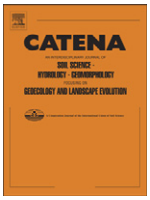
Catena 140 (2016) 9–14

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena



Dolomite application enhances CH_4 uptake in an acidic soil

Muhammad Shaaban [a], Qi-an Peng [a], Shan Lin [a], Yupeng Wu [a], Muhammad Salman Khalid [a], Lei Wu [a], Yongliang Mo [a,b], Ronggui Hu [a,*]

[a] College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China
[b] Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China

ARTICLE INFO

Article history:
Received 10 August 2015
Received in revised form 10 January 2016
Accepted 14 January 2016
Available online 21 January 2016

Keywords:
Ultisol
Soil pH
Nitrogen fertilizer
Moisture
Greenhouse gas

ABSTRACT

Methane (CH_4) is a potent greenhouse gas and agricultural soils are the main source of atmospheric CH_4. Information regarding CH_4 emission from acidic soils is limited in the literature. A laboratory study was conducted to examine CH_4 emissions following dolomite application in an acidic paddy soil. Dolomite was applied to the acidic soil (Ultisol) under two levels of moisture and nitrogen (N) fertilizer in a factorial design. Dolomite was applied at the rates of 0, 1, and 2 g kg^{-1} soil (D0, D1, and D2 respectively) under two moisture levels of 55% and 90% water-filled pore space (WFPS). Each treatment of dolomite under two moisture levels was further treated with 0 and 200 mg N kg^{-1} soil. Soil moisture of 90% WFPS produced ($p \leq 0.001$) CH_4 emissions while uptake was observed in 55% WFPS. Nitrogen fertilizer application significantly increased CH_4 emissions in 90% WFPS while inhibited uptake in 55% WFPS. Maximum cumulative CH_4 emission (1784.88 μg CH_4-C kg^{-1}) was observed under 90% WFPS in N fertilizer application without dolomite application. Application of dolomite decreased cumulative CH_4 emissions by 39% in 90% WFPS, and enhanced CH_4 uptake up to 15 times in 55% WFPS with D2 treatment in fertilizer treated soil. Results indicated that dolomite application has the potential to enhance the uptake and to decrease the emissions of CH_4 in acidic soils.

1. Introduction

Methane (CH_4) is a potent greenhouse gas and agricultural soils are regarded as a main source of CH_4 sink and release into atmosphere (Page et al., 2010). The main factors that affect CH_4 emission or uptake include soil aeration (Weslien et al., 2009), moisture (Hiltbrunner et al., 2012), organic carbon (Bolan et al., 2011), fertilizers (Page et al., 2010), and soil pH (Saari et al., 2004).

Soil pH is a key factor controlling the production and oxidation of CH_4 (Page et al., 2010). Although some studies reported that CH_4 production increased with an increase in soil pH (Le Mer and Roger, 2001), the CH_4 emission is generally decreased with an increase in soil pH (Schnell and King, 1994). The increase in soil pH promotes the growth of methanotrophs that oxidize CH_4 (Inubushi et al., 2005). Fu et al. (2012) reported that low soil pH inhibited activities of CH_4 oxidizing microorganisms and thereby CH_4 emission was observed under acidic conditions. Therefore, acidic soils can be a source of CH_4 release instead of consumption. Soil pH of agricultural soils has decreased worldwide mainly due to the excessive use of nitrogen (N) fertilizers (Qu et al., 2013). Nitrogen fertilizers contribute annually about 20 to 33 kmol H^+ ha^{-1} in agricultural soils, subsequently causing soil acidification (Guo et al., 2010). And thus the decline in soil pH impacts CH_4 emissions and uptake (Menyailo et al., 2012).

To rectify acidic soils different strategies are recommended, for instance, the optimal use of N fertilizer and application of lime or dolomite. Dolomite [$CaMg(CO_3)_2$] is an appropriate and economical natural liming material used for the amelioration of acidic agricultural soils (Shaaban et al., 2014b). Dolomite is highly alkaline, contains calcium (Ca^{2+}) and magnesium (Mg^{2+}) in its structural layer, and therefore aids to diminish acidity as well as Ca and Mg deficiencies in soils (Bolland et al., 2004). Application of dolomite not only increases soil pH, but also influences CH_4 production and oxidation (Bolan et al., 2011).

Although it is well known that dolomite is a good ameliorating agent of soil properties, the effects of dolomite application on soil CH_4 emission and/or uptake are not clearly understood. We hypothesized that the application of dolomite can trigger C and N cycling and thereby decrease or increase in CH_4 emissions. Therefore, we designed a laboratory study which aimed to examine the effects of dolomite application on CH_4 emissions/uptake from an acidic soil. Furthermore, the interactions between dolomite application with N fertilizer and moisture on CH_4 emissions were also investigated.

2. Materials and methods

2.1. Soil sampling and analysis

Soil used in this study was sampled from a rice paddy field in Xianning city of Hubei province, China (30°01′16.4″N, 114°21′51.7″E;

---

* Corresponding author.
E-mail addresses: rghu@mail.hzau.edu.cn, shabanbzu@hotmail.com (R. Hu).

http://dx.doi.org/10.1016/j.catena.2016.01.014
0341-8162/© 2016 Elsevier B.V. All rights reserved.

Table 1
Characteristics of soil used in the experiment[a].

pH	Total C (g kg^{-1})	Dissolved organic C (mg kg^{-1})	Total N (g kg^{-1})	NH_4^+-N (mg kg^{-1})	NO_3^--N (mg kg^{-1})	Bulk density (g cm^{-3})	Clay (%)	Silt (%)	Sand (%)
5.52	1.90	146.42	0.16	10.01	0.29	1.2	26.23	61.13	12.62

[a] Soil is classified as Ultisol (Soil Survey Staff, 2010, Soil Taxonomy System of USA), and Acrisols and Ferralsols (FAO/UNESCO, 1974).

43 m above sea level), classified as Ultisol (Soil Survey Staff, 2010, Soil Taxonomy System of USA), and Acrisol and Ferralsol (FAO/UNESCO, 1974). The soil was obtained from 0 to 20 cm depth from five points in the selected field. Soil samples were mixed and homogenized to make a composite sample. And after plant debris, stones, and large organisms such as earthworms were removed, soil was stored in plastic bags and transported to the laboratory.

Soil was air dried, crumbled, and passed through a 2 mm diameter sieve. Soil pH was determined in a soil mixture prepared by adding distilled water (1:2.5, soil:distilled water) (Shaaban et al., 2013a; Shaaban et al., 2013b). Ammonium (NH_4^+-N), nitrate (NO_3^--N), microbial biomass C (MBC) and dissolved organic C (DOC) were analyzed as described in our earlier studies (Lin et al., 2013; Shaaban et al., 2014a; Shaaban et al., 2015b; Shaaban et al., 2016). Basic information of the soil used in the experiment was given in Table 1.

2.2. Experimental treatments and design

Dolomite was added to the acidic soil under two levels of soil moisture with or without ammonium sulfate [$(NH_4)_2SO_4$]. A factorial arrangement of experimental treatments was designed as follows: Dolomite (0, 1 and 2 g kg^{-1} soil, named as D0, D1 and D2, respectively) was applied to soil under two moisture levels [(55% and 90% water filled pore space (WFPS)]. Each treatment of dolomite and moisture was further treated with two levels of N fertilizer [0 and 200 mg N as $(NH_4)_2SO_4$]. Each treatment was replicated three times. Dolomite was applied as 2.5 and 5.0 t ha^{-1} in D1 and D2 treatment, respectively. Ammonium sulfate was applied at the rate of 100 kg ha^{-1}.

The experiment was conducted aerobically under controlled conditions in a growth chamber at a temperature of 25 °C for 52 days as described previously (Shaaban et al., 2014b). Soil (300 g) was placed in a glass jar (1000 ml) for each treatment and replicated three times. Soil in jars was pre-incubated at 40% WFPS for 7 days at 25 °C. After pre-incubation, dolomite (<0.3 mm) was added and mixed thoroughly in the soil. Ammonium sulfate was dissolved in distilled water and added to the soil. After treating soil with dolomite and fertilizer, the WFPS was adjusted to 55% and 90% using distilled water. A thin polythene film containing 50 pinholes was placed over the top of each glass jar. The treatment jars were stored and incubated for 52 days. Moisture contents were maintained at 55% and 90% by weighing the jars three times a week, and adding distilled water if needed. During the entire study period, soil sub-samples were taken from jars at day 1, 2, 3, 4, 5, 7, 10, 17, 24, 31, 38, 45 and 52 to analyze soil pH, DOC, MBC, NH_4^+-N and NO_3^--N.

2.3. Gas sampling and analysis

A concurrent set of jars (100 g soil in each treatment jar) with the identical treatments as described above was prepared to measure CH_4 emissions. Before gas sampling, polythene film was removed from the jars and exposed to open air for about 1/2 hour to let the ambient air go inside the jars. Treatment jars were then closed with the lids fitted with a three-way stopcock and a gas-tight rubber septum for one hour as described in earlier studies (Augustenborg et al., 2012; Liu et al., 2014; Shaaban et al., 2015a). Two gas samples were collected from the headspace of the jars with a plastic syringe immediately after closure and again after 2 h. Samples of gas were taken concurrently with soil sub-samples. The CH_4 concentration was analyzed using a gas chromatograph (Agilent 7890 A, USA), and the methods described by Wang and Wang (2003).

2.4. Calculation of gas flux

The fluxes were calculated using the equation as described by Liu et al. (2014).

$$F = p \times V/W \times \Delta c/\Delta t \times 273/(T + 273)$$

Where F is gas emission rate (μg kg^{-1} h^{-1}), p is gas density at standard conditions, V is the volume of the glass jars, W is the weight of soil, Δc is the gas production, Δt is the sealed time for gas production, and T is the temperature at which experiment was conducted (25 °C).

Cumulative CH_4 fluxes (μg kg^{-1}) were calculated using the daily emissions over the 52-day period as described by Shaaban et al. (2015a).

$$\text{Cumulative gas flux} = \sum_{i=1}^{n} (\text{Ri} \times 24 \times \text{Di})$$

where Ri is the gas emission (μg kg^{-1} h^{-1}) of sampling dates, Di is the number of days in the sampling interval, and n is the number of sampling times.

2.5. Statistical analysis

Three-way analysis of variance (ANOVA) was performed to analyze the main and interactive effects of three factors studied in the present study (dolomite, moisture and N fertilizer). Tukey post hoc tests were utilized to identify significant differences between treatments at $p \leq 0.001$, $p \leq 0.01$ or $p \leq 0.05$. Pearson correlation analysis was also

Table 2
Results of analysis of variance (ANOVA) for variables.

	pH		CH_4		DOC		MBC		NH_4^+-N		NO_3^--N	
Factors	F	p	F	p	F	p	F	p	F	p	F	p
Dolomite	943.47	**	3.99	*	42.48	**	80.27	**	24.34	**	37.15	**
Moisture	18.62	**	158.86	**	24.21	**	21.16	**	268.17	**	3.77	*
Fertilizer	154.98	**	2.92	*	5.86	*	4.95	*	765.65	**	12.11	**
Dolomite × moisture	0.29	ns	1.32	ns	0.67	ns	1.15	ns	1.48	ns	0.09	ns
Dolomite × fertilizer	36.02	**	0.18	ns	0.11	ns	0.45	ns	4.56	*	0.10	ns
Dolomite × moisture × fertilizer	0.02	ns	0.41	ns	0.14	ns	0.33	ns	49.29	**	0.04	ns

ns: not significant, DOC: dissolved organic carbon, MBC: microbial biomass carbon.
* $p < 0.05$.
** $p < 0.001$.