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Rational utilization of leguminous green manure to mitigate methane emissions by influencing methanogenic and methanotrophic communities

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ABSTRACT

Although rice straw return is widely recommended for maintaining or improving soil fertility and rice yields, it inevitably increases methane (CH_4) emissions. Effective measures to mitigate CH_4 emissions while guaranteeing grain yields are urgently needed. A 2-year mesocosm experiment was conducted. Six management systems, i.e., no residue (traditional management, CF), 100% rice straw (a popular practice among farmers, FR), 50% rice straw (F1/2R), leguminous green manure (FM), mixture of leguminous green manure and 100% rice straw (FMR), and a mixture of leguminous green manure and 50% rice straw (FM1/2R), were used. Compared with the CF, the organic residue returns could effectively improve rice productivity but increase the CH_4 emissions. Notably, when compared with the FR, both F1/2R and FM could reduce the CH_4 emissions, with equal crop yields, and FM1/2R not only increased the rice yields but also reduced the CH_4 emissions, whereas FMR increased the rice yields and the CH_4 emissions. Applications of organic residues significantly increased the soil methane production potentials (MPPs), methane oxidation potentials (MOPs), the abundances of methanogens and methanotrophs, and changed methanogenic and methanotrophic community structures in comparison with the CF. The partial least squares path model (PLS-PM) results showed that the MPPs had a strong direct effect on CH_4 emissions, whereas an abundance of methanogens could serve as a proxy for predicting CH_4 emissions. Moreover, relatively high MOPs associated with high Type I/Type II methanotroph ratios and relatively low dissolved organic carbon (DOC) concentrations were found to be central in lowering CH_4 emission fractions under the F1/2R and FM1/2R treatments. Above all, the combined utilization of leguminous green manure and rice straw exhibited potential prospects for the enhancement of rice yields and for the mitigation of CH_4 emissions, and the practice of mixing leguminous green manure with 50% rice straw performed the best of the treatments tested.

1. Introduction

Methane (CH_4) is the second largest contributor to radiative forcing after carbon dioxide, causing approximately 15–20% of the observed global warming (IPCC 2013). In the 2000 s, global CH_4 from paddy soils was estimated at 33–40 Tg CH_4 $year^{-1}$, accounting for 6–7% of global emissions (Ciais et al., 2014). Paddy CH_4 emissions result as an integrated effect of production and consumption (oxidation) in soils. Better knowledge of the processes that affect CH_4 emissions may reveal more means of effectively mitigating the CH_4 emissions from paddy soils.

Methane is the final product of anaerobic methanogens, which include acetoclastic and hydrogenotrophic methanogens and play a vital role in all biogenically produced CH_4 found in anoxic habitats (Conrad, 2007). To date, only the genera *Methanosarcina* and *Methanosaeta* (both belonging to order *Methanosarcinales*) have been identified as

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