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Nitrous oxide emissions in response to straw incorporation is regulated by historical fertilization☆

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ABSTRACT

The incorporation of crop straw with fertilization is beneficial for soil carbon sequestration and cropland fertility improvement. Yet, relatively little is known about how fertilization regulates the emissions of the greenhouse gas nitrous oxide (N_2O) in response to straw incorporation, particularly in soils subjected to long-term fertilization regimes. Herein, the arable soil subjected to a 31-year history of five inorganic or organic fertilizer regimes (unfertilized; chemical fertilizer application, NPK; 200% NPK application, 2 × NPK; manure application, M; NPK plus manure application, NPKM) was incubated with and without rice straw to evaluate how historical fertilization influences the impact of straw addition on N_2O emissions. The results showed that compared to the unfertilized treatment, historical fertilization strongly increased N_2O emissions by 0.48- to 34-fold, resulting from increased contents of hot water-extracted organic carbon (HWEOC), NO_3^-, and available phosphorus (Olsen-P). Straw addition had little impact on N_2O emission from the unfertilized and NPK treatments, primarily due to Olsen-P limitation. In contrast, straw addition increased N_2O emissions by 102–316% from the 2 × NPK, M, and NPKM treatments as compared to the corresponding straw-unamended treatments. These results indicated that N_2O emissions in response to straw addition were largely regulated by historical fertilization. The N_2O emissions were closely associated with the depletion of NO_3^- and decoupled from change in NH_4^+ content, suggesting that NO_3^- was the main substrate for N_2O production upon straw addition. The stoichiometric ratios of HWEOC to mineral N and mineral N to Olsen-P were key factors affecting N_2O emissions, underscoring the importance of resource stoichiometry in regulating N_2O emissions. In conclusion, historical fertilization largely regulated the impacts of crop straw incorporation on N_2O emissions via shifts in NO_3^- depletion and the stoichiometry of HWEOC, mineral N, and Olsen-P.

1. Introduction

Crop straw incorporation into soils, as a prevailing agricultural practice, is of significant importance to soil organic carbon (SOC) sequestration and crop productivity improvement and contributes to climate change mitigation and sustainable agroecosystems (Lal, 2004; Paustian et al., 2016). However, such climate benefits from straw incorporation may be negated by the increased emissions of nitrous oxide (N_2O) (Hu et al., 2013; Lugato et al., 2018) — a major greenhouse gas (GHG) related to the destruction of the stratospheric ozone layer (Ravishankara et al., 2009). Recently, some concerns have been raised regarding N_2O emissions under straw incorporation—an issue that has been less well studied in comparison to other agricultural practices, such as chemical fertilizers and manure application (Meng et al., 2005; Yang et al., 2015; Huang et al., 2017; Zhang et al., 2019). Straw addition greatly affects soil N_2O emissions, but the results are inconsistent. For example, straw addition has been reported to have positive (Li et al., 2013b; Xia et al., 2018), neutral (Malhi and Lemke, 2007; John et al., 2020),

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