

METHANE AND NITROUS OXIDE EMISSIONS FROM RICE FIELD SOIL IN PHAEOZEM AND MITIGATIVE MEASURES

Jin Yue ,(Key Laboratory of Terrestrial Ecological Process ,Institute of Applied Ecology ,Chinese Academy of Sciences,Shenyang, China)

Wei Liang, Jie Wu, Yi Shi and Guohong Huang(Key Laboratory of Terrestrial Ecological Process ,Institute of Applied Ecology ,Chinese Academy of Sciences,Shenyang,China)

ABSTRACT

Methane and nitrous oxide emissions from rice field soil in phaeozem were determined. The results show that methane emission amount from rice growing season is much lower than any other region in China. There is a trade-off relationship between Methane and nitrous oxide emissions ($r=-0.513, p<0.05$). Under the same fertilization compared with continual irrigation, intermittent irrigation can reduce significantly Methane emission and increase nitrous oxide emission, but the overall warming potential of greenhouse effect is reduced greatly while rice yield is not affected. So intermittent irrigation is an effective irrigative measure to reduce greenhouse gas emissions from rice paddy field. In addition the investigation on Methane and nitrous oxide emissions and their related microbial process shows positive relation between methanogens number and Methane emission ($R^2=0.82, p<0.05$) and shows the important relationship between the numbers of nitrifiers and denitrifiers and nitrous oxide emissions.

1.0 INTRODUCTION

Methane (CH_4) and nitrous oxide (N_2O) are greenhouse gases with important impacts on our environment. Increasing atmospheric N_2O concentration may also be detrimental to the stratospheric ozone layer. The concentrations of CH_4 and N_2O are lower than carbon dioxide (CO_2), but their global warming potential are 23 and 296 times as strong as that of CO_2 respectively (IPCC, 2001). The concentration of CH_4 increase by 4.9 ppb/yr and N_2O increase by $0.8 \pm$

0.2ppb/yr(IPCC,2001).Agricultural soil is a major source of CH₄ and N₂O. CH₄ and N₂O emitted by rice field have already been studied in burozem and krasnozem ,but CH₄ and N₂O emissions data in phaeozem are not attained currently in China.In this paper, CH₄ and N₂O emissions from rice field in phaeozem was determined.Mitigative measures of CH₄ and N₂O emissions is also explored in the paper.CH₄ and N₂O emitted from soil are products of microbial metabolism, so CH₄ and N₂O related microbial process had been studied in this paper.

2.0 MATERIALS AND METHODS

2.1 STUDY SITE AND SOILS

The study site located in Hailun,Heilongjiang,China(47° 26´N,126° 38´ E).Soil type is phaeozem.Physical-chemical properties of tested soils:pH7.02,organic matter 48.2g·kg⁻¹,total N 2.2 g·kg⁻¹.Three rice fields had been selected as experiment plot under three treatments. (A) Flooded,slow-releasing urea; (B) Flooded,urea; (C)Intermittent irrigation,urea.Drying field period:July 3 ~ July 13;August 1 ~ August 8, drainage time: August 28.

2.2 COLLECT AND MEASUREMENT OF CH₄ AND N₂O

CH₄ and N₂O was collected using closed chamber measurement.CH₄ was analyzed using a gas chromatograph(Shimadzu GC-14B)with a detector(FID)opetated at 200? .The injecting port temperature was 100? .The column temperature was 100? .The carrier gas was N₂. N₂O was analyzed using a gas chromatograph(Shimadzu GC-14A)with a detector(ECD)opetated at 300? .The injecting port temperature was 100? .The column temperature was 60? .The carrier gas was Ar-CH₄. Formula for gas flux: $F = \frac{m}{A} \times \frac{t}{t = 273 / (273 + T)} \times V \times \frac{c}{A} \times t = \frac{273}{(273 + T)} \times \frac{V}{A} \times \frac{c}{t}$

2.3 MEASUREMENT OF BACTERIA

Sample fresh soils(0-10cm) in rice growing season used as bacteria measure.Nitrifiers culture medium:(NH₄)₂SO₄ 2.0g; NaH₂PO₄ 0.25g; MnSO₄·4H₂O 0.01g; K₂HPO₄ 0.75g; MgSO₄·7H₂O 0.03g; CaCO₃ 5.0g; distilled water 1000ml.Denitrifiers culture medium: tartaric acid kalium natrium 20g; KNO₃ 2g; K₂HPO₄ 0.5g; MgSO₄·7H₂O 0.2g; distilled water 1000ml.

Methanogens culture medium: HCOONa 5g; CH₃COONa 5g; CH₃OH 5ml; H₂/CO₂ (80/20 volume ratio,full of tube space); soil lixivium 300ml; NH₄Cl 1g; MgCl₂ 0.1g; K₂HPO₄ 4g; KH₂PO₄ 4g; cysteine 0.5g; resazurin 0.002g; trace element solution 10ml; distilled water 685ml.Hungate

anaerobic technique is adopted to confect culture medium(Qian Z-S,1986).Methanotrophs culture medium: NaNO_3 1.0g; NH_4Cl 0.25g; KH_2PO_4 0.26g; $\text{K}_2\text{HPO}_4 \cdot 3\text{H}_2\text{O}$ 0.74g; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ 1.0g; CaCl_2 0.2g; $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 0.004g; EDTA 0.01g; trace element solution 10ml; soil lixivium 100ml; agar 18g; distilled water 890ml.take count of bacteria number use MPN measurement

3.0 RESULTS AND DISCUSSION

3.1 RELATION OF CH_4 AND N_2O EMISSIONS FROM RICE FIELD SOILS IN PHAEOZEM AND THEIR EMISSION AMOUNT

Figure1 illustrates CH_4 and N_2O emissions have obvious seasonal variation under the treatments of continual irrigation and urea(ambient). CH_4 emission from soils is very small befor flooding and after rice field drainage ,while N_2O emission is very high.During flooding(from July to August) CH_4 flux is very high,but N_2O emission is very small. Correlation analysis results of CH_4 emission and N_2O emission show that there is a significant trade-off relationship between CH_4 and N_2O ($r=-0.513,n=17,p<0.05$).This relationship had already been reported in other types of soils(Chen G-X,1995;Zucong Cai, 1997),now the results in phaeozem prove this relationship. Correlation analysis about CH_4 and N_2O emissions under the treatments of intermittent irrigation shows that the trade-off relationship is not significant(see figure2).

CH_4 and N_2O emissions total amount from rice growing season were measured(see table1), CH_4 emissions under three treatments are all much lower than any other region in China. CH_4 flux from rice growing season in Shenyang,China is $7.4\text{g}\cdot\text{m}^{-2}$ (Chen G-X,1995), and in south of China the range of CH_4 flux is $13.3\sim 17.28\text{g}\cdot\text{m}^{-2}$ (Wang M-X,1994).

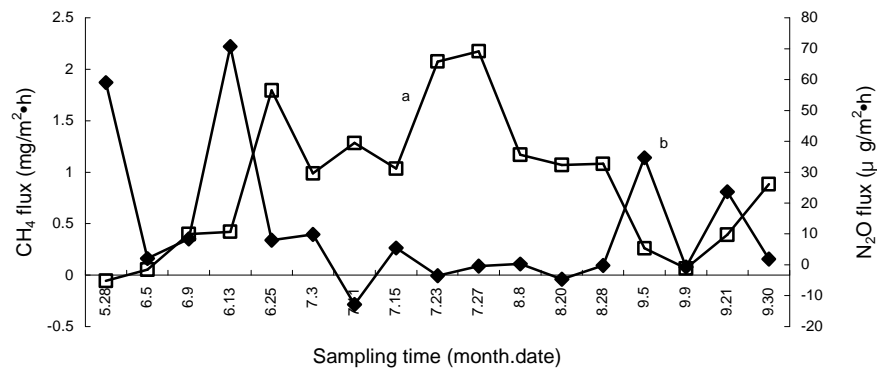


Fig.1 Seasonal variation of CH_4 and N_2O emissions from rice field under the treatments of continual irrigation and urea

a. CH_4 b. N_2O

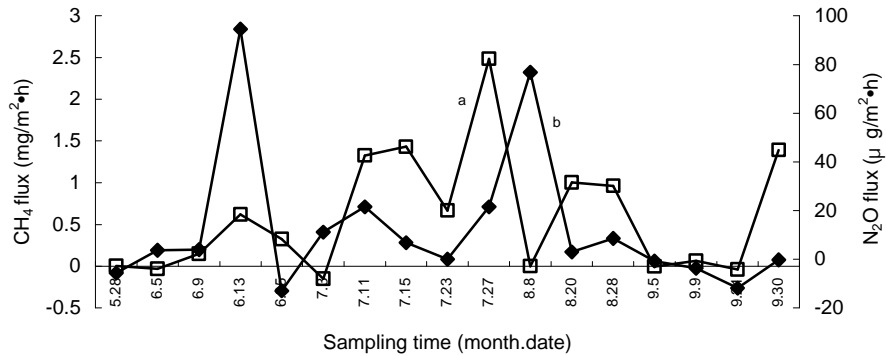


Fig.2 Seasonal variation of CH₄ and N₂O emissions from rice field under the treatments of intermittent irrigation and urea

a. CH₄ b.N₂O

3.2 MICROBIAL PROCESS OF CH₄ AND N₂O EMISSIONS

Anaerobic degradation of organic matter in the biosphere is one of the most important sources of atmospheric CH₄. The degradation is accomplished by a complex microbial community consisting of hydrolytic, fermentative, syntrophic, homoacetogenic and methanogenic microorganisms. CH₄ is produced by methanogenic bacteria in the anaerobic layer of paddy soils and oxidized by methanotrophic bacteria in the surface layer of submerged paddy soils and in the rice rhizosphere where both O₂ and CH₄ are available. The emission of CH₄ from rice field to the atmosphere is the result of the balance between its production and oxidation. Moderate temperature for methanogens is 35- 37°C (Rajagopal B S, 1988; Schütz H, 1990). Methanogens number increase as soil temperature rise gradually. During July and August methanogens number is largest in the rice growing season, and CH₄ emission is also very high in this period (see figure3). Regression analysis results show that there is a significant positive correlation between the variation of CH₄ flux and methanogens number (R²=0.82, p<0.05). Under the treatment of intermittent irrigation, when dry field methanogens number decrease because of abundance of atmospheric O₂ entering the surface layer of submerged paddy soils (see figure3), while methanotrophs number increase (see figure4). CH₄ emission is very low at this period (see figure3).

Denitrification and nitrification are the primary biological sources of N₂O. Nitrifiers, denitrifiers and N₂O emission from rice growing season in phaeozem are measured. The results show that under the same water management the treatments of applying slow-releasing urea nitrifiers and denitrifiers number are much larger than applying urea (ambient) after August (figure5,6). N₂O emission is also much higher than ambient. But in rice growing season variation of N₂O flux and variation of nitrifiers and denitrifiers is not significantly positive correlated.

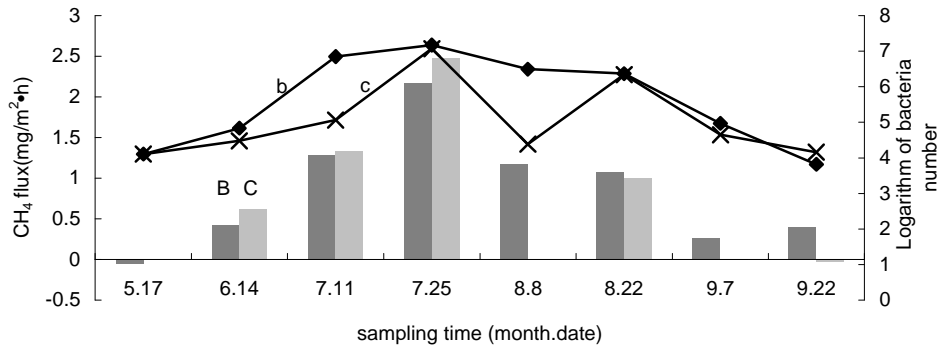


Fig.3 Relationship between CH₄ emission and methanogens with different water managements
 B. CH₄ emission from continual irrigation C. CH₄ emission from intermittent irrigation
 b. Methanogens number from continual irrigation c. Methanogens number from intermittent irrigation

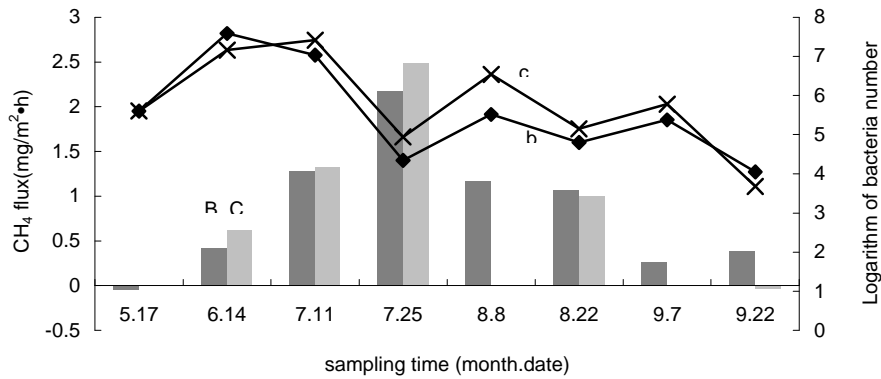


Fig.4 Relationship between CH₄ emission and methanotrophs with different water managements
 B. CH₄ emission from continual irrigation C. CH₄ emission from intermittent irrigation
 b. Methanotrophs number from continual irrigation c. Methanotrophs number from intermittent irrigation

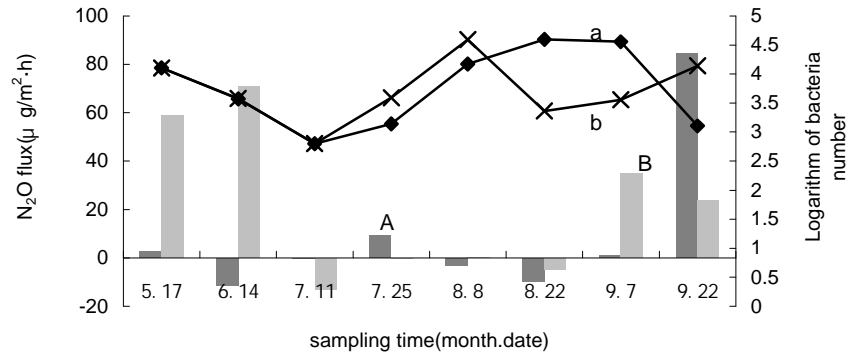


Fig.5 Relationship between N₂O emissions and nitrifiers with different fertilizers
 A. N₂O emission with Slow-releasing urea B. N₂O emission with Urea a. Nitrifiers number with Slow-releasing urea b. Nitrifiers number with Urea

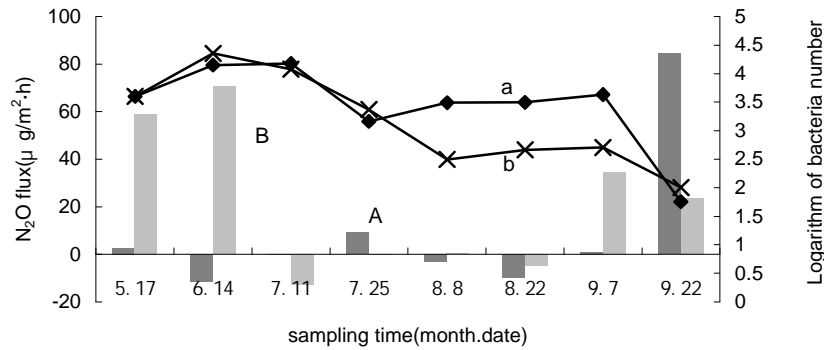


Fig.6 Relationship between N₂O emission and denitrifiers with different fertilizers
 A. N₂O emission with Slow-releasing urea B. N₂O emission with Urea a. Denitrifiers number with Slow-releasing urea b. Denitrifiers number with Urea

3.3 EFFECTS OF FERTILIZATION AND WATER MANAGEMENT ON CH₄ AND N₂O EMISSIONS

Table 1 Effects of fertilization and irrigation on emissions of CH₄ and N₂O

Treatments	CH ₄ flux		N ₂ O flux	
	Averageflux (mg/m ² ·h)	Emission amount (g/m ²)	Averageflux (μ g/m ² ·h)	Emission amount (g/m ²)
Flooded with Slow-releasing urea	0.96	2.89	7.58	0.02
Flooded with Urea	0.83	2.48	18.51	0.06
Intermittent irrigation with Urea	0.56	1.68	25.92	0.08

Table 2 Effects of fertilization and irrigation on rice field

	yield(kg/ha)	Weight (g)
Flooded with Slow-releasing urea	6376.7	24.8
Flooded with Urea	6333.3	25.1
Intermittent irrigation with Urea	6320.0	24.6

CH₄ and N₂O average fluxes from rice growing season are obtained(see table1).Compared with continual irrigation, under intermittent irrigation CH₄ average flux decrease obviously and N₂O average flux increase. This result accords with other simulation experiment(Cai Z-C,1999).In upland field applying long-lasting ammonium bicarbonate and slow-releasing urea can reduce N₂O emission significantly(Hiroko A,2000; Huang G-H,1998).Our results show that CH₄ average flux under the treatment of applying slow-releasing urea is higher than under the treatment of applying urea,while N₂O average flux is much lower(see table1). The overall warming potential of greenhouse effect of CH₄ and N₂O from rice field soil is calculated according to CH₄ and N₂O average fluxes and their warming potential respectively(Cai Z-C,1999), warming potential per mol CH₄ equals 23 and warming potential per mol N₂O equals 296.Under the treatments of continual irrigation and urea(ambient) the overall warming potential of greenhouse effect of CH₄ and N₂O equals 1.318, it equals 1.431 under the treatments of continual irrigation and slow-releasing urea, compared with ambient it increases by 8.6%. The overall warming potential of greenhouse effect equals 0.979 under the treatments of intermittent irrigation and urea, compared with ambient it decreases by 25.7%,it is reduced greatly.Rice yield is not affected by different treatments(see table2). Intermittent irrigation can be an effective water management to reduce greenhouse gas emissions from rice field soils.

4.0CONCLUSION

CH₄ and N₂O emissions from rice field soil in phaeozem have obvious seasonal variation.There is a trade-off relationship between Methane and nitrous oxide emissions. CH₄ emission from rice growing season is much lower than any other region in China.

Intermittent irrigation can reduce significantly CH₄ emission and increase N₂O emission ,but the overall warming potential of greenhouse effect is reduced greatly while rice yield is not affected. So intermittent irrigation is an effective irrigative measure to reduce greenhouse gas emissions from rice field soils.

Microbial process have effects on CH₄ and N₂O emissions from paddy soils.There is a positive correlation between methanogens number and CH₄ emission.

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