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Effect of Vertical Distribution of Soil Water on N_2O Emission under Drip Irrigation

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Abstract

N_2O emission has obvious water effect, but the current research is not deep enough. The soil wetting mode of drip irrigation technology is obviously different from that of conventional irrigation. Using the method of soil box indoor simulation, the N_2O emission under different soil vertical water content was analyzed. Hydrus Software was used to simulate the soil wetting body under different drip irrigation technical parameters, the relationship between the combination of drip irrigation technical parameters and soil vertical water content was studied, and then the relationship between the N_2O emission and the combination of drip irrigation technical parameters was proposed. The results showed that soil N_2O emission flux increased with the increase of soil moisture, and the maximum emission flux was three times as much as the minimum emission flux. Under the condition of uniform distribution of soil moisture, soil N_2O emission flux was smaller than that under non-uniform distribution of soil moisture. Hydrus software simulation results show that drip flow rate is 2.0 L/h, the irrigation period is 5 days, the irrigation quota is 12 mm, and the soil N_2O emission flux is the largest. Adjusting the combination of technical parameters of drip irrigation can reduce soil N_2O emission flux.

Keywords

Drip Irrigation, N_2O, Emissions, Soil Moisture, Vertical Distribution

1. Introduction

N_2O is one of the three most important greenhouse gases, and its greenhouse effect has attracted more and more scholars' attention (IPCC, 2013). Farmland production is the main way to produce N_2O gas. As a large agricultural country, the study of N_2O emission mechanism and control measures in farmland is of great practical significance to the sustainable development of agricultural production and the improvement of global climate in China.

Drip irrigation technology has the benefits of saving water, increasing production and reducing emission, and has been widely used in the world. Drip irrigation uses drip head to moisten soil, which has obvious alternating wetting and drying boundary; especially in the vertical direction, this vertical wet and dry boundary of the soil will interfere with the nitrification and denitrification process and affect the emissions of soil N_2O. At present, no scholars have carried out substantive work on this issue (Watzinger et al., 2005; Xu et al., 2012; Wang, Mao, & Yan, 2014).

The amount of drip irrigation affects the vertical distribution of soil wetting body, and the vertical depth of wetting body directly affects the N_2O emission of soil. At present, there's not enough research in this area (Deurer et al., 2008; Huang et al., 2007; Zou et al., 2009).

Therefore, it is of great significance to study the mechanism of vertical distribution of soil water on N_2O emission in protected vegetable fields under drip irrigation point source infiltration, to improve the water effect theory of N_2O emission in farmland, and to reveal the greenhouse effect of protected vegetable fields in the application of drip irrigation technology.

2. Materials and Methods

Field experiment and indoor simulation were used to study the results. Field experiments were conducted at the school water-saving irrigation test base. There are drip irrigation test site, sprinkler irrigation test site and greenhouse greenhouse in the test base, and equipped with intelligent micro-irrigation system, which is typical representative. It has automatic observation meteorological station, real-time monitoring system of soil moisture, intelligent micro-irrigation test system and other experimental observation conditions. The base has abundant sunshine, warm and humid all year round. The soil texture belongs to sandy loam and is weak alkaline. There are gas chromatograph, static chamber (self-made, patented), tubular soil moisture analyzer (Trime-T_3), TDR soil moisture analyzer, redox potentiometer, KU/PF soil unsaturated hydraulic conductivity measurement system and so on.

Taking typical soil as the research object, indoor soil box simulation test was carried out. A vertical distribution simulation soil box (length × width × height = 60 cm × 50 cm × 50 cm) was made to simulate soil N_2O emission under different vertical distribution of water in drip irrigation.

Different water content layers (80% - 90% field water holding capacity, 70% - 80% field water holding capacity and 60% - 70% field water holding capacity) were set up in the soil box to simulate the vertical distribution of soil water, which are shown in the **Figure 1**. The static chamber-gas chromatography method was used to determine soil N_2O emissions, and the vertical distribution characteristics of soil water on soil N_2O emissions were revealed. Ring pattern.

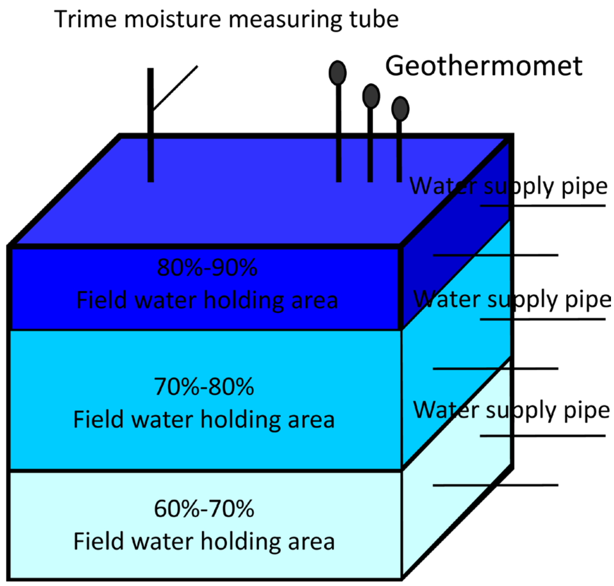

Figure 1. Schematic diagram of simulation experiment on vertical distribution of soil moisture.

Based on the analysis of the influence of soil vertical distribution on soil N_2O emission, a soil simulation experiment was carried out to study the relationship between N_2O emission distribution and soil water spatial distribution (vertical and horizontal). The soil water movement model of point source infiltration was calibrated and validated by using Hydtrus-2D/3D software.

On this basis, the simulation experiment of point source infiltration in soil box was carried out, and the effects of vertical distribution of soil moisture on N_2O emission were observed in different soil moisture content regions (horizontal direction). Then the mathematical model between N_2O emission and vertical and horizontal distribution characteristics of soil moisture was established, and the main effects were identified.

3. Results and Analysis

3.1. N_2O Emission from Soil under Vertical Non-Uniform Distribution of Soil Water

In order to ensure the accuracy, soil moisture was supplemented by soil drying method where the Equi-pf (soil profile moisture measurement system) could not be observed. The evaporation simulation experiment of soil vertical distribution was carried out by using KLSET-1200 (height 30 cm).

The soil is packed in four layers. The soil texture is sandy loam. The weight and water content are controlled at 22%, 18%, 14% and 10% respectively. The soil temperature is controlled at 20 - 25 degrees Celsius. After soil moisture zoning is set up, supplementary irrigation is needed for each experimental treatment and soil box sampling to ensure that the moisture content of each soil layer is kept within the set range.

The static box method is used for continuous sampling for about 20 days. Before gas sampling, the static box bottom slot should be embedded in the soil box beforehand, and the bottom slot after embedding should be level with the soil surface. At the same time, Equi-pf was used to observe the spatial distribution (vertical and horizontal) of soil, and to observe the movement law of soil box wetting front and soil temperature. The sampling results are shown in **Table 1**.

As can be seen from **Table 1**, with the gradual increase of soil water content (10% to 22%), soil N_2O emissions increased from 188.86 ug/(m^2·h) to 521.38 ug/(m^2·h) and then decreased to 164.12 ug/(m^2·h), which experienced a process of first increasing and then decreasing.

The main reason is that when the soil water content increases to 22%, it is close to the field water holding capacity of 23%. Therefore, higher water content inhibits nitrification and denitrification and reduces N_2O emission. When soil water content is low, N_2O emission flux is positively correlated with soil water content.

However, when the soil water content exceeds a certain range, such as 77% to 86% of saturated water content or 90% to 100% of field water retention, the soil porosity is reduced, and the reduction of soil oxygen content promotes denitrification. The emission flux of N_2O will gradually decrease (Zou et al., 2009; Van Groenigen et al., 2005).

The maximum value of N_2O emission flux appears in the average water content of 18%, which is equivalent to 80% to 90% of field water holding capacity. It is consistent with the research conclusions of other scholars (Zhang, 2017; Li, 2017).

3.2. N_2O Emission from Soil under Vertical Uniform Distribution of Soil Water

For comparison, the soil moisture content in the soil box was set at 22%, 18%, 14% and 10% respectively (vertical uniform distribution). Water is supplied to the soil through the Markov bottle to ensure the uniformity and stability of soil moisture content. The sampling results are shown in the **Table 2**.

As can be seen from the **Table 2**, with the gradual increase of soil water content (10% to 22%), soil N_2O emissions increased from 160.42 ug/(m^2·h) to 488.91 ug/(m^2·h) and then decreased to 169.55 ug/(m^2·h), which experienced a process of first increasing and then decreasing.

The main reason is that with the increase in soil water content, moisture increases

Table 1. N_2O emission in soil water vertical non-uniform distribution.

Average Weight Moisture Content/%	N_2O Emission flux μg/(m^2·h)	Soil Temperature/˚C
22	164.12	24.2
18	521.38	22.6
14	286.91	23.4
10	188.86	23.8

Table 2. N_2O emission in soil water vertical uniform distribution.

Average Weight Moisture Content/%	N_2O Emission flux μg/(m^2·h)	Soil Temperature/˚C
22	169.55	24.2
18	488.91	22.6
14	270.06	23.4
10	160.42	23.8

nitrification and promotes N_2O emissions. Therefore, higher water content inhibits nitrification and denitrification and reduces N_2O emission. When soil water content is low, N_2O emission flux is positively correlated with soil water content. The maximum N_2O emission flux also occurs at an average moisture content of 18%.

3.3. Comparison of N_2O Emissions under Vertical Uniform and Non-Uniform Distribution of Soil Moisture

From Table 1 and Table 2, it can be seen that the N_2O emission flux is higher than the uniform distribution when the soil moisture content is non-uniform (except 22% moisture content). When the average soil moisture content is 10%, the difference between them is the greatest, reaching 15%. With the increase of soil water content, the difference between them decreases gradually, and the closer to the field water holding capacity, the smaller the difference between them. However, when the soil moisture content is 22%, the difference is not significant. The main reason is that when the soil moisture content is close to the field moisture content, the soil moisture content is higher. Both vertical and non-uniform distribution of soil moisture inhibit N_2O emission, and there is no obvious difference between them.

3.4. Vertical Distribution of Soil Water under Different Drip Irrigation Technical Parameters

Hydrus software was used to simulate the vertical distribution of soil water under different drip irrigation technical parameters. The vertical distribution of soil water under drip irrigation technical parameters was analyzed. Combining the relationship between the vertical distribution of soil water and soil N_2O emission, the relationship between N_2O emission and drip irrigation technical parameters (drip flow, irrigation cycle and irrigation quota) was discussed.

Different technical parameters of drip irrigation were set to simulate soil water movement. The dripper flow rate is set to 1.1 L/h, 2.0 L/h and 4.0 L/h. The irrigation cycle is 3 days, 5 days and 7 days respectively. The irrigation quota M is 8 mm, 12 mm and 16 mm. The simulation results show that the vertical distribution of soil wetting body is the closest to 10% of the average soil moisture content in drip irrigation belt with drip flow rate of 4.0 L/h, irrigation period of 7 days and irrigation quota of 12 mm. The vertical distribution of soil wetting body in drip irrigation belt with drip flow rate of 4.0 L/h is the closest to that in drip irrigation belt with drip flow rate of 4.0 L/h, irrigation period of 3 days and irrigation quota of 16 mm. The average soil moisture content of 22% is the closest.

As can be seen from Table 2 and Table 3, combining with the simulation results of soil tank, the maximum N_2O emission flux corresponds to 18% of the soil vertical moisture content, and the corresponding technical parameters of drip irrigation are drip irrigation belt with drip head discharge of 2.0 L/h. The irrigation period is 5 days, the irrigation quota is 12 mm, and the minimum N_2O emission flux corresponds to 10% of the soil vertical moisture content. Therefore, different combinations of drip irrigation technical parameters can control soil vertical moisture content, and then affect soil N_2O emissions.

4. Conclusion and Recommendation

Agricultural production activities affect greenhouse gas emissions. Soil moisture is an important determinant of N_2O emission from farmland. Under drip irrigation, the distribution of soil moisture is different from that under conventional irrigation, and there are some differences in vertical distribution. The change of soil wetting process will promote nitrification and denitrification, and affect N_2O emission. Studying the relationship between the vertical distribution of soil water and N_2O emission in drip irrigation is of great significance for enriching the theory of greenhouse gas emission and scientific exploration of reducing N_2O emission by adjusting the technical factors of drip irrigation. In this paper, N_2O emission is observed by indoor soil box and simulated by Hydrus software. The conclusions are as follows:

1) When the soil moisture content is low (lower than the field capacity), the N_2O emission flux increases with the increase of soil moisture content, and the maximum N_2O emission flux is three times of the minimum value. When the soil moisture content is close to the field capacity, the N_2O emission flux decreases, and the N_2O emission under the vertical uniform distribution of soil moisture decreases. Flux is lower than non-uniform distribution of soil moisture.

2) Hydrus software simulation study of soil wetting body shows that the soil N_2O emission flux is the largest when the drip flow rate is 2.0 L/h, the irrigation period is 5 days and the irrigation quota is 12 mm; the soil N_2O emission flux is the smallest when the drip flow rate is 4.0 L/h, the irrigation period is 7 days and

Table 3. Table of correspondence between technical parameters of drip irrigation and vertical average water content of soil.

Average weight moisture content/%	Drip flow rate L/h	Irrigation period/d	Irrigation quota/mm
22	4.0	3	16
18	2.0	5	12
14	1.1	7	16
10	4.0	7	12

the irrigation quota is 12 mm. Therefore, adjusting the combination of technical parameters of drip irrigation can reduce the N_2O emission flux of soil.

3) The conclusion of this paper is that the indoor part of the soil box is completed with Hydrus software, and the test conditions are not comprehensive enough. In the future, we need to consider as many factors as possible, carry out orthogonal test design, and carry out test verification in the field.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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