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NITROUS OXIDE EMISSIONS AND ITS INFLUENCING FACTORS INMAIZE FIELD

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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 three treatments: No fertilizer + Crop rotation for comparison (CK); inorganic fertilizer + Crop rotation (CR); inorganic fertilizer + Continuous cropping (CC). Therefore, the experiment was designed to study the variation features of N_2O emissions in maize-growing season and analyze the impact of soil moisture, temperature and nitrate nitrogen content on N_2O emissions after application of Crop rotation and Continuous cropping. The results indicated that: N_2O emissions reached two peaks in maize-growing season, which mainly occurred in 1-11 days after application of Crop rotation and Continuous cropping; the cumulated amount of N_2O emissions within 15 days after application of Crop rotation and Continuous cropping accounted for 22.16%-38.23% of the cumulated amount of N_2O emissions during the whole growing season and total emission amount during growth period. Meanwhile, the average N_2O emission flux of the three treatment process could be ranked as CC＞CR＞CK, which shall be measured as 0.056, 0.010 and 0.007 $mg \cdot m^{-2} \cdot h^{-1}$ respectively; The total N_2O emissions of soil after application of Continuous cropping were improved for 7 times respectively as compared with single application of Crop rotation. According to relevant analysis, N_2O emission flux of maize yellow soil was mainly related with the nitrate nitrogen content ($P<0.05$) in farmland, from which it could be concluded that N_2O emission in maize yellow soil was free from any influence of local soil moisture content, air temperature or soil temperature. Moreover, N_2O emissions of maize yellow soil were increased after application of Continuous cropping. Therefore, an important way to reduce N_2O emissions of maize yellow soil was to control the application reasonable Crop rotation.

Keywords: N2o Emission; C/N Ratio; Yellow Cornfield; China; Environmental Factors.

1. INTRODUCTION

N_2O is one of the main greenhouse gases that lead to the greenhouse effect. With the rising global temperatures, the emission of greenhouse gases has become the focus of attention. Among all sources of N_2O emissions, the total amount of N_2O emissions in farmland soil accounts for 70% or so [1] [2], among which N_2O emissions in dry farmland can be regarded as an important emission source[3,4]. 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[5] [6] [7] [8]. According to the research reports, Crop rotation and Continuous cropping on soil physical and chemical properties had different impacts on the maize field, not only can improve the soil permeability and vega oxygen, and conducive to the growth and development of maize roots, and promote the absorption of nitrogen in the soil, reducing N_2O emissions in maize field [9] [10] [11].

As one of the main cultivated soils in southwest China, yellow soils are mainly populated with commercial crops such as maize. In recent years, the measures, such as applying Crop rotation and Continuous cropping, have been taken to improve soil properties and conditions for growth of maize. Currently, the effect of Crop rotation and Continuous cropping on N_2O emissions in arid farmland has been reported. According to research on the Effect of Croprotation and Continuous cropping on the Emission of N_2O from the late rice field in the Guangzhou, China. according to[12], the Crop rotation treatment can improve N_2O emission in field soils as compared with Continuous cropping treatment; according to research on the Effect of Crop rotation and Continuous cropping on the Emission of N_2O from the dry farmland[11], indicate that the Crop rotation treatment can reduce N_2O emission in field soils as compared with Continuous cropping treatment. In addition, other related research has also indicated that N_2O emissions in day farmland soil are related to environmental factors. The research on the effect of Crop rotation and Continuous cropping in yellow soil of southwest China on N_2O emission characteristics and environmental factors of farmland soil in maize-growing season has not been reported. Therefore, this paper will take maizes in yellow soil as an object to study the effect of crop rotation and continuous cropping on N_2O emission characteristics and environmental factors of farmland soil, providing a scientific basis for reasonable control and reduction of N_2O emissions in maize yellow soil.

2. MATERIAL AND METHOD

2.1 Overview on Test Area

The experiment was conducted in Long gang Long-term Nutrient Research Station in Guizhou Province in April to September of 2016, featuring geological location at E107°06'40.8", N26°52'24.8", elevation of 1,130 meters, frost-free period for 240-265 days, annual average temperature of 13.5°C to 14.6°C, annual sunshine duration for 948.2-1,084.8 hours and average rainfall of 1,129.9-1,205.9 mm. The test area was established at the corn and maize wheel as locating points for experiment since 2008. In addition, Shundan No.7 corn variety was selected for experiment in yellow soils with fertility status from 0 to 20cm featuring total nitrogen 1.6g.kg^{-1}, total phosphorus 0.6g.kg^{-1}, organic matter 39.7g.kg^{-1}, alkali-hydrolyzable nitrogen 136.0 mg.kg^{-1}, available phosphorus 12.2 mg.kg^{-1}, rapidly-available potassium 153.1 mg.kg^{-1} and pH7.4.

2.2 Test Design and Management

The experiment was designed with three treatment processes, No fertilizer + Crop rotation for comparison (CK); inorganic fertilizer + Crop rotation (CR); inorganic fertilizer + Continuous cropping (CC). The basic fertilizer used during corn experiment was composed of 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%). In addition, the phosphate fertilizer and potash fertilizer shall be applied in the basic fertilizer at one time. After application, the ammonium nitrate 103 kg.hm^{-2} (N: 35%) can be used for the first additional fertilization and ammonium nitrate 171kg.hm^{-2}(N: 35%) for the second additional fertilization.

First, dig out a 10cm wide field ditch in cornfield, apply basic fertilizer in one side of the ditch and transplant the corn seedlings in another side; then earth up; at last, apply additional fertilizer on the soil surface at 5cm away from maize plants for two times. Other management measures shall be implemented in accordance with the management and cultivation system of local cornfields. Moreover, the corn seedlings were applied with basic fertilizer and transplanted in May 8th based on the planting distance of 33cm, row spacing of 60cm and cultivated density of 50001 plants per hm^{-2}. Since there were 90 plants in each row and 8 rows in each

Community, there totals 720 plants in each community. The first additional fertilizer shall be applied in June 1st, and second additional fertilized in June 24th. (**Table 1**)

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

Treatment	Fertilizer application rates (kg.hm^{-2})				
	Basal fertilizer			Top fertilizer(1)	Top fertilizer(2)
	N	P_2O_5	K_2O	N	N
CK	0	0	0	36	60
CR	24	60	60	36	60
CC	24	60	60	36	60

2.3 Sample Collection

2.3.1 Gas sample

Gases in cornfield were collected in May to August of 2016. Each community was equipped with three fixed gas collection points to store the static chamber (60×50×30cm=0.9m3) for artificial collection of greenhouse gases under the same conditions. The inner top of the chamber were 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 (50ml) respectively. In addition, each community was provided with three fixed foundations, which were inserted into soil at 20cm. When sampling, place the static chamber on the foundation and ensure no exchange between internal and external gases of the chamber. Then, collect gas samples every 15 minutes in the first 45 minutes. Usually, gas samples were collected within the period from 8:00 to 11:00. 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, postpone the sampling time and draw three parallel samples every time. During each collection of gas sample, record the surface and air temperature of that day. After collection, complete the sample test in time.

2.3.2 Soil sample

First, draw a combined soil sample (0-20cm soil layer) between two plants, and place into an ice box. Then, reserve the sample at low temperature. During the testing, screen the soil sample with a 5mm mesh, and extract from 0.01mol/L$CaCl_2$ solution to measure the content of nitrate nitrogen and ammonium nitrogen. Meteorological data of cornfield soils can be automatically recorded by Onset HOBO Temperature and Humidity Recorder.

2.4 Sample Test

This research will adopt the static chamber - meteorological chromatography to measure N_20 and gas chromatography (HP 7890A) to measure gas content with the chromatographic column filled by Porpak Q.

The content of NH_4^+-N and NO_3^--N can be measured by a continuous flow analyzer (Flastar 5000 Analyzer) [13].

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 minutes and dry the blades at the temperature of 75℃ before weighing.

2.5 Calculation Method and Data Analysis

N_2O emission flux can be calculated based on the following formula[12]:

$F = \Delta m/A\times\Delta t = (m2-m1)/A\times\Delta t = [C2\times V\times M0\times 273/(273+T2)-C1\times V\times M0\times 273/(273+T1)]/[A\times(t2-t1)\times 22.4\times 10^{-3}]\times 1000$

Where F represents N_2O emission flux ($mg.m^{-2}.h^{-1}$); A represents the area of sampled soil (m2); V represents the volume of static closed chamber (m3); m1 and m2 represent the initially and finally measured weight (g) of certain greenhouse gas in the closed chamber respectively; t1 and t2 represent the time of initial and final measurement (h) respectively; C1 and C2 represent 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; Mo represents the molar mass of greenhouse gases. According to the relation curve between the content and time of gas samples, the accumulated N2O emission can be calculated as Emission flux multiplied by the corresponding observation days[14].

N_2O emission coefficient = (N_2O emissions of nitrogen treatment - N_2O emissions of CK treatment)/ nitrogen fertilizer rate×100

The test data can be arranged into a diagram via EXCEL 2010 and analyzed with SPSS 11.5 software. Moreover, the significance test shall be analyzed with Duncan method.

3. RESULT

3.1 Dynamics of N2o Emission

The variation trend of N_2O emission flux in cornfield was relatively similar at different treatment processes (**Fig 1**), namely N_2O emission flux amounted during the early stage of maize growth period and declined during the later stage. During the entire growth period, 2 times of N_2O emission peaks occurred at different treatment processes: the first peak of N_2O emission occurred in 1-5 days after application of basic fertilizer (May 9th to May 19th), when the peak emission flux of CR and CC represent 0.013 and 0.346 $mg\cdot m^{-2}\cdot h^{-1}$ respectively; the second peak of N_2O emission occurred in 2-8 days after the first additional fertilizer (June 2nd to June 8th), when the peak emission flux of CR and CC represent 0.125 and 0.298 $mg\cdot m^{-2}\cdot h^{-1}$ respectively; the peak of N_2O emission occurred in 1-7 days after the first additional fertilizer (May 9th to May 15th), when the peak emission flux of CK represent 0.079 $mg\cdot m^{-2}\cdot h^{-1}$;after application of basic fertilizer, the cumulated N_2O emissions during the first additional fertilizer accounts for 22.16%, 35.71% and 38.23% of total emissions during the entire growth period, which means N_2O emission flux mainly concentrate on one week after application of basic fertilizer.

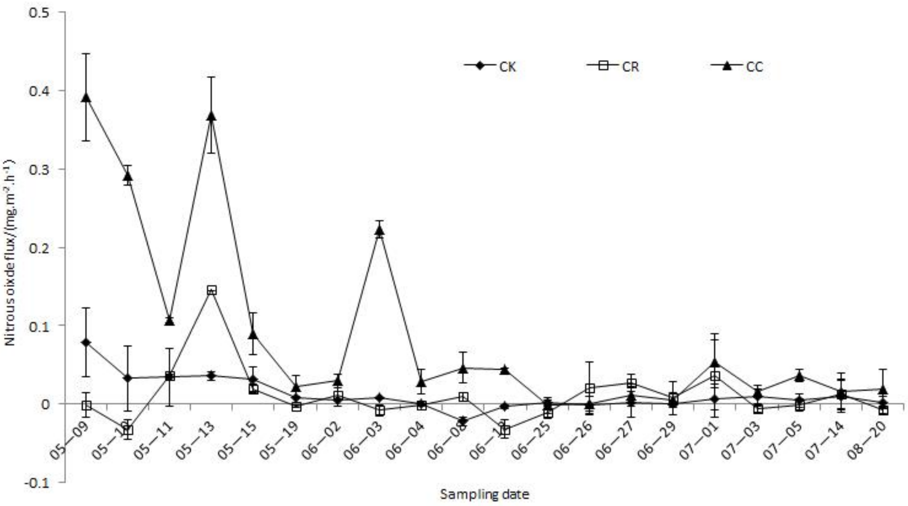

Fig.1 Effect of crop rotation and continuous cropping on N_2O emission flux in cornfield soils in maize-growing season

During the whole growth period, where Crop rotation are applied, N_2O emission peaks are relatively small with more smooth emission flux and no significant difference; where Continuous cropping are applied, N_2O emission flux will be enhanced dramatically to be significantly higher than Crop rotation treatment ($P<0.05$);During the whole growth period, the average N_2O emission flux can be ranked as CC＞CR＞CK, which can be calculated as 0.056, 0.010 and 0.007 $mg\cdot m^{-2}\cdot h^{-1}$;Therefore, it is indicated that Continuous cropping can improve N_2O emission flux in cornfield soils.

3.2 Relation between N2o Emission and Biomass

During the whole maize-growing season, the total N_2O emission after Crop rotation treatment remains at a lower level (**Table 2**) with no significant difference ($P<0.05$); the Continuous cropping treatment will greatly improve the total N_2O emission in cornfield for 9.6 and 7.0 times respectively as compared with CK and CR treatment, which indicates that the Continuous cropping treatment can improve the total N_2O emission in cornfield.

From the perspective of maize biomass (**Table 2**), the CR treatment greatly improves maize biomass for 2.9 times and 1.1 times respectively as compared with CK treatment and CC treatment (P<0.05); the Continuous cropping treatment greatly improve N_2O emission and emission coefficient per unit biomass as compared with CK treatment and CR treatment, including 6.5 and 3.3 times respectively for N_2O emission per unit biomass and 7.5 times respectively for N_2O emission coefficient, which means the Continuous cropping treatment will improve maize biomass and N_2O emission in cornfield. According to the results, the Continuous cropping treatment can improve N_2O emission and emission coefficient per unit biomass.

Table.2 Effect of crop rotation and continuous cropping on total N_2O emissions and biomass in maize yellow soil

Treatment	N_2O total emissions/(kg·hm^{-2})	Biomass/(kg·hm^{-2})	Emission per unit biomass /(g.kg^{-1})	Emission factor coefficient/%
CK	0.19b	5353.14b	0.04	—
CR	0.26b	15636.18a	0.02	0.02
CC	1.82a	13929.89ab	0.13	1.5

Note：Statistically significant assumptions for P＜0.05.

Table.3 Correlation between N_2O emission flux and environmental factors during the whole maize-growing season

Treatment	nitrate nitrogen	air temperature	soil temperature	soil moisture content
CK	0.75	-0.18	-0.05	0.86
CR	0.28	-0.04	-0.05	0.17
CC	0.97*	-0.44	-1.86	0.10

Note：Statistically significant assumptions for P＜0.05 .

3.3 Relation between N₂o Emission and Environmental Factors

According to correlation analysis (**Table 3**), the nitrate nitrogen content of different treatment is positively correlated with N_2O emissions in cornfield soils, among which N_2O emission flux after CR treatment and CC treatment are positively correlated with the nitrate nitrogen content of cornfield soil. Therefore, it indicates that the nitrate nitrogen content is related with N_2O emissions in cornfield.

Therefore, it can be concluded that the air and soil temperatures are negatively correlated with N_2O emissions in cornfield soils (**Table 3**) with no significant difference, which means the air and soil temperatures during maize-growing season cannot be regarded as the main factors to affect N_2O emissions.

According to relevant analysis on the moisture content and N_2O emission in cornfield (**Table 3**), the moisture content of different treatment process is positively correlated with N_2O emission in cornfield soils with no significant difference, which means the moisture content during maize-growing season is uncorrelated with N_2O emission in cornfield soil.

4. DISCUSSION

N_2O emission in typical Huang-huai Sea plain farmland soil is 2.01 ～ 5.97 kg·hm^{-2} [15]. The experiment result shows that the total emission output of N_2O in maize field is 0.19～1.82 kg·hm^{-2}, there is a certain difference, that N_2O emissions in maize field is not high. In this experiment, the N_2O emission is the lowest in the maize field treated by CK, which is consistent with the predecessors' study results [16].The total N_2O emission after Crop rotation treatment remains at a lower level with no significant difference (P<0.05); the Continuous cropping treatment will greatly improve the total N_2O emission in cornfield for 9.6 and 7.0 times respectively as compared with CK and CR treatment. Farmland nitrogen and different cropping system will affect the soil N_2O emissions, as a result of continuous cropping obstacle decreased cornfield soil N_2O emissions [17]. Nitrogen fertilizer inputs increase the source of nitrogen and N_2O emissions in cornfield. During the experiment, the peak flux of N_2O emission will occur in 1-5 days after application of basic fertilizer (May 9th to May 19th), 2-8 days after the first additional fertilizer (June 2nd to June 8th). Therefore, it can be concluded that the two peaks will occur in 1-8 days after fertilizer treatment, which is similar to the research result that N_2O emission mainly occurs in 11 days after fertilizer treatment[18][19]. During the entire growth period, N_2O emission flux mainly concentrate on cornfield after application of fertilizer. Because nitrogen fertilizer inputs increase the source of nitrogen and N2O emissions in cornfield, as the consumption of nitrogen source, the N_2O emission flux also gradually reduce [20].

N_2O emission flux will be enhanced dramatically to be significantly higher than Crop rotation treatment ($P<0.05$);During the whole growth period, the average N_2O emission flux can be ranked as CC＞CR＞CK; Therefore, it is indicated that Continuous cropping can improve N_2O emission flux in cornfield soils. Because soil N_2O emission is the process of nitrification and denitrification in the soil cause [21]. Different cropping systems have a different impact on crop growth and development, can indirectly accumulation and decomposition of soil organic matter and different impact on the relationship between the nitrogen fertilizer, soil nitrogen and crop nitrogen uptake, and lead to soil nitrification and denitrification process affected [22][15]. From the perspective of maize biomass, the CR treatment greatly improves maize biomass for 9.6 times and 7.0 times respectively as compared with CK treatment and CC treatment ($P<0.05$). Continuous cropping cause continuous cropping obstacle to maize growth and development in field, which reduces the maize biomass accumulation.According to relevant reports, the N_2O emission coefficient of dry farmland in China remains between 0.22% and 1.53% [23]. However, in this research the N_2O emission coefficient of cornfield soil remains between 0.02% and 1.5% within N_2O emission coefficient range of dry farmland in China; after the continuous cropping treatment, the N_2O emission coefficient of cornfield soil remains higher than that of crop rotation treatment, but higher than the recommended value 1.25% of international farmland [24]. Therefore, although the continuous cropping will improve N_2O emission coefficient, the N_2O emission in yellow cornfield remains lower than that in other area or crop fields.

According to the research results, N_2O emission flux is positively correlated with the nitrate nitrogen content during the maize-growing season, which is comparatively similar to the research results made by [25]. In addition, N_2O emission in farmland soil can also be affected by the nitrate nitrogen content and environmental factors [4] [26] [27]. However, according to the experiment results, N_2O emission in cornfield soil is negatively correlated with the temperature (including air and soil temperature) and positively correlated with moisture content with no significant difference as compared with previous research results.

5. 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 N_2O emission flux peak will occur in maize yellow soil after fertilizer treatment, and N_2O emissions mainly concentrate on after basic fertilizer treatment; the average N_2O emissions flux of No fertilizer + Crop rotation for comparison treatment is relatively close with inorganic fertilizer + Crop rotation treatment. Therefore, continuous cropping can increase corn field N2O emissions. Secondly, the continuous cropping treatment in maize yellow soil has improved the maize biomass, N_2O emissions per biomass and N_2O emission coefficient. Thirdly, Under the experiment conditions, variations in N_2O emission flux in cornfield soil after crop rotation and continuous cropping treatment are mainly caused by soil nitrate nitrogen content in farmland, from which it could be concluded that N_2O emission in maize yellow soil was free from any influence of local soil moisture content, air temperature or soil temperature.

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Novelty statement

1. Long-term fertilizer research under the condition of rotation cropping patterns on soil n_2o emissions
2. This study observed the crops throughout the growing season of farmland soil n_2o emissions, comprehensive analysis of the growth of crop and fertilizer into the impact on soil n_2o emission, respectively, in order to clear the characteristics of farmland soil n_2o emission.
3. This study adopts the different environmental factors (no^{3-}-N, temperature and soil water content) correlation analysis was carried out on the farmland soil n_2o emission.
4. This research adopts the unit biomass n_2o emission quality of crop dry matter accumulation and farmland soil n_2o emissions were analyzed.