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Research Article

The Influence of N_2O Emission to Water and Nitrogen Coupling Mechanism in Black Soil under Drip Irrigation Mode

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This experiment is aimed at revealing the main characteristics of N_2O emission from soybean in black soil and clarifying the relationship between N_2O emission and environmental factors; in this experiment, static chamber-gas chromatography field observation method was used; meanwhile, three different drip irrigation amounts (300 mm, 350 mm, and 400 mm) and five different nitrogen application amounts (0, 63, 72, 81, and 90 kg/hm^2) were set up to study the effects of different coupling modes on soybean N_2O emission and the relationship between N_2O emission and environmental factors. The results showed that the peak value of N_2O emission flux of soybean mainly occurred in July and August, and the amount of N_2O emission flux in each growth period was flowering-podding period > branching period > seedling period > grain filling period. N_2O emission increased with the increase of drip irrigation amount and nitrogen application amount. The effects of drip irrigation and nitrogen application on N_2O emission were significantly different. Under the three drip irrigation modes, the N_2O emission fluxes of most treatments were significantly correlated with the temperature in that day, and the soil temperature in different soil depths was significantly correlated with the N_2O emission fluxes. The correlation relationship between the temperature of each soil layer under drip irrigation 300 mm and N_2O emission fluxes was less than that under drip irrigation 350 mm and drip irrigation 400 mm. There was no significant correlation between N_2O emission flux and NH_4^+-N and NO_3-N, and there was no significant correlation between N_2O cumulative emission and dry matter quality in the aboveground part of soybean. It shows that the emission of N_2O itself is affected by multiple environmental factors and shows certain randomness. The research results can provide important theoretical basis and technical support for realizing nitrogen reduction and efficient utilization of soybean water and fertilizer in the black soil region of northeastern part of China.

1. Introduction

Irrigation and nitrogen application are two important factors affecting soil N_2O emission. Due to frequent spring droughts and excessive application of nitrogen fertilizer in the western part of Northeast China, N_2O emissions showed a significant increase trend [1, 2]. In recent years, the soybean planting area in the black soil area of northeast China has grown rapidly, and the soybean planting area in Heilongjiang Province alone has reached more than 60 million mu [3]. As an efficient water-saving irrigation technology, drip irrigation has the advantages of small irrigation quota, high utilization efficiency of irrigation water, and easy automatic control. It has been widely used in many countries in the world (especially in arid and semiarid areas). As for the environmental effects of drip irrigation, most of the previous studies focused on soil salt migration, water distribution, and coupling effect of water and fertilizer [4, 5], and less attention was paid to its impact on greenhouse gas emission. With the increasing application of drip irrigation technology, it is necessary to carry out in-depth research on the impact of drip irrigation technology on N_2O emission. At the same time, due to traditional planting habits, most farmers are also used to applying chemical nitrogen fertilizer in large quantities. Excessive application of nitrogen fertilizer not only increases costs but also causes environmental pollution and sharply increases N_2O emissions [6].

Drip irrigation has a significant impact on N_2O emission in farmland [7–12], and the reason is that drip irrigation changes the transformation process of soil nitrogen. However, the research results on N_2O emission have increased and decreased, and the research conclusions are not consistent. There are also different views on the mechanism of water influencing N_2O emission. Whether these differences are related to specific regional climate conditions and farmland ecological environment needs further experimental verification.

Increased application of nitrogen fertilizer can promote soil N_2O emissions [13–18], but the quantitative relationship between emissions and nitrogen application rate varies greatly among regions. To further explore the response mechanism of different climate, soil, and crops to soybean N_2O emission and nitrogen application rate, and to coordinate the contradiction between soybean nitrogen application and N_2O emission, has become a research hotspot at home and abroad.

Aiming at the problems of waste of water and fertilizer resources, low nitrogen fertilizer utilization rate, and increased greenhouse gas N_2O emission in the production of black soil soybean in China, this project studies the N_2O emission effect and nitrogen fertilizer utilization efficiency improvement mechanism under the condition of reducing nitrogen fertilizer application under the drip irrigation mode. The research results can provide application basic theory and technical support for realizing the efficient utilization of soybean water and fertilizer resources and reducing greenhouse gas N_2O emission in the black soil area. It is of great significance to ensure national food security, regional water security, and ecological environment.

Therefore, based on northeastern black soil soybeans, this study studied different drip irrigation amount and reduced nitrogen fertilizer application to control N_2O emission and improve nitrogen use efficiency, which is of great significance for scientific development of water and nitrogen resource management strategies compatible with water saving, yield increasing (stable yield), and emission reduction of black soil soybeans. It can also play an important role in providing technical support to the realization of the strategic goals of "one control, two reduction, and three solving" which means as follows: firstly, the total amount of water used in agriculture industry should be controlled; secondly, the amount of fertilizer and pesticides should be reduced; and thirdly, the pollution caused by livestock, poultry, plastic film mulching, and waste straw burning should be solved by recycling.

2. Materials and Methods

2.1. Test Site and Basic Information. The experiment was conducted in Heshan Farm Science and Technology Park, Heihe City, Heilongjiang Province (48°43′~49°03′ N, 124°56′~126°21′ E). The average annual temperature in the test area was ≥10°C, the annual effective accumulated temperature was 2000°C~2300°C, and the frost-free period was 115-120 d, belonging to the cold temperate continental climate, and the rainy season was mostly concentrated in summer. The local soil type is mainly black soil, and the cultivated land is weakly acidic. The basic physical and chemical properties of 0-20 cm soil layer in the test site are as follows: the soil bulk density was 1.21 g/cm^3, alkali-hydrolyzable nitrogen was 137.8 mg/kg, available phosphorus was 20.35 mg/kg, available potassium was 180.16 mg/kg, organic matter was 22.1 g/kg, and pH was 6.26.

2.2. Experimental Design

2.2.1. Layout of the Test Area. The plant crop is soybean, and the tested variety is Heihe 43, the main local soybean variety (provided by Beidahuang Seed Company). The tested fertilizers were urea (N = 46%), potassium (K_2O = 60%), and diamine (P_2O_5 = 16%). The planting method was "one ridge, single tube, and double row," the ridge height was 0.2 m, the ridge width was 0.4 m, the ditch bottom width was 0.4 m, the ridge spacing was 1 m, two rows of soybean were planted on the ridge, and the seedling number was 360,000 plants/hm^2. Drip irrigation belt was laid in the middle of the ridge, the flow rate of the drip head was 1.38 L/h, the distance between the drip heads was 0.3 m, and the area of each test plot was 10 m × 10 m = 100 m^2. The test layout is shown in Figure 1.

2.2.2. Field Plot Experiment Design. Under the same conditions of soybean varieties, densities, pesticide application, and other technologies, three different drip irrigation amounts were set up in the experiment, 300 mm, 350 mm, 400 mm, respectively, and no irrigation was taken as the control. The drip irrigation amount ratio in each growth period was seedling period: branching period: flowering-podding period: grain filling period = 1.5 : 1.5 : 5 : 2. Five different nitrogen application rates were set: conventional nitrogen application level of 90 kg/hm^2, nitrogen reduction level of 10% 81 kg/hm^2, nitrogen reduction level of 20% 72 kg/hm^2, nitrogen reduction level of 30% 63 kg/hm^2, and zero nitrogen application level, with fertilization ratio of base fertilizer: top fertilizer (applied with water drops at flowering and grain filling period) = 2 : 1. Potassium fertilizer (30 kg/hm^2) and phosphate fertilizer (150 kg/hm^2) were applied once as base fertilizer. A total of 16 treatments were used in the comprehensive experimental design method. Each treatment was repeated for 3 times, and a total of 48 test cells were randomly arranged. The experimental design is shown in Table 1.

2.3. Determination and Analysis Methods

2.3.1. N_2O Sampling and Determination. N_2O gas was collected and determined by static chamber gas chromatography

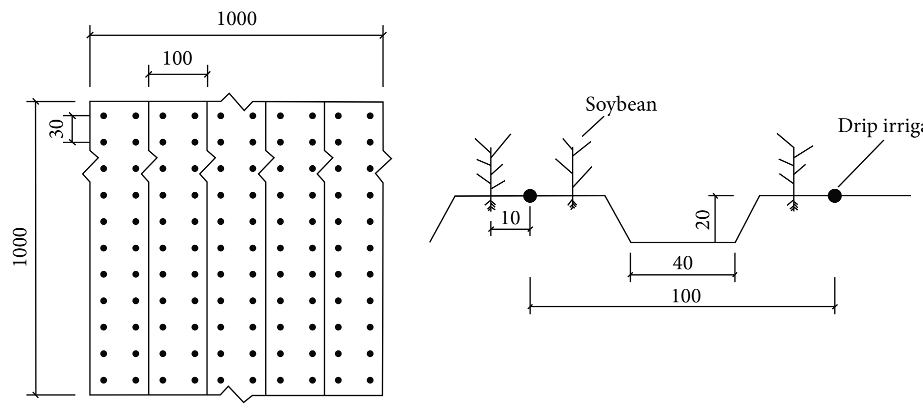

Figure 1: The layout of field plot experiment.

method. The static chamber sampling system is shown in Figure 2. It is an airtight bottomless box made of organic glass, with a volume of $50 \times 50 \times 100\,cm^3$. The depth of the ground box is about 15 cm. The upper part of the base is equipped with a 5 cm deep water tank, which is sealed with water before gas sample collection. The gas collection time is from 8 : 00 to 10 : 00. The micro electric fan is started before gas extraction, and the gas sample in the box is extracted with a 50 mL syringe at 0, 10, 20, and 30 min after the gas in the box is uniform. Then, the gas sample is brought back to the laboratory and detected and analyzed by Shimadzu GC-14B gas chromatograph. Gas samples were collected twice at each growth period, with an interval of 7 days (additional measurements were required in case of rainfall).

The N_2O emission flux soybean was calculated by using internationally common formula:

$$F = \rho h \cdot \frac{dC}{dt} \cdot \frac{273}{273 + t} \cdot \frac{p}{p_0}. \quad (1)$$

In which, F is N_2O emission flux, and the unit is $\mu g/m^2 \cdot h$; ρ is the N_2O density in standard state, and ρN_2O is equal to $1.964\,g/cm^3$; H is the effective height of chamber, and the unit is m; dC/dt is the change rate of gas concentration in the sampling chamber during the sampling process, $mL/m^3 \cdot h$; t stands for average temperature in the sampling chamber, and the unit is °C; P is air pressure in sampling chamber, and the unit is kPa; P_0 is the standard atmospheric pressure, and the unit is kPa. (This test area is located in the plain region, and the impact of pressure is relatively small. P was considered equal to the standard atmospheric pressure.)

2.3.2. Determination of Nitrate and Ammonium Nitrogen. The collected fresh soil samples were sipped 5 mm and weighed 24.00 g into a 200 mL plastic bottle. 100 mL KCL with a concentration of 1 mol/L was added for extraction, oscillation, filtration, and filtrate using Seal Analytical GmbH (Germany, AA3), with sensitivity 0.001 AUFS.

2.3.3. Observation of Meteorological Factors. The meteorological data are recorded automatically by DZZ2 automatic weather station (Tianjin Meteorological Instrument Factory) of the test station. At the same time of gas sampling, soil surface temperature, soil temperature at 5 cm layer, and soil temperature at 10 cm layer were measured with a thermometer.

Table 1: The treatment in field plot experiment.

Treatment	Drip amount (mm)	Nitrogen application amount (kg/hm^2)
W1N4	300	90
W2N4	350	90
W3N4	400	90
W1N3	300	81
W2N3	350	81
W3N3	400	81
W1N2	300	72
W2N2	350	72
W3N2	400	72
W1N1	300	63
W2N1	350	63
W3N1	400	63
W1N0	300	0
W2N0	350	0
W3N0	400	0
CK	0	90

2.3.4. Dry Matter Determination. Three representative plants were selected from each plot at each growth period for dry matter determination in an oven (105°C).

2.4. Data Processing. Microsoft Excel 2010 and Surfer software were used for data processing, and SPSS was used for variance analysis.

3. Result Analysis

3.1. Effects of Different Treatments on N_2O Emission Fluxes and Emissions of Soybean

3.1.1. Effects of Different Treatments on N_2O Emission Flux of Soybean. Changes in N_2O emission fluxes of soybeans

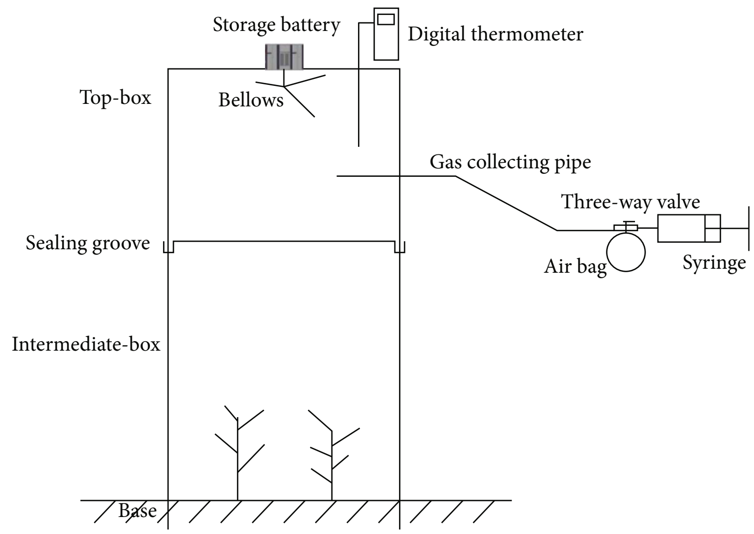

Figure 2: Diagram of static chamber sampling system.

during the growth period under different drip irrigation and nitrogen application rates are shown in Figure 3. The variation trend of N_2O emission fluxes of all treatments is consistent. The peak values of emission fluxes of all treatments are concentrated in July and August, which is due to the increased rainfall in July and August of this year and the increase of soil moisture after rainfall, which improves the activities of nitrifying and denitrifying bacteria in the soil, promotes the production rate of nitrate and ammonium nitrogen, and thus significantly increases the production rate of N_2O. The maximum N_2O emission flux of each treatment in this experiment was 48.63 μg·m^{-2}·h^{-1} on July 21.

3.1.2. Effects of Different Treatments on N_2O Emission of Soybean. The changes of N_2O emission in different treatments and growth periods of soybean during the growth period are shown in Figure 4. The total N_2O emission in each growth period was flowering-podding period > branching period > seedling period > seed filling period. W3N4 treatment, namely, drip irrigation amount of 400 mm, nitrogen application rate of 90 kg/hm^2, and N_2O emission, reached the maximum, which was 50.4 kg/hm^2. In W1N0 treatment, when the drip irrigation amount was 300 mm and the nitrogen application rate was 0 kg/hm^2, the cumulative emission of N_2O reached the minimum, which was 22 kg/hm^2. Under the same nitrogen application level, the greater the drip irrigation amount, the greater the N_2O emission. Compared with the 300 mm drip irrigation amount, the N_2O emission increased by 5.46% and 11.64% with the increase of drip irrigation amount and nitrogen application amount, respectively, when the drip irrigation amount was 350 mm and 400 mm. Under the same drip irrigation level, the higher the nitrogen application rate, the higher the N_2O emission. Compared with the nitrogen application rate of 90 kg/hm^2, the N_2O emission of other nitrogen reduction levels decreased by 14.59%, 28.78%, 53.7%, and 109.79%, respectively. It can be seen that the N_2O emission increased with the increase of drip irrigation rate and nitrogen application rate during the growth period of soybean.

Table 2 shows the results of two-factor variance analysis of effects of different drip irrigation levels and nitrogen application levels on N_2O emission of soybean. The results show that different drip irrigation levels and nitrogen application levels have extremely significant differences on N_2O emission ($P < 0.01$), while the interaction between drip irrigation levels and nitrogen application levels has no significant difference on N_2O emission ($P > 0.05$).

3.2. Relationship between Meteorological Factors and N_2O Emission Flux of Soybean. Correlation analysis was made between N_2O emission fluxes of each treatment and the minimum, maximum, and average temperatures on the sampling day, and the results are shown in Table 3. N_2O emission fluxes were positively correlated with maximum temperature, minimum temperature, and average temperature.

In W1 (300 mm) drip irrigation mode, there was no significant correlation between N_2O emission fluxes and the maximum and average air temperature. In WIN2 (300 mm drip irrigation, 72 kg/hm^2 nitrogen application) and W1N0 (300 mm drip irrigation, 0 kg/hm^2 nitrogen application), there was a significant correlation between N_2O emission fluxes and the minimum air temperature at the 0.05 level. W1N1 (drip irrigation 300 mm, nitrogen application 63 kg/hm^2) was significantly correlated with the minimum temperature at 0.01 level, while the other treatments had no significant correlation with the minimum temperature. Under W2 (350 mm) drip irrigation mode, there was no significant relationship between W2N0 (drip irrigation volume 350 mm, nitrogen application rate 0 kg/hm^2) and the maximum temperature, and there was a significant relationship between the other treatments and the maximum temperature, minimum temperature, and average temperature at the level of 0.05 or 0.01. Under W3 (400 mm) drip irrigation mode, there was a significant correlation between each treatment and the minimum temperature and average

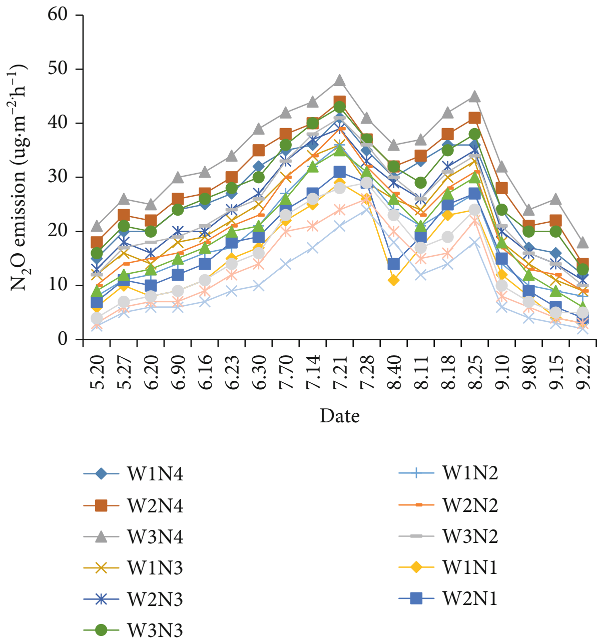

Figure 3: Changes of N_2O emission fluxes under different treatments during each soybean growth period.

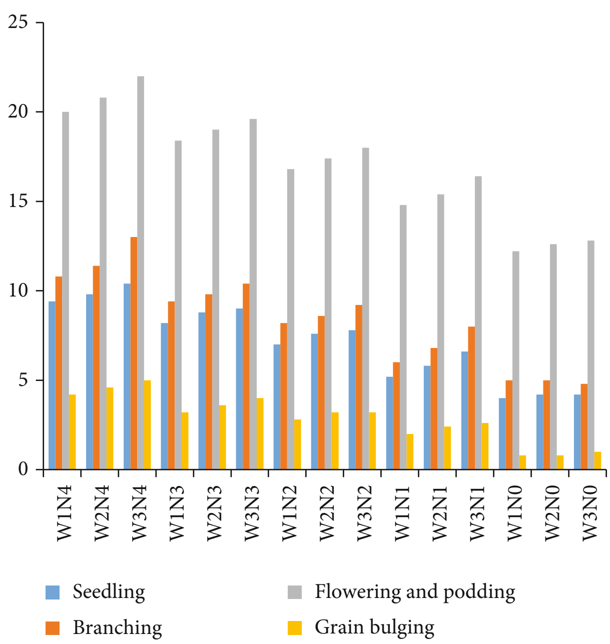

Figure 4: Change of mean value of N_2O emission fluxes in different growth periods of soybean.

temperature at the level of 0.05 or 0.01, but there was no significant correlation with the maximum temperature. By comparing the correlation coefficients, it was found that under W1 (300 mm) drip irrigation mode, the correlation coefficient of high fertilization treatment was slightly smaller than that of low fertilization treatment, indicating that nitrogen application weakened the influence of temperature on N_2O emission flux.

Table 2: Two-factor variance analysis of effects of drip irrigation and nitrogen application rate on N_2O emission of soybean.

Treatment	Drip amount	Nitrogen amount	Drip amount × nitrogen amount
P value	0.002	0.002	0.047

Table 3: Correlation analysis between N_2O emission fluxes and air temperature in each sample of each treatment.

Treatment	Maximum temperature (°C)	Minimum temperature (°C)	Average air temperature (°C)
W1N4	0.010	0.038	0.025
W2N4	0.048*	0.054*	0.057*
W3N4	0.045	0.076**	0.066**
W1N3	0.011	0.042	0.028
W2N3	0.056*	0.047*	0.057*
W3N3	0.040	0.071**	0.060**
W1N2	0.014	0.047*	0.033
W2N2	0.057*	0.053*	0.060**
W3N2	0.039	0.067**	0.058*
W1N1	0.016	0.060**	0.041
W2N1	0.051*	0.062**	0.062**
W3N1	0.044	0.080**	0.067**
W1N0	0.016	0.056*	0.039
W2N0	0.042	0.058*	0.055*
W3N0	0.040	0.076**	0.063**

3.3. Correlation between Soybean Soil Factors and N_2O Emission Fluxes. Table 4 shows the correlation analysis between N_2O emission fluxes of different treatments and soil ammonium and nitrate nitrogen contents in soybean growing season. W1 (300 mm) drip irrigation treatment W1N1 (300 mm drip irrigation, nitrogen application rate 63 kg/hm^2) had a significant positive correlation with ammonium nitrogen. W2 (350 mm) drip irrigation had no significant correlation with the contents of ammonium and nitrate nitrogen in soil. Under the W3 (400 mm) drip irrigation mode, W3N4 (400 mm drip irrigation, 90 kg/hm^2 nitrogen application rate), W3N2 (300 mm drip irrigation, 72 kg/hm^2 nitrogen application rate) and W3N0 (400 mm drip irrigation, 0 kg/hm^2 nitrogen application rate) had a significant negative correlation with nitrate nitrogen ($P < 0.05$). Through the experiment, it was found that when the drip irrigation amount was small, there were more alternate times of drying and wetting in the soil, the physical and chemical environment of the soil was changed more frequently, and the N_2O emission flux was affected by many factors. Therefore, the correlation between the treatments in this study and the soil NO_3- and NH_4^+-N contents was poor. However, when the drip irrigation amount is large, the soil is humid for a long time and the soil environment is relatively stable. Therefore, the N_2O emission flux of some treatments in W3 (400 mm) is significantly correlated with nitrate nitrogen.

Table 4: Correlation analysis between N_2O emission fluxes and soil factors in each treatment.

Treatment	Ammonium nitrogen	Nitrate nitrogen
W1N4	-0.671	-0.286
W2N4	-0.145	-0.700
W3N4	0.249	-0.883*
W1N3	-0.531	-0.316
W2N3	-0.026	-0.583
W3N3	0.295	-0.740
W1N2	-0.278	-0.599
W2N2	-0.072	-0.491
W3N2	0.187	-0.885*
W1N1	0.883*	0.179
W2N1	0.137	-0.502
W3N1	0.373	-0.719
W1N0	-0.429	-0.696
W2N0	0.131	-0.501
W3N0	0.270	-0.832*

3.4. Relationship between N_2O Flux and Soil Temperature. Different drip irrigation as well as the straw returned to change paddy soil physical and chemical conditions, leading to soil factors affecting N_2O emissions in the change, different drip irrigation mode changed soil dry and wet state, different fertilizer rate changed the state of the growth of soybean plant, and these factors will lead to changes in soil temperature of different processing. The temperature of different soil layer is also one of the important factors affecting nitrification and denitrification in rice field. The relationship between soil surface temperature, soil temperature at 5 cm layer, and soil temperature at 10 cm layer and N_2O emission flux under three drip irrigation quantities is shown in Figures 5–13. The correlation analysis results of soil temperature and N_2O emission flux under different drip irrigation amounts are shown in Table 5.

The N_2O emission fluxes under the three drip irrigation modes increased with the increase of soil temperature at different depths. The slope of the fitting equation of N_2O emission flux and soil temperature shows a trend of gradual increase with the increase of soil depth, indicating that the soil depth under the three drip irrigation amounts is larger and the increase of soil temperature has a greater promoting effect on N_2O emission flux. The increasing rate of N_2O emission flux with the temperature of 5 cm soil layer and 10 cm soil layer was greater than that of drip irrigation of 350 mm and 400 mm, and the N_2O emission flux with the increase of soil surface temperature was the largest under drip irrigation of 350 mm. By comparing R^2 of the fitting equation between N_2O emission flux and soil temperature under three drip irrigation amounts, it can be seen that the linear fitting effect of soil temperature and N_2O emission flux under drip irrigation amount of 400 mm is the best, followed by drip irrigation amount of 350 mm, and the worst is drip irrigation amount of 300 mm. The fitting effect of 300 mm drip irrigation and 400 mm drip irrigation equations gradually became better with the increase of soil depth, and when the drip irrigation amount was 350 mm, the fitting effect at 5 cm was the best, followed by the soil surface, and the worst at 10 cm. The correlation between temperature at different soil depths and N_2O emission flux under three types of drip irrigation was extremely significant ($P < 0.01$). By comparing the correlation coefficient between temperature at different soil depths and N_2O emission flux under three types of irrigation and three drip irrigation modes (Table 5), it can be seen that the correlation coefficient is the highest when drip irrigation is 400 mm under different soil depths. Drip irrigation of 350 mm followed, and drip irrigation of 300 mm was the smallest, indicating that soil temperature had a strong correlation with N_2O emission flux when drip irrigation was large. When drip irrigation was small, the correlation coefficients increased gradually with the increase of soil depth, while when drip irrigation was 350 mm, the correlation coefficients increased first and then decreased with the increase of soil depth, and the correlation coefficients reached the maximum at 5 cm.

3.5. Relationship between Dry Matter Quality of Soybean Overground and N_2O Cumulative Emission. As shown in Figure 14, the correlation analysis between soybean overground dry matter quality and N_2O cumulative emissions shows that there is a positive correlation between N_2O cumulative emissions and soybean overground dry matter quality ($R^2 = 0.0049$), but the was no significant correlation. Although correlation analysis showed that N_2O cumulative emissions increased with the increase of soybean dry matter mass, the slope of regression equation was very small and the correlation was low. The aboveground part of soybean can provide strong transport conditions for N_2O emission through plant aerenchyma, but N_2O emission is also affected by other environmental factors, and the process and influencing factors of N_2O emission are complicated and greatly uncertain.

4. Discussion

N_2O emissions are affected by nitrification and denitrification reactions occurring in soil, which will change due to the changes in soil physical and chemical properties caused by different irrigation and fertilization methods [19]. At present, there are different conclusions about the effect of irrigation amount on N_2O emission. Studies have shown that due to the large amount of irrigation, the soil pore water content is higher, which will produce an environment that inhibits denitrification reaction and reduce the N_2O emission compared with drip irrigation [20]. Other studies have shown that the effective reduction of N_2O emission is due to the dominant role of nitrification reaction [21], while denitrification reaction mainly occurs under the condition of abundant water, thus promoting N_2O emission. This study shows that under the condition of same *n* application rate, the smaller the drip irrigation, and effectively reduces the amount of N_2O emissions, and in the whole soybean growth season, peak emissions are mainly concentrated in

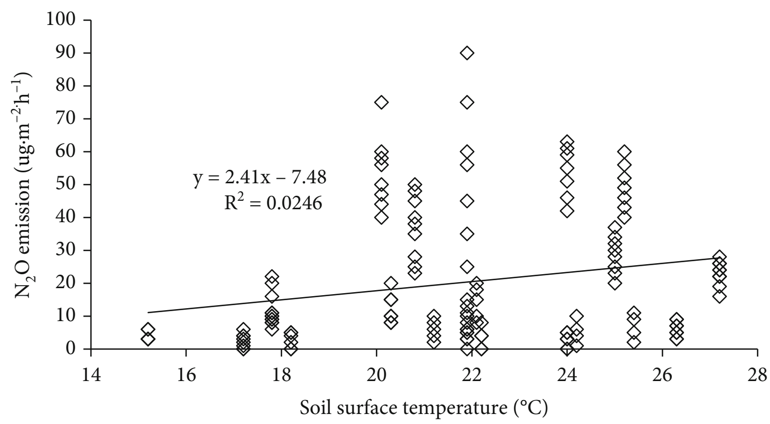

Figure 5: Relationship between soil surface temperature and N_2O emission flux under 300 mm drip amount.

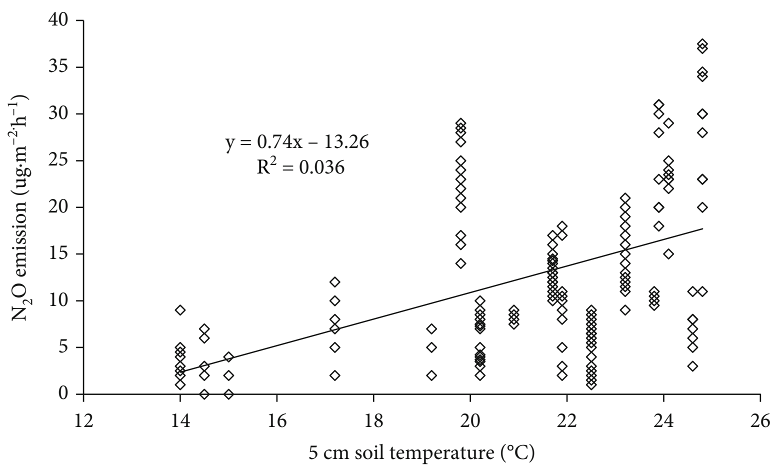

Figure 6: Relationship between temperature in 5 mm deep soil and N_2O emission flux when the drop amount is 300 mm.

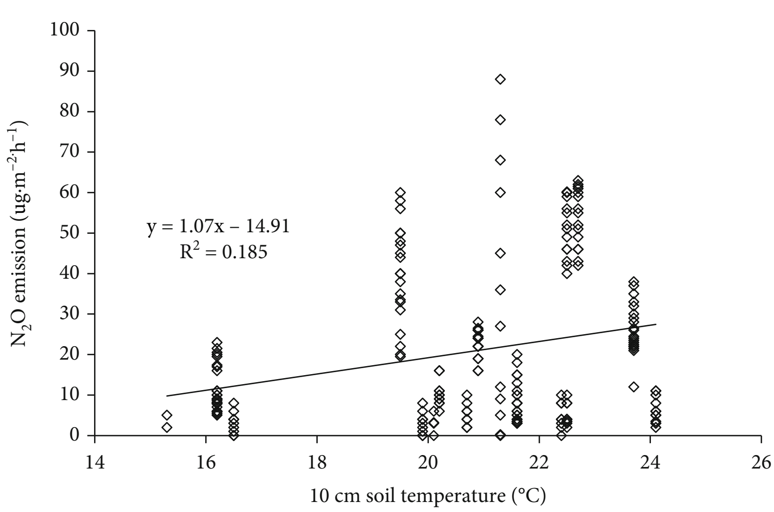

Figure 7: Relationship between temperature and N_2O emission flux when drip amount is 350 mm.

July and August, the results of the study and Liu et al. [22]. The results are consistent; this may be because the soil moisture content with low denitrification reaction is suppressed, thus reducing N_2O emissions, and emission peak that appeared mainly in July and August may be because the Heilongjiang Province in the western region is a dry area; annual

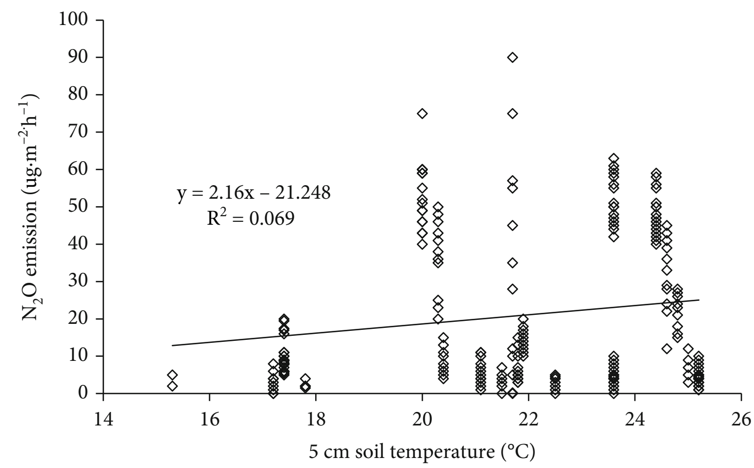

Figure 8: Relationship between soil surface temperature and N_2O emission flux when drip amount is 350 mm.

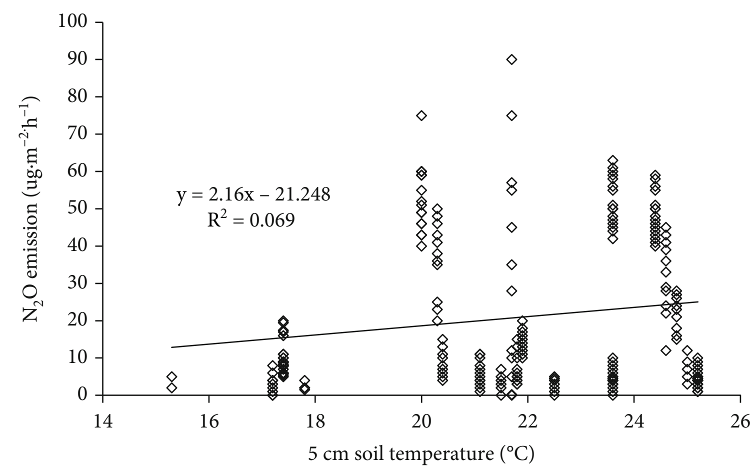

Figure 9: Relationship between 5 mm deep soil temperature and N_2O emission flux when drip amount is 350 mm.

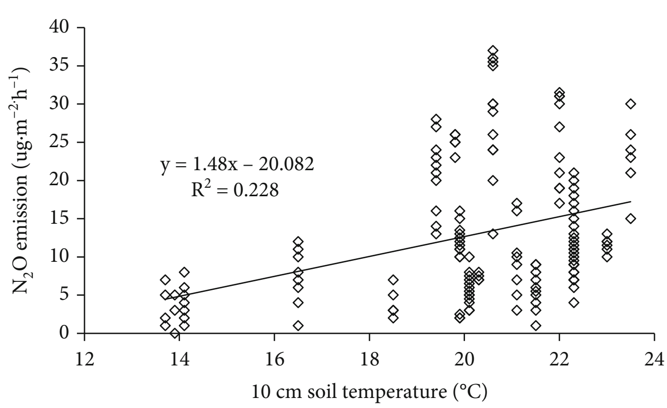

Figure 10: Relationship between10 cm deep soil temperature and N_2O emission flux when drip amount is350 mm.

precipitation mainly concentrated in July and August, with soil surface moisture after precipitation; soil moisture content increased significantly, microbial activity accelerated the mineralization of soil organic matter, and NH_4^+ as nitration reaction substrate, NO_3- is the reaction substrate of denitrification reaction [23], and the high temperature weather in Heilongjiang region concentrated in July and August throughout the year, and the high temperature and high humidity soil environment promote denitrification reaction, thus increasing the emission of N_2O.

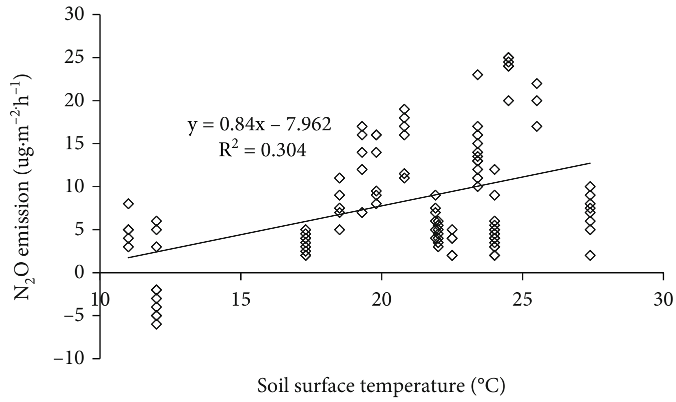

Figure 11: Relationship between soil surface temperature and N_2O emission flux when drip amount is 400 mm.

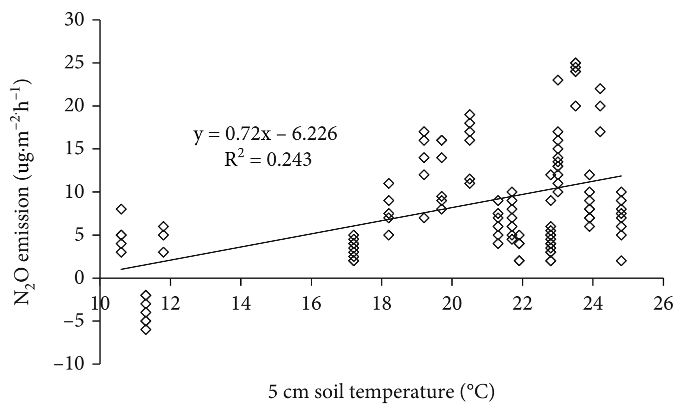

Figure 12: Relationship between 5 mm deep soil temperature and N_2O emission flux when drip amount is 400 mm.

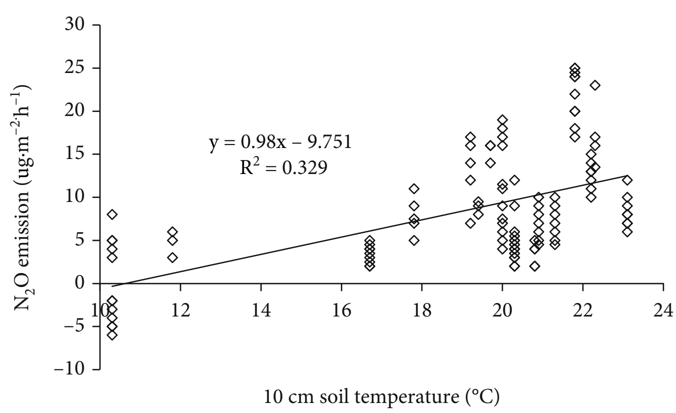

Figure 13: Relationship between 10 cm deep soil temperature and N_2O emission flux when drip amount is 400 mm.

Table 5: Correlation analysis between soil temperature and N_2O emission flux under different drip rates.

Drip irrigation amount	The correlation coefficient		
	The soil surface temperature	5 cm deep soil temperature	10 cm deep soil temperature
300 mm	0.194^{**}	0.225^{**}	0.281^{**}
350 mm	0.544^{**}	0.548^{**}	0.527^{**}
400 mm	0.551^{**}	0.583^{**}	0.620^{**}

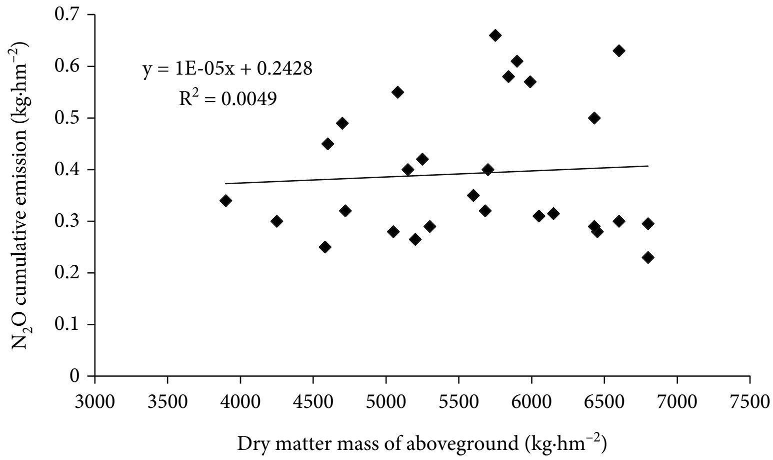

Figure 14: Relationship between dry matter mass of soybean in the overground part and N_2O cumulative emission.

This study pointed out that the three kinds of drip irrigation mode most of the processing amount of N_2O emission flux there is significant correlation with the temperature, soil temperature and air temperature is one of the important factors, further analysis showed that the three kinds of drip irrigation quantity model under different soil depth of Mark Twain and the relationship between N_2O emission flux exists significant correlation, which is similar to previous research results. Ly et al. [24] also reached a similar conclusion in the study of grassland N_2O emission. A large number of experiments have shown that both nitrification and denitrification are positively correlated with soil temperature [25]. In the soybean planting environment, the increase of temperature in different soil layers can promote microbial activity, thus promoting the emission of N_2O. In this study, the correlation between soil temperature and N_2O emission flux under 300 mm drip irrigation is less than that under 350 mm drip irrigation and 400 mm drip irrigation, which may be because frequent changes of soil moisture content under 300 mm drip irrigation weaken the influence of soil temperature on soil moisture content, while when the drip irrigation is larger, the variation range of soil moisture content is smaller. In a stable soil environment, temperature may be the main factor affecting N_2O emission from paddy fields. Temperature not only affects the production of N_2O but also affects the emission of N_2O from soybean by affecting the diffusion of N_2O in soil and the transport route of N_2O. This is consistent with the research results of Yalan et al. [26] and Jinsai et al. [27].

Although the production of N_2O is related to the transformation of different forms of nitrogen in the soil, it was found in this study that the correlation between N_2O emission flux and NH_4^+-N and NO_3–N concentrations was poor, which may be due to the fact that only soil samples at different growth periods were taken in this study, which was relatively small in number and not representative enough. The emission of N_2O itself is affected by multiple environmental factors and shows certain randomness. Therefore, there is no significant correlation between N_2O emission flux and NH_4^+-N and NO_3-N in most treatments in this experiment. In the next step, we will increase the number and frequency of samples, to establish the correlation model between water, fertilizer, and N_2O emission from soybean, verify the simulation results with the analysis results, and study the N_2O emission of black soil soybean by different water and fertilizer from a deeper mechanism.

5. Conclusion

(1) The variation trend of N_2O emission fluxes of soybean under different treatments was consistent during the whole growth period. The peak values of emission fluxes of all treatments were concentrated in July and August, and the overall N_2O emission in each growth period is shown as follows: pod period > branching period > seedling period > bulking period. N_2O emission increased with the increase of drip irrigation amount and nitrogen application amount. The effects of drip irrigation amount and nitrogen application rate on N_2O emission were significantly different ($P < 0.01$), while the interaction between drip irrigation amount and nitrogen application level had no significant difference on N_2O emission ($P > 0.05$)

(2) Most of the N_2O emission fluxes under the three drip irrigation modes were significantly correlated with the temperature of the day, and soil temperature at different soil depths was significantly correlated with the N_2O emission fluxes. The correlation between the temperature of each soil layer under drip irrigation 300 mm and N_2O emission fluxes was less than that under drip irrigation 350 mm and drip irrigation 400 mm

(3) There is a poor correlation between N_2O emission fluxes and concentrations of NH_4^+-N and NO_3–N, and there is no significant correlation between N_2O emission fluxes and NH_4^+-N and NO^3-N in most treatments, indicating that the emission of N_2O itself is stochastic to a certain extent under the influence of

multiple environmental factors. There was no significant correlation between N_2O cumulative emission and soybean overground dry matter

(4) Based on experimental analysis, this paper controls N_2O emission and improves nitrogen use efficiency by controlling the amount of water and fertilizer application, which is of great significance for scientifically formulating water and nitrogen resource management strategies compatible with water saving, yield increasing (stable yield), and emission reduction of black soil soybean. It can also play an important technical support role for the realization of the strategic goal of "one control, two reductions, and three basics" proposed by the Ministry of Agriculture and Rural Areas of China

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors do not have any possible conflicts of interest.

Acknowledgments

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References

[1] X. X. Zhang, S. Yin, Y. S. Li, H. Zhuang, C. Li, and C. Liu, "Comparison of greenhouse gas emissions from rice paddy fields under different nitrogen fertilization loads in Chongming Island, Eastern China," *Science of the Total Environment*, vol. 472, pp. 381–388, 2014.

[2] H. Hou, S. Peng, J. Xu, S. Yang, and Z. Mao, "Seasonal variations of CH_4 and N_2O emissions in response to water management of paddy fields located in southeast China," *Chemosphere*, vol. 89, no. 7, pp. 884–892, 2012.

[3] X. Liu, S. J. Herbert, J. Jin, Q. Zhang, and G. Wang, "Study on fertilizer utilization rate of maize and soybean in black soil region," *Plant and Soil*, vol. 10, no. 3, pp. 324–332, 2014.

[4] Q. Xuebin and P. Hongbin, "Research status and priorities of environmental effects of water-saving irrigation," *Transactions of the Chinese society of agricultural engineering*, vol. 16, no. 4, pp. 37–40, 2000.

[5] T. Lijia, W. Fengxin, and G. Xiaoxiao, "Effects of plastic mulching drip irrigation on greenhouse gas emission," *Chinese agricultural science bulletin*, vol. 29, no. 3, pp. 17–23, 2013.

[6] L. Yue and J. Xiaotang, "The key to reducing nitrous oxide in farmland is rational nitrogen application," *Journal of agro-environment science*, vol. 39, no. 4, pp. 842–851, 2020.

[7] C. Scheer, R. Wassmann, K. Kienzler, N. Ibragimov, and R. Eschanov, "Nitrous oxide emissions from fertilized, irrigated cotton (*Gossypium hirsutum* L.) in the Aral Sea basin, Uzbekistan: influence of nitrogen applications and irrigation practices," *Soil biology& biochemistry*, vol. 40, no. 2, pp. 290–301, 2008.

[8] L. Sanchez-Martín, A. Meijide, L. Garcia-Torres, and A. Vallejo, "Combination of drip irrigation and organic fertilizer for mitigating emissions of nitrogen oxides in semiarid climate," *Agricultural Ecosystems& environment*, vol. 137, no. 1-2, pp. 99–107, 2010.

[9] C. M. Kallenbach, D. E. Rolston, and W. R. Horwath, "Cover cropping affects soil N_2O and CO_2 emissions differently depending on type of irrigation," *Agriculture, Ecosystems and Environment*, vol. 137, no. 3-4, pp. 251–260, 2010.

[10] L. Sánchez-Martín, A. Arce, A. Benito, L. Garcia-Torres, and A. Vallejo, "Influence of drip and furrow irrigation systems on nitrogen oxide emissions from a horticultural crop," *Soil biology& biochemistry*, vol. 40, no. 7, pp. 1698–1706, 2008.

[11] Q. Yuchun, G. Shufang, D. Yunshe et al., "Effects of irrigation on greenhouse effect and soil carbon storage," *Scientia Agricultura Sinica*, vol. 47, no. 9, pp. 1764–1773, 2014.

[12] X. U. Hua, X. I. N. G. Guangxi, C. A. I. Zucong, and Z. Hetian, "Effects of soil moisture and nitrogen fertilizer application on N_2O emission in rice," *Chinese Journal of Applied Ecology*, vol. 10, no. 2, pp. 186–188, 1999.

[13] G. U. O. Wenyi, W. Dan, J. Liang et al., "Response of soybean plant growth and greenhouse gas to different fertilization methods in black soil," *Soybean science*, vol. 36, no. 2, pp. 274–279, 2017.

[14] R. Su, K. Liu, B. Wang et al., "Effects of nitrogen application level on CH_4 and N_2O emission and rice yield in Jianghan plain," *Journal of agricultural science and technology of China*, vol. 18, no. 5, pp. 118–125, 2016.

[15] H. Xiaoyu, M. Xingzhu, C. Miaomiao et al., "Application of nitrogen fertilizer and synergist to increase yield, quality and efficiency of rice in cold region," *Journal of Soil and Water Conservation*, vol. 33, no. 4, pp. 175–179+307, 2019.

[16] M. Erdeng, M. Jing, M. Hua, and C. Zucong, "Effects of fertilization on N_2O emission in paddy field," *Journal of agro-environment science*, vol. 28, no. 12, pp. 2453–2458, 2009.

[17] S. Yana, L. Yan, and C. Ziqiang, "Effects of nitrogen fertilizer level on bacterial community and N_2O emission in paddy field," *Chinese Journal of Eco-Agriculture*, vol. 25, no. 9, pp. 1266–1275, 2017.

[18] Y. Li, E. Lin, and M. Rao, "The effect of agricultural practices on methane and nitrous oxide emissions from rice field and pot experiments," *Nutrient Cycling in Agroecosystems*, vol. 49, no. 1-3, pp. 47–50, 1997.

[19] H. R. Li, W. P. Hao, X. R. Mei, and R. Guo, "Effect of different irrigation and fertilization managements on N_2O emissions and yeild in summer maize-winter wheat field," *Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE)*, vol. 34, no. 16, pp. 103–112, 2018.

[20] X. P. Gao, M. Tenuta, A. Nelson et al., "Effect of nitrogen fertilizer rate on nitrous oxide emission from irrigated potato on a clay loam soil in Manitoba, Canada," *Canadian Journal of Soil Science*, vol. 93, no. 1, pp. 1–11, 2013.

[21] H. A. Mooney and P. A. Matson, "Exchange of materials between terrestrial ecosystems and the atmosphere," *Science*, vol. 238, no. 4829, pp. 926–932, 1987.

[22] C. Y. Liu, K. Wang, S. X. Meng et al., "Effects of irrigation, fertilization and crop straw management on nitrous oxide and nitric oxide emissions from a wheat-maize rotation field in

northern China," *Ecosystems & Environment*, vol. 140, no. 1-2, pp. 226–233, 2011.

[23] H. Qingju, W. Yuesi, S. Changchun, and J. Changsheng, "Effects of land reclamation on CH_4 and N_2O emission in marsh wetland," *Acta Ecologica Sinica*, vol. 27, no. 8, pp. 3417–3426, 2007.

[24] P. Ly, Q. Duong Vu, L. S. Jensen, A. Pandey, and A. de Neergaard, "Effects of rice straw, biochar and mineral fertiliser on methane (CH_4) and nitrous oxide (N_2O) emissions from rice (*Oryza sativa* L.) grown in a rain-fed lowland rice soil of Cambodia: a pot experiment," *Paddy and Water Environment*, vol. 13, no. 4, pp. 465–475, 2015.

[25] R. J. Brooks and M. A. Semenov, "Spatial interpolation of the LARS-WG stochastic weather generator in Great Britain," *Journal of Japan Society for Business Ethics Study*, vol. 11, no. 2, pp. 205–216, 1999.

[26] J. Yalan, X. Y. Suolong, W. Xiaoqi, T. Wei, L. Qianqian, and M. Lei, "Influence of three biochars produced by three Leguminosae plants on Hainan latosol properties and N2O emission," *Journal of Southern Agriculture*, vol. 48, no. 8, pp. 1381–1387, 2017.

[27] C. H. E. N. Jinsai, W. A. N. G. Guangshuai, Z. H. A. N. G. Yingying, G. Yang, and L. Kun, "The effects of soybean-maize intercropping on N2O emission from soil," *Journal of Irrigation and Drainage*, vol. 39, no. 9, pp. 32–40, 2020.