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Full Length Article

Effect of Organic Fertilizer on N_2O Emission in Yellow Cornfield

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Abstract

The experiment was conducted to explore the impact of different environmental factors on nitrous oxide (N_2O) emission flux after application of fertilizer. An experiment was conducted in 2016 to determine the N_2O emissions in maize yellow soil. There were four treatments: no fertilizer (CK); common fertilizer (CF); chemical fertilizer + organic fertilizer (OF); fertilizer + bio-organic fertilizer (BF). Therefore, the experiment was designed to study N_2O emission characteristics and environmental factors after application of organic fertilizer. The results indicated that N_2O emissions reached three peaks in corn-growing season. An average N_2O emission flux of the four treatment process could be ranked as OF>BF>CF>CK, which was measured as 0.080, 0.069, 0.010 and 0.007 $mg \cdot m^{-2} \cdot h^{-1}$ respectively; the total N_2O emissions of soil after application of OF and BF were improved for 15 times and 11 times, respectively as compared with CK. According to relevant analysis, N_2O emission flux of yellow cornfield was mainly related either to the carbon-nitrogen ratio ($P<0.05$) in the farmland or to the soil nitrate nitrogen (N) content ($P<0.05$) after application of organic fertilizer. Moreover, N_2O emissions of yellow cornfield were increased after application of OF and BF, and relatively reduced after CF. As a result, the increased N_2O emissions were mainly caused by carbon nitrogen ratio and soil nitrate content of cornfield. Therefore, an important way to reduce N_2O emissions in cornfield is to control the application of organic fertilizer and carbon nitrogen ratio.

Keywords: N_2O emission; Fertilizer combinations; C/N ratio; Yellow cornfield; China

Introduction

With rising global temperatures, the emission of greenhouse gases has become the focus of attention. Nitrous oxide (N_2O) is one of the main greenhouse gases that leads to the greenhouse effect. Among all sources of N_2O emissions, the total amount of N_2O emissions in farmland soil accounts for 70% or so (Mosier *et al.*, 1998), among which N_2O emissions in dry farmland can be regarded as an important emission source (Li *et al.*, 2006; He *et al.*, 2016). Therefore, the reduction of greenhouse gas emissions in dry farmland is of great significance to the global climate change and sustainable agricultural development.

Although N_2O emissions in farmland are generated during nitrification and denitrification process under soil, the types and forms of nitrogen fertilizer, environmental factors (temperature and rainfall), soil conditions (moisture content), farmland cultivation and management measures will have a certain impact on N_2O emissions (Zheng *et al.*, 1997; Cai *et al.*, 2012; Liao and Yan, 2010). According to research reports, increased nitrogen fertilizer promotes the emission of farmland greenhouse gases (Chen *et al.*, 2015) whilst application of organic fertilizer release more N_2O as compared with application of chemical fertilizer. However, other research suggests that when adding bio-organic fertilizer to inorganic fertilizer, it can change the microenvironment of soil and promote crops to absorb nitrogen element in soil, thus reducing N_2O emissions in farmland (Venterea *et al.*, 2012).

As the main cultivated soils in southwest China, yellow soils are mainly populated with grain crops such as corns. In recent years, the measures, such as applying organic fertilizer or bio-organic fertilizer, have been taken to improve soil properties and conditions for growth of corns. Currently, the effect of nitrogen fertilizer on N_2O emissions in cornfield soil has been reported. conducted by Li *et al.* (2015), organic fertilizer treatment can increase N_2O emission in cornfield soils as compared with chemical fertilizer treatment; according to Zeng *et al.* (2013), the organic manure is more conducive to N_2O emissions in cornfield soils than chemical fertilizer; according to research on the effect of N-fertilizer rate on N_2O emission in black soil of cornfield, Hao *et al.* (2013), point out that N_2O emissions in farmland soil are related to the nitrogen fertilizer rate which can be reduced to constrain N_2O emissions in cornfield soil. In addition, other related

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research has also indicated that N_2O emissions in day farmland soil are related to environmental factors (Gao *et al.*, 2013).

Since previous research mainly focus on the effect of fertilizer rate and variety on N_2O emissions in cornfield, the research on the effect of organic fertilizer and bio-organic fertilizer in yellow soil of southwest China on N_2O emission characteristics and environmental factors of farmland soil in corn-growing season have not been reported. Therefore, object is to study the effect of organic fertilizer on N_2O emission characteristics and environmental factors of farmland soil in order to provide a scientific basis for reasonable control and reduction of N_2O emissions in cornfield soils.

Materials and Methods

Overview of Experimental Site

The experiment was conducted in Longgang Long-term Nutrient Research Station in Guizhou Province in April to September of 2016, with geological location at E107°06'40.8", N26°52'24.8", elevation of 1,130 meters, frost-free period for 240days, annual average temperature of 13.5℃, annual sunshine for 948.2 h and average rainfall of 1,129.9 mm. The experimental area was established at the corn and flue-cured tobacco wheel as locating points for experiment since 2008.

Crop Growing Details

Shundan No. 7 corn seedling was selected for experiment in yellow soils with fertility status from 0 to 20 cm making total N 1.6 g kg^{-1}, total P 0.6 g kg^{-1}, organic matter 39.7 g kg^{-1}, alkali-hydrolyzable N 136.0 mg kg^{-1}, available P 12.2 mg kg^{-1}, readily-available K 153.1 mg kg^{-1} and pH7.4. Corn varieties were tested at seedling stage (10 day old plants), huge bellbottom period (35 day old plants), pollination period (60 day old plants), ratooning buds (80 day old plants) and full ripeness period (90 day old plants).

Experimental Design and Management

The experiment was designed with four treatments, viz., no fertilizer (CK); common fertilizer (CF); chemical fertilizer + organic fertilizer (OF); chemical fertilizer + bio-organic fertilizer (BF) with specific fertilizer rate (Table 1). The basic fertilizers used during experiment was compound fertilizer 75 kg hm^{-2} (N: 32%, P_2O_5 4%), calcium superphosphate 407 kg hm^{-2} (P_2O_5 14%) and potassium sulfate 118 kg hm^{-2} (K_2O 51%). However, organic fertilizer was decomposed cow dung 7500 kg hm^{-2} (N 1.4%; P_2O_5 0.4%; K_2O 2.1%) and bio-organic fertilizer 750 kg hm^{-2} (N 2.6%; P_2O_5 2.2%; K_2O 2.8%). In addition, the phosphate fertilizer, potash fertilizer, organic fertilizer and bio-organic fertilizer were applied in the basic fertilizer at one time. After application, the ammonium nitrate 103 kg hm^{-2} (N: 35%) was used as first additional fertilization and ammonium nitrate 171 kg hm^{-2}(N: 35%) for the second additional fertilization.

While conducting experiment, we first dug out 10 cm wide field ditch in cornfield, applied basic fertilizer on one side of the ditch and transplant the corn seedlings on the other side and earthened up. At the end, we applied additional fertilizer on the soil surface 5 cm away from tobacco plants for two times. Other management measures were implemented in accordance with the management and cultivation system of local cornfields. Moreover, the corn seedlings were applied with basic fertilizer and transplanted on May 8th based on the plant-to-plant distance of 33 cm, row spacing of 60 cm and cultivation density of 50530 plants per hm^{-2}. There were 90 plants in each row and 8 rows in each plot, totals 720 plants in each plot. The first additional fertilizer was applied on June 1st, and second on June 24th.

Sample Collection

Gas sampling: Gases in cornfield were collected from May to August in the year 2016. Each community was equipped with three fixed gas collection points to store the static chamber (60×50×30 cm=0.9 m^3) for artificial collection of greenhouse gases under the same conditions. The inner top of the chamber was installed with micro-electric fans, temperature probes and gas collection pipes. Among them, the terminals of collection pipes exposed outside the static chamber were connected with three-way valves, which were connected to the gas collection bag and injector (50 mL), respectively. In addition, each community was provided with three fixed foundations, which were inserted into soil at 20 cm depth. At the sampling time, it was made sure that from the static chamber on the foundation, no exchange of gases between internal and external side of the chamber occurs. Gas samples were collected after every 15 min in the first 45 min from 8:00 to 11:00 a.m. After transplanting, collect gas samples every 15 days and collect additional samples in 1, 2, 3, 5, 7 and 11 days after fertilization. In case of heavy rainfalls, the sampling was postponed. During each collection of gas sample, we recorded the surface and air temperature of that day.

Soil sampling: We first draw a combined soil sample (0–20 cm soil depth) between two plants, and place onto an ice box followed by its preservation at low temperature. For soil analysis, the sample was screened the soil sample with a 5 mm mesh, and extract from 0.01 mol/L $CaCl_2$ solution to measure the content of NO_3-N and NH_4-N. Meteorological data of cornfield soils can be automatically recorded by Onset HOBO Temperature and Humidity Recorder.

Plant sampling: First, harvest the corn plants at one time during mature stage, and place the harvested blades into a drying oven after cleaning. Then, deactivate enzymes at the temperature of 105℃ for 30 min and dry the blades at the temperature of 75℃ before weighing.

Sample Analysis

The static chamber meteorological chromatography was used to measure N_20 and gas chromatography (HP 7890A) was used to measure gas content with the chromatographic column filled by Porpak Q. The content of NH^{4+}-N and NO^{3-}-N were measured by a continuous flow analyzer (Flastar 5000 Analyzer) (Bao, 2000).

Calculation Method and Data Analysis

N_2O emission flux can be calculated based on the following formula (Hou *et al*., 2015):

$$F=\Delta m/A\times\Delta t=(m2-mL)/A\times\Delta t= [C2\times V\times M0\times 273/(273+T2)-C1\times V\times M0\times 273/(273+T1)]/[A\times(t2-t1)\times 22.4\times 10^{-3}]\times 1000$$

Where, F represents N_2O emission flux (mg m^{-2} h^{-1}); A represents the area of sampled soil (m^2); V represents the volume of static closed chamber (m^3); m1 and m2 represent the initially and final weight (g), respectively of greenhouse gas in the closed chamber; t1 and t2 represent the time of initial and final measurement (h), respectively; C1 and C2 show the initially and finally measured content of volume percent for certain greenhouse gas in the closed chamber respectively; T1 and T2 represent the chamber temperature of initial and final measurement, respectively and Mo indicates the molar mass of greenhouse gases. According to relation curve between the content and time of gas samples, the accumulated N_2O emission was calculated as emission flux multiplied by the corresponding observation days (Diao *et al*., 2013).

$$\text{N2O emission coefficient} = \frac{(\text{N2O emissions of nitrogen treatment} - \text{N2O emissions of CK treatment})}{\text{nitrogen fertilizer rate} \times 100}$$

The test data was arranged into a diagram via M.S. Excel 2010 and analyzed with SPSS 11.5 software. Moreover, the significance test was analyzed with Duncan's New Multiple Range Test.

Results

Dynamics of N_2O Emission

The variation trend of N_2O emission flux in cornfield was similar at different treatment processes (Fig. 1), The N_2O emission flux mounted during early stage of corn growth and declined at later stage. During the entire growth period, three times of N_2O emission peaks occurred at different treatment processes. The first peak of N_2O emission occurred in 1–7 days after application of basic fertilizer (May 9th to May 15th), when the peak emission flux of CK, CF, OF and BF represent 0.079, 0.146, 0.987 and 1.354 mg·m^{-2}·h^{-1} respectively; the second peak of N_2O emission occurred in 1–5 days after the first additional fertilizer (June 2nd to June 7th), when the peak emission flux of CK, CF, OF and BF represent 0.025, 0.011, 0.168 and 0.142 mg·m^{-2}·h^{-1} respectively; the third peak of N_2O emission occurred in 7–10 days after the second additional fertilizer (June 29th to July 3rd), when the peak emission flux of CK, CF, OF and BF represent 0.010, 0.036, 0.092 and 0.088 mg·m^{-2}·h^{-1} respectively; after application of basic fertilizer, the cumulated N_2O emissions during the first additional fertilizer accounts for 26.11, 34.26, 33.72 and 33.04% of total emissions during the entire growth period, which implied that N_2O emission flux mainly was concentrated one week after application of basic fertilizer.

During whole growth period, where no fertilizer or chemical fertilizers were applied, N_2O emission peaks were relatively smaller with more smooth emission flux and no significant difference, where organic fertilizer and bio-organic fertilizer were applied N_2O emission flux was enhanced dramatically being significantly higher than chemical fertilizer treatment ($P<0.05$), where organic fertilizer and bio-organic fertilizer were applied N_2O emission flux was enhanced by 4.27 and 3.42 times, respectively within 7 days after basic fertilizer treatment as compared with chemical fertilizer treatment for 14.96 and 12.65 times respectively within 1–5 days after the first additional fertilizer treatment as compared with chemical fertilizer treatment, and for 2.54 and 2.43 times, respectively within 7–10 days after the second additional fertilizer treatment as compared with chemical fertilizer treatment. In addition, N_2O emission flux after organic fertilizer treatment was usually higher than that of bio-organic treatment. The results indicate that N_2O emission flux will be greatly enhanced after organic and bio-organic fertilizer treatment. During the whole growth period, the average N_2O emission flux was ranked as OF>BF>CF>CK and calculated as 0.080, 0.069, 0.010 and 0.007 mg·m^{-2}·h^{-1}. After application of organic and bio-organic fertilizer, N_2O emission peaks mainly arose on 1–7 days after basic fertilizer treatment, while N_2O emission after CK and chemical fertilizer treatment remained relatively lower. Therefore, organic fertilizer and bio-organic fertilizer improved N_2O emission flux in cornfield.

Relation between N_2O Emission and Fertilizers

During the whole corn-growing season, the total N_2O emission after chemical fertilizer treatment and CK remains at a lower level (Table 2) from 0.11–3.59 kg·hm^{-2} with no significant difference, the organic fertilizer and bio-organic fertilizer treatment will greatly improve the total N_2O emission in cornfield for 15 and 11 times, respectively as compared with chemical fertilizer treatment, which indicates that the organic fertilizer and bio-organic fertilizer treatment can improve the total N_2O emission in cornfield. The organic fertilizer treatment greatly improved corn biomass as compared to chemical fertilizer treatment and bio-organic treatment ($P<0.05$) in this study (Table 2).

Table 1: Fertilizer rate of different treatment process (kg.hm^{-2})

Treatment	Fertilizer application rates (kg.hm^{-2})										
	Maize field										
	Basal fertilizer									Top fertilizer(1)	Top fertilizer(2)
	chemical fertilizer			organic fertilizer			biological fertilizer			chemical fertilizer	chemical fertilizer
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	N
CK	0	0	0	0	0	0	0	0	0	0	0
CF	24	60	60	0	0	0	0	0	0	36	60
OF	24	60	60	105	30	158	0	0	0	36	60
BF	24	60	60	0	0	0	20	17	16	36	60

Note: when applying basic fertilizer, the phosphate fertilizer, potash fertilizer and organic fertilizer shall be applied at one time, and the additional fertilizer shall be applied based on conventional method and time

Table 2: Effect of organic fertilizer on total N_2O emissions and biomass in yellow cornfield

Treatment	N_2O total emissions/(kg·hm^{-2})	Biomass/(kg·hm^{-2})	Emission per unit biomass /(g.kg^{-1})	Emission factor coefficient/%
CK	0.19±0.01 c	3911.53±765.91 c	0.05±0.007 b	—
CF	0.28±0.10 c	14846.98±2580.82 b	0.02±0.008 c	0.07±0.01 c
OF	2.18±0.14a	15516.50±782.46 a	0.14±0.004 a	0.88±0.06 b
BF	1.89±0.18 b	11995.57±659.16 b	0.16±0.023 a	1.22±0.12 a

Note: statistically assuming $P < 0.05$

The organic fertilizer and bio-organic fertilizer greatly improved N_2O emission and emission coefficient per unit biomass as compared with chemical fertilizer treatment. This implied that the organic fertilizer treatment improved corn biomass and N_2O emission in cornfield. The organic fertilizer and bio-organic fertilizer treatment can improve N_2O emission and emission coefficient per unit biomass.

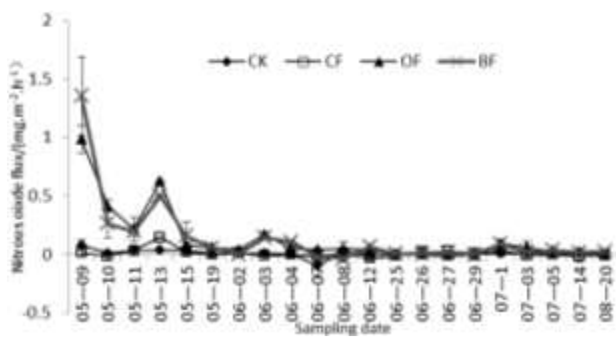

Fig. 1: Effect of organic fertilizer on N_2O emission flux in cornfield soils in corn-growing season

Relation between Carbon and Nitrogen Input and N_2O Emission

As given in Table 3, N_2O emission flux was positively correlated with carbon input, nitrogen input and carbon-nitrogen ratio, among which the carbon-nitrogen ratio can reach the significant difference level ($P<0.05$). Therefore, N_2O emission was related with the carbon-nitrogen ratio: greater carbon-nitrogen ratio in organic fertilizer can lead to larger N_2O emission flux.

Relation between Nitrate-N and N_2O Emission

The nitrate-N content of different fertilizer treatment was positively correlated with N_2O emissions in the cornfield. N_2O emission flux after organic fertilizer treatment was positively correlated with the nitrate-N content of cornfield soil. However, there was no significant difference in other fertilizer treatment. Therefore, nitrate-N content was related with N_2O emissions in cornfield after organic fertilizer treatment (Table 4).

Relation between Temperature and N_2O Emission

The air and soil temperatures were negatively correlated with N_2O emissions in cornfield with no significant difference. This indicated that the air and soil temperatures during corn-growing season cannot be regarded as the main factors to affect N_2O emissions (Table 4).

Relation between Soil Moisture and N_2O Emission

Results showed that the moisture content of different treatment process was positively correlated with N_2O emission in cornfield soils with no significant difference, indicating that moisture content during corn-growing season was uncorrelated with N_2O emission (Table 3).

Discussion

Since N_2O emission is directly related with nitrogen content in farmland, the total N_2O emission remained at its lowest level in the cornfield after no fertilizer treatment (Shcherbak *et al.*, 2014). Since the organic fertilizer and bio-organic fertilizer treatment can affect N_2O emission in the soil. Total N_2O emissions were significantly higher than chemical fertilizer treatment ($P<0.05$) for 15 and 11 times respectively. In addition, the organic fertilizer treatment can improve the content of organic matter, provide carbon and nitrogen sources and improve soil microbial activity and escalated N_2O emission (Lu, 2015).

During the experiment, the peak flux of N_2O emission

Table 3: Correlation between carbon and nitrogen input in cornfield and N_2O emission flux in corn-growing season

Treatment	Total carbon input(kg/hm2)	Total nitrogen input(kg/hm2)	carbon nitrogen ratio
CK	-	-	-
CF	-	120	-
OF	337	225	1.50
BF	135	140	0.96
N_2O emission correlation	0.91	0.82	0.98*

Note: statistically assuming P*P<0.05, **P<0.01

Table 4: Correlation between N_2O emission flux and environmental factors during the whole corn-growing season

Treatment		nitrate-N	air temperature	soil temperature	soil moisture content
CK	R	0.75	-0.18	-0.05	0.86
CF	R	0.28	-0.04	-0.05	0.17
OF	R	0.96*	-0.44	-0.15	0.48
BF	R	0.90	-0.44	-0.21	0.13

Note: statistically assuming P*P<0.05, **P<0.01

occurred in five days after basic fertilizer treatment, 1–7 days after the first additional fertilizer treatment and 7–10 days after the second fertilizer treatment (Fig. 1). Therefore, it can be concluded that the three peaks will occur in 10 days after fertilizer treatment, which is similar to the research result made by Shan *et al.* (2016) that N_2O emission mainly occurs in 11 days after fertilizer treatment.

The total N_2O emissions of different fertilizer treatment were ranked as OF>BF>CF>CK. This means that the additional organic and bio-organic fertilizer treatment affects N_2O emission in farmland (Zou *et al.*, 2004). This is mainly because the organic fertilizer and bio-organic fertilizer contain both nitrogen and carbon elements, which can change the carbon-nitrogen ratio in cornfield soil and affect the decomposition capacity of soil microorganism, thus changing N_2O emissions in farmland (Liu *et al.*, 2014; Gao *et al.*, 2016). According to the research results, N_2O emission flux in cornfield is significantly correlated with the carbon-nitrogen ratio, which further confirms the conclusion.

In this experiment, the organic fertilizer treatment greatly improved corn biomass as compared to chemical fertilizer treatment (Table 2). The supplemental organic fertilizer helped crops to show improved plant biomass (Deng *et al.*, 2010; Zhang *et al.*, 2016). According to relevant reports, the N_2O emission coefficient of dry farmland in China remained between 0.22 and 1.53% (Zheng *et al.*, 2004). However, in this research the N_2O emission coefficient of cornfield soil remained between 0.07 and 1.22% within N_2O emission coefficient range of dry farmland in China with, the organic fertilizer and bio-organic fertilizer treatment. The N_2O emission coefficient of cornfield soil remained higher than that of chemical fertilizer treatment, but lower than the recommended value 1.25% of international farmland (Bouwman, 2001). Therefore, although the increased nitrogen content increased N_2O emission coefficient, the N_2O emission in this study remained lower than in other area or crop fields (Table 2).

According to the research results, N_2O emission flux was positively correlated with the nitrate-N content during corn-growing season, which is similar to the results of Bao and Xiao-tang (2011). The only difference is that N_2O emission flux of cornfield soil after organic fertilizer treatment was correlated with the nitrate-N content ($P<0.05$) with no significant relation between N_2O emission flux of other treatment and the nitrate-N content. In addition, N_2O emission in farmland can also be affected by the nitrate-N content and environmental factors (Zheng *et al.*, 1997; Wang *et al.*, 2010; Shi *et al.*, 2013). However, according to results, N_2O emission in cornfield was negatively correlated with the temperature (including air and soil temperature) and positively correlated with moisture content with no great difference when compared to studied.

Conclusion

Firstly the N_2O emission flux peak will occur in yellow cornfield after fertilizer treatment, and N_2O emissions mainly concentrate on 7 days after basic fertilizer treatment; the average N_2O emissions flux of organic fertilizer and bio-organic fertilizer treatment were higher than that of chemical fertilizer treatment. Therefore, additional organic fertilizer and bio-organic fertilizer treatment can improve N_2O emission in cornfield soil. Secondly, the additional organic fertilizer and bio-organic fertilizer treatment has improved the corn biomass, N_2O emissions per biomass and N_2O emission coefficient. Thirdly, variations in N_2O emission flux in cornfield after fertilizer treatment are mainly caused by carbon-nitrogen ratio in farmland, and N_2O emissions in yellow cornfield are free from effects of local air temperature, soil temperature and moisture content.

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