Importance of Harvesting Time of Winter Cover Crop Rye as Green Manure on Controlling CH_4 Production in Paddy Soil Condition

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Abstract Winter cover crop cultivation provides high amount of organic matter when applied as green manure in paddy soils but can adversely increase methane (CH_4) production during rice cultivation. Main organic components (cellulose, hemicellulose, lignin,) concentrations of cover crops may vary according to the different harvesting dates and might affect differently CH_4 production in the paddy soil when applied as green manure. In this study, aboveground biomass of rye (*Secale cereale* L.) was harvested over a week interval for 9 weeks (April 23 to June 19) and then mixed with dried paddy soil with the rate of 5 Mg ha^{-1} on dry-weight base for incubation test. The concentration of total C, cellulose, and lignin of rye biomass was steadily increased with crop maturing, but total N and labile C concentrations were reversely decreased. Methane production activity has very high positive correlation with labile C (water-soluble C, hot-water-extractable C) concentration of rye biomass but negative correlation with C/N ratio, total C, and lignin concentrations. Therefore, CH_4 production activity was higher in soils treated with early-harvested rye to that of the late-harvested rye treatment. Rye that was harvested on the 2nd–3rd week after the 1st harvesting date had slightly lower labile C but very high amount of total N, which could be the optimum harvesting period to regulate CH_4 production without compromising its ability to provide added N supply when used as green manure in paddy soil. Conclusively, selection of the

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optimum period of rye harvesting is considerable to regulate CH_4 production and improve soil fertility during green manure application in paddy soils.

Keywords Winter cover crop • Cellulose • Lignin • Hemicellulose • Methane • Paddy soil

Introduction

Green manuring is considered an important management practice to increase the soil organic matter level and reduce the dependence on mineral fertilizers. Nonleguminous cover crops, like rye (*Secale cereale* L.) and barley (*Hordeum vulgare*), have comparatively higher biomass productivity (Zhang et al. 2007) and may supply more nutrients into the soil as green manure. Rice cultivation in the flooded paddy soil is one of the major anthropogenic sources of CH_4, which has a 25 times higher GWP than carbon dioxide (CO_2) over a 100-year time horizon. Methane is mainly produced from the decomposition of organic matter by methanogenic archaea under extremely reduced conditions (Ghani et al. 2000). High organic matter inputs may accelerate CH_4 emissions; however, little is known on the effect of quality of cover crop incorporation to CH_4 production in paddy soils. In this study, rye was harvested at different periods, and its main organic components such as total C and N, cellulose, hemicelluloses, and lignin contents were investigated. To decide the optimum harvesting and incorporation of rye biomass as green manure for minimizing CH_4 emission during rice cultivation and maximizing nutrient supply, different-stage-harvested biomasses were mixed with soil and incubated for 4 weeks. Net CH_4 production activity was evaluated in the incubation test, and then total CH_4 production potential was estimated by multiplying with biomass productivity.

Materials and Methods

Rye harvesting for green manure purpose is recommended in the mid-May in Southern Korea. In this study, rye was harvested at a week interval for 9 weeks from April 23 to June 19, 2010. The chemical properties such as total C and N, water-soluble and hot-water-extractable C and N, cellulose, hemicelluloses, and lignin contents were determined. To investigate CH_4 production activity, 5.0-g air-dried paddy soil was inoculated into 20-mL serum bottle bottles and added with 0.139 g of rye (on dry-weight basis) and maintained under anaerobic condition by adding 10 mL distilled H_2O. The serum bottles were sealed with a butyl rubber stopper, and its CH_4 headspace concentration was monitored for 4 weeks.

Table 1 Total and labile carbon and nitrogen concentration of rye biomass as affected by different harvesting time

	Carbon (%, wt wt^{-1})			Nitrogen (% wt wt^{-1})		
Month/date	Total	WS	HWE	Total	WS	HWE
4/23 (1st)	49.1	2.01	0.75	2.73	0.75	0.26
4/30 (2nd)	50.8	1.75	1.02	2.98	1.02	0.29
5/07 (3rd)	51.5	1.19	0.67	1.62	0.67	0.12
5/15 (4th)	52.9	1.09	0.35	0.89	0.35	0.19
5/20 (5th)	52.8	0.75	0.07	0.56	0.07	0.05
5/28 (6th)	53.6	0.88	0.12	0.60	0.12	0.06
6/04 (7th)	53.9	1.31	0.04	0.31	0.04	0.03
6/11 (8th)	54.1	0.99	0.06	0.35	0.06	0.03
6/19 (9th)	54.3	0.39	0.02	0.33	0.02	0.02

Note: *WS* water soluble; *HWE* hot water extractable

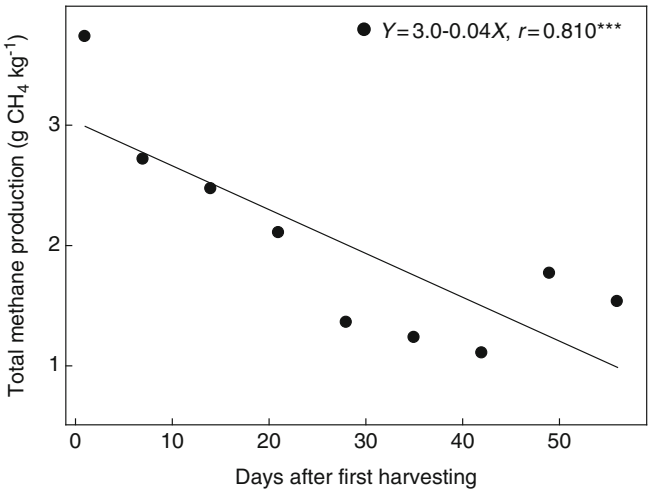

Fig. 1 Total CH_4 production in rye biomass incorporated soil (5 Mg ha^{-1} on dried-weight base) as affected by different harvesting time

Results and Discussion

The contents of total C, cellulose, and lignin of rye biomass steadily increased with delaying harvesting season. In contrast, the contents of total N, protein, and labile C were changed reversely (Table 1). Under the same weight of rye biomass incorporation (5 Mg ha^{-1} on dried-weight base), CH_4 production activity was significantly decreased with delaying harvesting season (Fig. 1). Different with the general information, which CH_4 production has high positive correlation with total C content (Wang et al. 1993), CH_4 production activity has significantly negative correlation with total biomass C, lignin, and cellulose but highly positive correlation with labile C and total N concentration. Total CH_4 production potential

which was estimated by multiplying net CH_4 production activity with biomass productivity (1.6–8.5 Mg ha^{-1} on dried-weight base) was increased with delaying the harvesting time. In considering the highest nutrient (N) supplying time as green manure, the optimum harvesting and incorporation time of rye biomass as green manure might be the mid-May, with the crop having the lowest C/N ratio, in Southern Korea.

Conclusion

Selection of the optimum time of rye harvesting is considerable to regulate CH_4 production and improve soil fertility during green manure application in paddy soils.

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