reduce annual N₂O production, and fertilization avoiding rainfall in grassland could be one option.

2. The mechanism of key factors inducing episodic CO₂ and N₂O fluxes

The CO₂ and N₂O productions of repacked soil cores with different aggregate sizes (0~2, 2~4.5mm), gravimetric water contents (GWC 0.35, 0.45 g g⁻¹) and bulk densities (BD 0.45, 0.66 g cm⁻³) were studied by incubation. The insignificant effects of BD, GWC or nutrient management on CO₂ flux contributed to the less episodic nature of CO₂ fluxes in field. Higher microbial biomass carbon (MBC) and water extractable organic carbon (WEOC) contents lead to greater CO₂ production in larger aggregate. The enhanced aeration by tillage was not likely to induce CO₂ hot moment due to the poor relationship between air-ratio with CO₂ emission. Optimal soil moisture for CO₂ emission was widely provided from 29~83% water filled pore space (WFPS), partly explaining the weak effect of rainfall on CO₂ hot moment. Manure addition enhanced N₂O emission by providing higher NO₃⁻. The extremely high N₂O production of high GWC and high BD treatments with 80% WFPS was owed to higher denitrification rate, and N₂O emission at low WFPS was generally small. This implied that the prompt increase in N₂O emission by rainfall was more typical for denitrification. Larger aggregate emitted more N₂O at low WFPS due to more anaerobic volume created by quicker soil respiration rate. N₂O production was much higher in small aggregate at 80% WFPS caused by greater NO₃⁻ supply by nitrification. Besides high WFPS, soil mineral N was required for high episodic N₂O emissions. Low NO₃⁻ level and high WFPS led to high potential of N₂O peak induced by fertilizer addition in grassland.