N_xO emissions in response to the irrigation lower limits under different irrigation modes in a lettuce field

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Abstract: Irrigation has a significant impact on N_xO (N_2O and NO) emissions from cultivated land, yet the N_2O or NO emission among the irrigation lower limits under different irrigation modes has not been well compared. In an irrigated lettuce field, three DR (drip irrigation) lower limits were designed, including 75% (DR1), 65% (DR2) and 55% (DR3) field capacity, and one FI (furrow irrigation) lower limit (65% field capacity). The N_2O and NO emission fluxes and soil nitrogen (N) forms were determined, and the linear correlation between these indicators was analyzed. Results showed that under the same irrigation regime, the N_2O and NO emissions from furrow irrigation treatment increased by 36.8% and 45.2% respectively compared to that from drip irrigation treatment. The cumulative N_2O and NO emissions under DR3 were 30.2% and 28.6% higher than under DR1, respectively. Moreover, DR1 was also the lowest among the four treatments in soil NO_3^--N concentration. The N_2O and NO emission fluxes were more correlated to soil NH_4^+-N (r=0.88 and 0.76) or NO_2^--N (r=0.90 and 0.80) concentration than soil NO_3^--N and soluble organic N, indicating that N_2O and NO were mainly produced by the soil nitrification process. When the irrigation regime was the same, N_2O and NO emissions were lower with drip irrigation than with furrow irrigation. Besides, drip irrigation with small quota but high frequency reduced N_2O and NO emission compared to that with large quota but low frequency.

Keywords: nitrous oxide, nitric oxide, drip irrigation, furrow irrigation, soil nitrogen
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1 Introduction

Climate change is a hot social issue attracted international concern. A study predicts that the global average temperature will increase by 2°C in 2025 and 4°C in 2100 compared with 100 years ago[1]. N_2O is one of the main greenhouse gases, and its global warming potential is about 300 times than that of CO_2. NO participates in photochemical reactions, destroys the ozone layer, and indirectly causes the greenhouse effect[2]. Agricultural production process emits a great amount of N_2O and NO gas[3]. Taking N_2O as example, the amount of N_2O emitted by global cultivated land is about 6.4×10^{12} g N, accounting for one fourth of the global total N_2O emissions[4]. Agricultural management measures, such as irrigation, fertilization, mulching and ploughing, are proved to have an impact on N_2O and NO emissions[5-8].

Irrigation is an indispensable agricultural management measure. Many studies showed that the irrigation amount (irrigation quota) affects the emission of nitrogen oxides from agricultural land[9]. The research by Chen et al.[10] showed that the soil N_2O emission increases gradually as irrigation quota increased, N_2O emission under 60% and 80% irrigation quotas decreased by 19.1% and 8.0% respectively compared to under full irrigation quota. Du et al.[11] employed the static box in-situ gas sampling method and found that average cumulative N_2O emission by full irrigation is 1.27 times than that by deficit irrigation.

In addition, irrigation modes (drip irrigation, flood irrigation, sprinkler irrigation, infiltration irrigation, etc.) also influence the N_2O and NO emissions[12]. The irrigation modes change the soil pore structure, affect the diffusion of O_2 in the soil, and then affect the soil microbial activities[13]. The nitrification and denitrification processes dominated by soil microorganisms are influenced, this finally impacting N_2O and NO emissions[14]. Moreover, different irrigation modes lead to different water and N distributions in the surface and profile soil, and have different effects on the leaching and mineralization of soil N[15-17], which will inevitably change the amount and location of available N in surface soil. Available N in surface soil is an important substrate responsible for N_2O and NO emissions[18].

In general, previous studies regarding the impact of irrigation on N_2O and NO emissions mainly focused on the irrigation quotas or irrigation modes, little attention has been paid to the irrigation

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frequency (controlled by different irrigation lower limits). The difference of N_2O or NO emission between drip and furrow irrigation under the same irrigation frequency was also rarely studied. This study designed three different lower limits of DR (drip irrigation) and one lower limit of FI (furrow irrigation), to investigate the regularity of N_2O and NO emissions under different treatments, and to analyze the relationship between N_2O (NO) emission and soil N forms. The objectives were: (1) to compare the N_2O/NO emission between DR and FI under the same irrigation lower limit; (2) to compare the N_2O/NO emission among different drip irrigation lower limits; (3) to explore the driving mechanism of N_2O and NO emission by the irrigations.

2 Materials and methods

2.1 Experimental site

The experiment was conducted at Fruit Science and Technology Demonstration Base from September 20 of 2021 to January 6 of 2022 in Yunxiao County, Fujian Province of China. Yunxiao County is under the subtropical marine monsoon climate. The frost free period is 347 d. The extreme maximum and the extreme minimum temperature are 38.1°C and –0.2°C, respectively. The annual average temperature is 21.3°C and the annual accumulated temperature is 7548.8°C. The annual precipitation in the experimental area is 1730.6 mm. The soil variety is the ferrallitic soil. The physical and chemical properties of soils in plough layer are as follows: pH of 5.9, bulk density of 1260 kg/m^3, field water capacity of 29.8%, organic matter of 3.45%, available N of 90.2 mg/kg, available P of 12.2 mg/kg and available K of 152.3 mg/kg.

2.2 Experimental design

The lettuce variety Feiqiao lettuce No. 1 was used as the experimental material. The substrate was used to cultivate seedlings. When these seedlings grew out 4-5 expanded leaves (October 15), they were transplanted into the soils. The rosette stage and fleshy stem expansion stage are the two stages when lettuce needs major amounts of water, and these two periods are the water sensitive periods for lettuce. Therefore, after transplanting, three different DR lower limits (75% (DR1), 65% (DR2) and 55% (DR3) field capacity) and one FI lower limit (65% field capacity) were arranged from the rosette stage for the lettuces. The soil moisture content of the cultivated layer was measured every day used for finding the lower limits. Once the moisture content reached the lower limit, the irrigation was started. The upper limit of all the treatments was 95%. For each time, the irrigation amount of FI was the same as that of DR2. The local irrigation habit was the furrow irrigation, and the irrigation water was applied to 1/3 of the furrow height then dried naturally. In this study, the converted furrow irrigation quota according to DR2 was consistent with the local practice. The irrigation quota was calculated as[19]:

$$M = S \times r \times h \times Q \times (q^1 - q^2)/0.95 \quad (1)$$

where, M is the irrigation quota, m^3; S is the irrigation area, m^2; r is the soil bulk density, kg/m^3; h is the planned depth of wetted soil (0.2 m); q is field water capacity, %; q^1 is the upper irrigation limit (95%); q^2 is the lower irrigation limit (75%, 65% or 55%), and 0.95 is the irrigation coefficient.

To sum up, there were four different treatments in this study, and each treatment was repeated three times. The division of lettuce growth stages and the treatment periods are listed in Table 1. The irrigation parameters are listed in Table 2.

Table 1 Growth stages of lettuce

Date	Growth stages	Irrigation treated periods
2021.9.20-2021.9.22	Seed germination	
2021.9.23-2021.10.15	Seedling stage	
2021.10.16-2021.11.21	Rosette stage	☆
2021.11.22-2022.1.2	Fleshy stem expansion stage	☆
2022.1.3-2022.1.6	Harvest stage	

Note: ☆ represents that in this period, the lettuce was treated with different irrigation treatments (three drip irrigation lower limits (75%, 65%, 55% field capacity) and one furrow irrigation lower limit (65% field capacity).

Table 2 The irrigation regime

Treatment	Rosette stage to fleshy stem expansion stage				The irrigation amount during whole growth period/mm
	Irrigation times	Irrigation interval/d	Irrigation quota/mm	Irrigation amount/mm	
DR1	8	9.5	15.8	126.5	284.1
DR2	5	15.2	23.7	118.6	276.2
DR3	3	25.3	31.6	94.9	252.5
FI	5	15.2	23.7	118.6	276.2

Field experimental area was separated into 12 blocks. Each treatment took up 3 blocks, and each block occupied an area of 8 m×4 m. In one block, three ridges of lettuces were cultivated, with the ridge height of 20 cm and width of 60 cm. The spacing between two ridges was 20 cm (Figure 1). The lettuce row-to-row spacing was 30 cm and plant-to-plant spacing was 35 cm. An additional soil ridge without lettuce cultivation was arranged between the furrow irrigation block and other block.

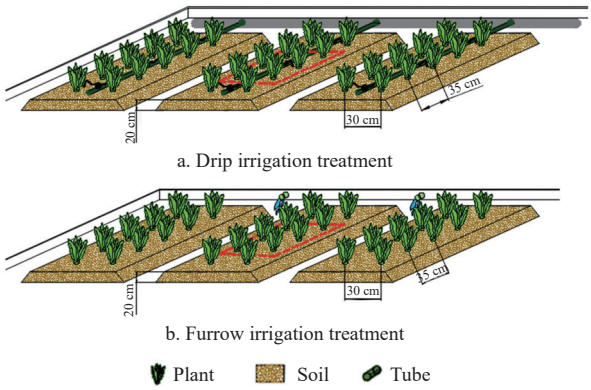


Figure 1 The experimental blocks

The fertilization management for each block was the same. Total fertilizer application rates were 675 kg/hm^2 of urea, 600 kg/hm^2 of calcium superphosphate and 375 kg/hm^2 of potassium sulfate. All the calcium superphosphate was applied as basal fertilizer, whereas the urea, as well as the potassium sulfate, was applied according to 40% for basal fertilizer, 20% for first topdressing and 40% for second topdressing. The dates for basal fertilization, first topdressing and second topdressing were October 15, November 1 and November 23, respectively. The fertilizers were applied into the 6 cm soil depth using a hole applicator. In early and late growth stages of lettuce, the heart rot and the downy mildew were prevented respectively using plant protection chemicals including propineb, imidacloprid, putrescine, etc.

2.3 Sampling and measurement

The gas collection device is a self-made cylindrical static cover (composed of cover and base, Figure 2). The cover body is made of PVC and enclosed with a layer of silver reflective film. The diameter of the cover body is 30cm and the height is 80 cm. The base can be buried in the soil, and the upper part is provided with a water tank to play a sealing role. Before collecting, the water tank is supplied with clean water, and then the cover is placed on the base.

A thermometer and a gas collection port are installed on the side of the cover. A small fan driven by the external battery is installed at the top of the cover to make the emitted gas distributed uniformly.

Figure 2 The gas sampling device

One fixed gas sampling point is set for each block. Gas samples were collected every 7 d from the second day after transplanting. For the whole growth stage of lettuce, 13 times of the gas sampling were conducted. Each collection started when there was no obvious water on the soil surface. The collection time was from 8:00 to 9:00 in the morning. The gas was collected at 0, 10, 20 and 30 min after sealing and the temperature inside the cover was recorded. A 50 mL syringe was used to extract gas and then injected into a 40 mL gas collecting bottle. The gas collecting bottles were taken to the laboratory to measure N_2O emission flux using a gas chromatograph (Agilent 7890B, Agilent Technologies, USA). At the same time, 1000 mL gas was collected into an airtight bag to measure the NO emission flux with a 42i NO-NO_2-NO_X analyzer (Thermo Environmental Instruments Inc., USA).

For each gas collection, soil samples in 0-10 cm soil layer were collected synchronously. The soil collection position was at the bottom of the base. After multi-point collection, the soils were mixed evenly for measuring the soil mass moisture content, NO_3^--N, NH_4^+-N, NO_2^--N and soluble organic N. The soil moisture content was measured by drying method[20]. The soluble total N was determined by the alkaline potassium persulfate oxidation method[21]. The NO_3^--N, NH_4^+-N and NO_2^--N were extracted using 0.01 mol/L $CaCl_2$[22] then determined by an automatic analyzer (Seal Analytical, USA).

2.4 Data analysis

The N_2O and NO emission fluxes are calculated as follows[23]:

$$F = \rho \cdot H \cdot \frac{273}{273+T} \cdot \frac{dc}{dt} \quad (2)$$

where, F is N_2O or NO emission flux, μg N/m^2·h; ρ is the density of N_2O and NO in the standard state, 1.25 and 0.625 kg/m^3; H is the effective height of the cover, m; T is the actual temperature inside the cover at the moment of measurement, °C; dc/dt is the change rate of N_2O or NO concentration, mL/L·h. Since the air pressure inside the cover is nearly constant, the impact of the air pressure on N_2O or no is ignored.

The cumulative emission of N_2O or NO is calculated according to the following equations[24,25]:

$$M = \sum (F_{i+1} + F_i)/2 \times (t_{i+1} - t_i) \times 24 \times 10^{-5} \quad (3)$$

where, M is the cumulative emission of N_2O or NO, kg N/hm^2; F is the i^{th} N_2O or NO emission flux, μg N/m^2·h; i is the number of measurements; t_{i+1}–t_i is the days between two determinations, d.

Soil soluble organic N is calculated according to [26]:

$$SON = STN - MN \quad (4)$$

where, SON is soil soluble organic N, mg/kg, STN is soluble total N, mg/kg, MN is mineral N, including NO_3^--N, NH_4^+-N and NO_2^--N.

The soil water filled pore spaces ($WFPS$, %) is calculated according to [27]:

$$SWPS = \left(\frac{\rho}{1-\rho/2.65}\right) \cdot Q_w \quad (5)$$

where, ρ is the soil bulk density, g/cm^3; 2.65 is the soil density, g/cm^3; Q_w is the soil mass moisture content, %.

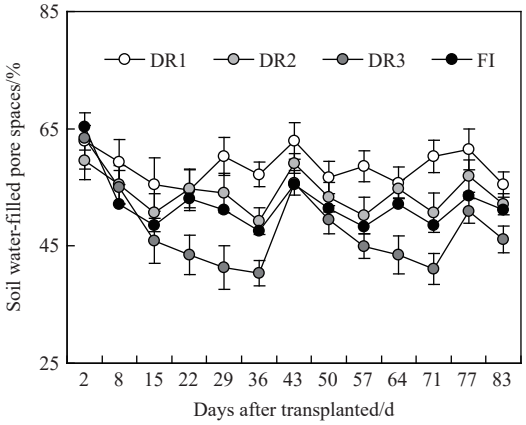
2.5 Statistical analysis

Significant differences among different treatments were calculated according to Duncan's multiple range test using SPSS 17.0 software.

3 Results and analysis

3.1 Dynamic changes of WFPS under different irrigation treatments

During the whole growth period of lettuce, the WFPS showed the fluctuating variation trend, and there were obvious differences of WFPS under different irrigation treatments (Figure 3). The WFPS under DR1 was in a high level, reaching 54.5%-62.9%; followed by DR2, reaching 49.2%-59.6%; DR3 was relatively lower, recording as 41.1%-63.4%. The variation trend of WFPS under DR2 and FI was similar, whereas the WFPS under DR2 was slightly higher than that under FI during the whole lettuce growth period. The maximum WFPS difference occurred on the 71 d after transplanting, and was 47.0% between DR1 and DR3. The average WFPS under DR1, DR2, DR3 and FI for the whole growth period was 58.5%, 53.9%, 47.8% and 52.2% respectively, and the maximum difference of average WFPS reached 22.4%.



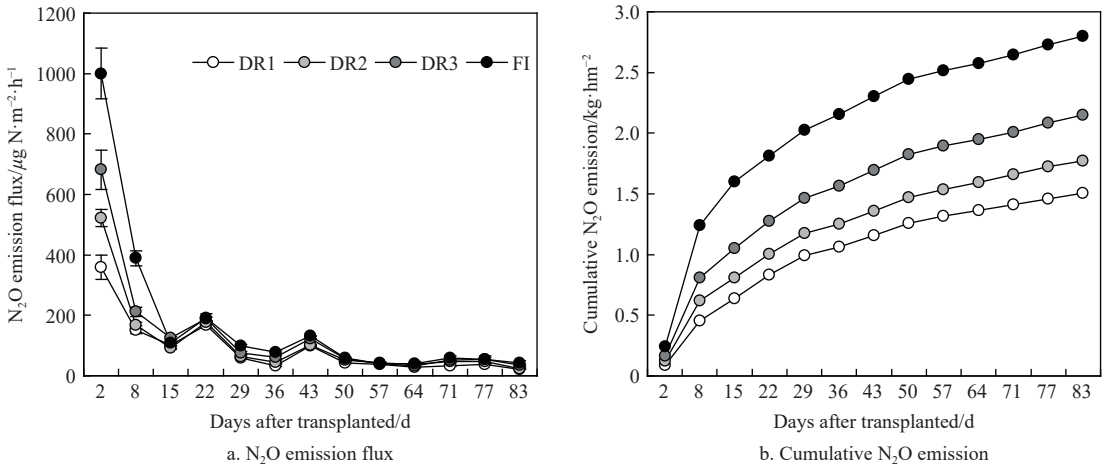
Note: DR1, DR2 and DR3 represent lower irrigation limits of 75%, 65% and 55% accounted for the field capacity, respectively. FI is the furrow irrigation treatment with the same irrigation regime as DR2.

Figure 3 Variation of WFPS under different irrigation treatments

3.2 Impact of different irrigation treatments on N_2O emission

The maximum N_2O emission flux appeared at the second day after transplanting, reaching 358.5-1000.2 μg N/m^2·h (Figure 4a). From 2 to 15 d after transplanting, the N_2O emission flux decreased significantly and then gradually stabilized. At 22 and 43 d after transplanting, the N_2O emission flux appeared two small peaks. The 22 d and 43 d after transplanting exactly corresponded to the second and third fertilization dates. In general, the N_2O emission flux of FI in the whole growth period was at the highest level among different treatments, while that of DR1 was overall the lowest.

There were two growth stages for the increase of cumulative N_2O emission (Figure 4b): the rapid growth stage was from 2 to 22 d after transplanting, and the relatively slow growth stage was occurred from 22 to 83 d after transplanting. The difference of the



a. N_2O emission flux b. Cumulative N_2O emission

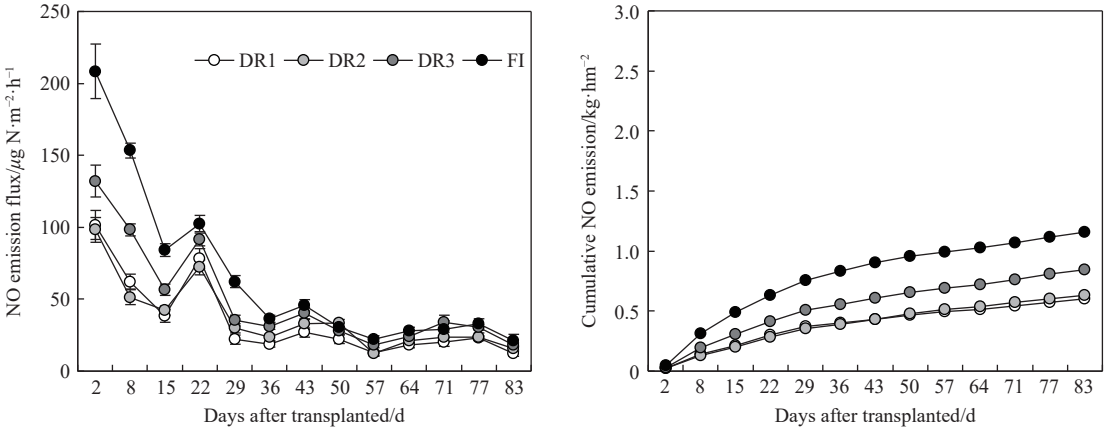
Note: DR1, DR2 and DR3 represent lower irrigation limits of 75%, 65% and 55% accounted for the field capacity, respectively. FI is the furrow irrigation treatment with the same irrigation regime as DR2. The Data were mean±SD.

Figure 4 Effect of different irrigation treatments on N_2O emission flux and cumulative N_2O emission

accumulated N_2O emission among treatments began to be obvious from 8 d after transplanting. At 8 d after transplanting, the accumulated N_2O emission under FI was the highest, which was nearly three times than that under DR1. At 83 d after transplanting, the last measurement, it was found that the cumulative N_2O emission under DR1, DR2, DR3 and FI were 1.50, 1.77, 2.15 and 2.80 kg N/hm^2. This suggested that under the same irrigation regime, the N_2O emission under furrow irrigation was 36.8% higher compared to that under drip irrigation. In addition, DR3 increased N_2O emissions by 30.2% compared with DR1, indicating that different irrigation regimes but same irrigation mode obviously affect the cumulative N_2O emission.

3.3 Impact of different irrigation treatments on NO emission

The variation regularity of NO emission flux was similar to that of N_2O (Figure 5a). After decreasing in early growth stage of lettuce, it tended to be stable from 29 d after transplanting. The difference of NO emission flux among the treatments was mainly detected in the early growth stage, especially during 2-29 d after transplanted. At harvest stage, the NO emission flux decreased to about one tenth of the highest. Among the different treatments, the NO emission flux under DR1 during the whole growth period was at a lower level, and the highest NO emission flux under DR1 occurred on the second day after transplanting, which was 101.4 μg N/m^2·h, less than half under FI at the same measurement time.



a. NO emission flux b. Cumulative NOemission

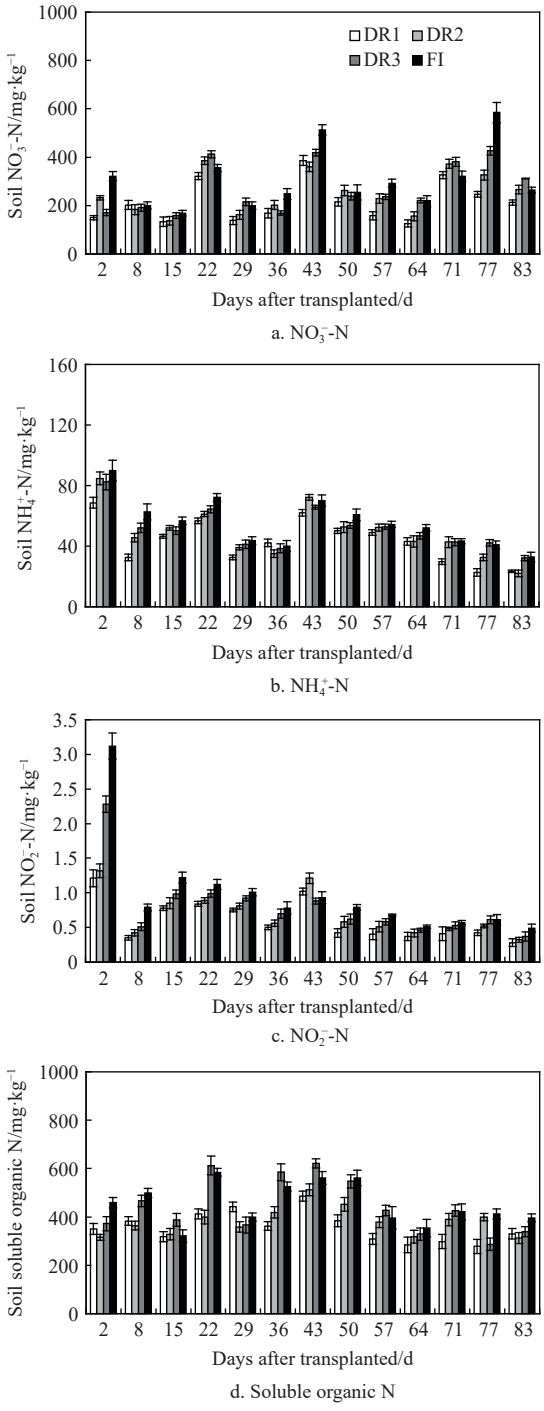
Note: DR1, DR2 and DR3 represent lower irrigation limits of 75%, 65% and 55% accounted for the field capacity, respectively. FI is the furrow irrigation treatment with the same irrigation regime as DR2.

Figure 5 Effect of different irrigation treatments on NO emission flux and cumulative NO emission

Cumulative NO emissions under DR1 and DR2 were not significantly different (Figure 5b), and both were obviously lower compared to under DR3 or FI. At 83 d after transplanting, the cumulative NO emissions under DR1, DR2, DR3 and FI were 0.60, 0.63, 0.84 and 1.15 kg N/hm^2. The average NO emission under drip irrigation was 0.69 kg N/hm^2, which was 40% less than that under FI. With the same irrigation regime, DR2 emitted 45.2% less NO in comparison to FI. Among the different drip irrigation treatments, DR3 emitted 28.6% more NO compared to DR1.

3.4 Impact of different irrigation treatments on soil N

In general, the contents of different forms of soil N from high to low were soil soluble organic N, NO_3^--N, NH_4^+-N and NO_2^--N (Figures 6a-6d). The overall variation regularity was that three peaks were found at 2 d, 22 d and 43 d after transplanting. This regularity was more obvious on soil NH_4^+-N and NO_2^--N. There were differences in soil NO_3^--N among the treatments, but this difference was not regular at each measurement, except that the NO_3^--N content under DR1 was generally in the lowest level among the four treatments. The soil NH_4^+-N or NO_2^--N content under FI and DR3 was higher than under DR1 and DR2 treatments. The average soil NH_4^+-N contents under FI, DR3, DR2 and DR1 during the whole growth period was 55.3, 51.1, 48.9 and 43.0 mg/kg, and



Note: DR1, DR2 and DR3 mean the lower irrigation limits of 75%, 65% and 55% accounted for the field capacity, separately. FI represent furrow irrigation treatment using the same irrigation regime as DR2. The data are mean±SD.

Figure 6 Effect of different irrigation treatments on soil NO_3^--N, NH_4^+-N, NO_2^--N and soluble organic N in 0-10 cm soil layer

the average NO_2^--N contents was 0.97, 0.80, 0.68 and 0.59 mg/kg. Compared with the other three different forms of N, soil soluble organic N was at a more stable level, and the variation range was relatively small. DR1 and DR2 have almost no difference in soil soluble organic, but both were lower than DR3.

3.5 Correlation analysis between N_2O (NO) emission and possible impact factors

The N_2O emission flux has a positive correlation with soil NH_4^+-N, with a correlation coefficient of 0.88 (Figure 7). Meanwhile, a stronger positive correlation between N_2O emission flux and NO_2^--

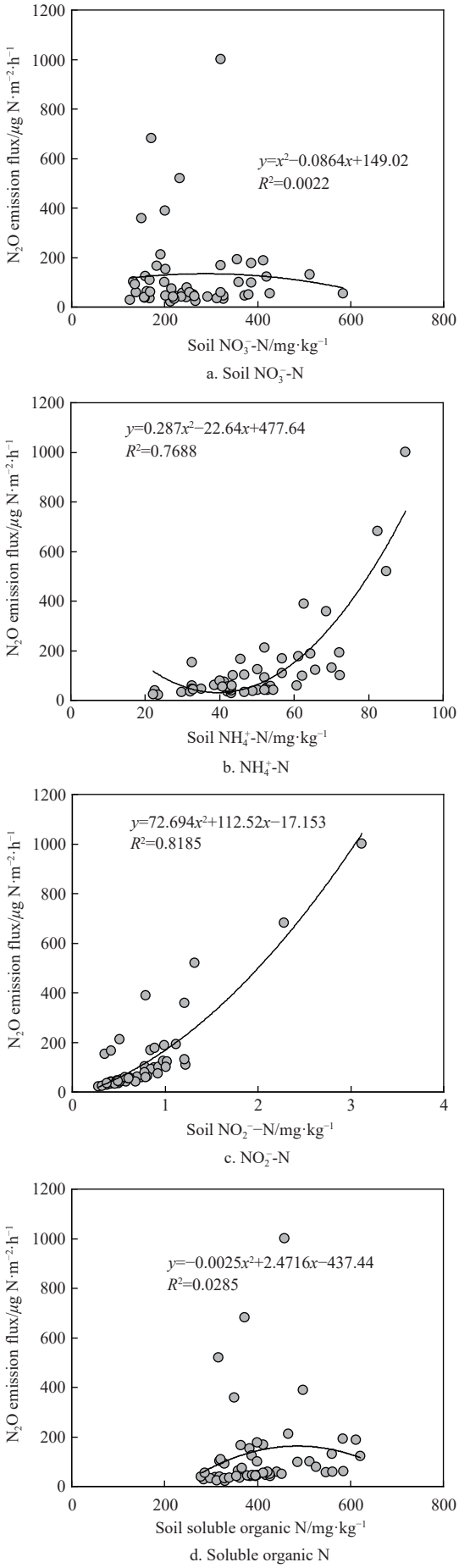


Figure 7 Correlation between N_2O emission and possible impact factors

N was observed, and the correlation coefficient reached 0.90. However, the correlation between N_2O emission flux and NO_3^--N or soluble organic N was not obvious.

Similarly, the NO emission fluxes were positively correlated with NH_4^+-N or NO_2^--N, with correlation coefficients of 0.76 and 0.80 respectively (Figure 8). However, the correlation coefficient between NO emission flux and NO_3^--N or soluble organic N was only 0.04 and 0.17, indicating that NO emission flux has no obvious relationship with NO_3^--N or soluble organic N in the surface soil.

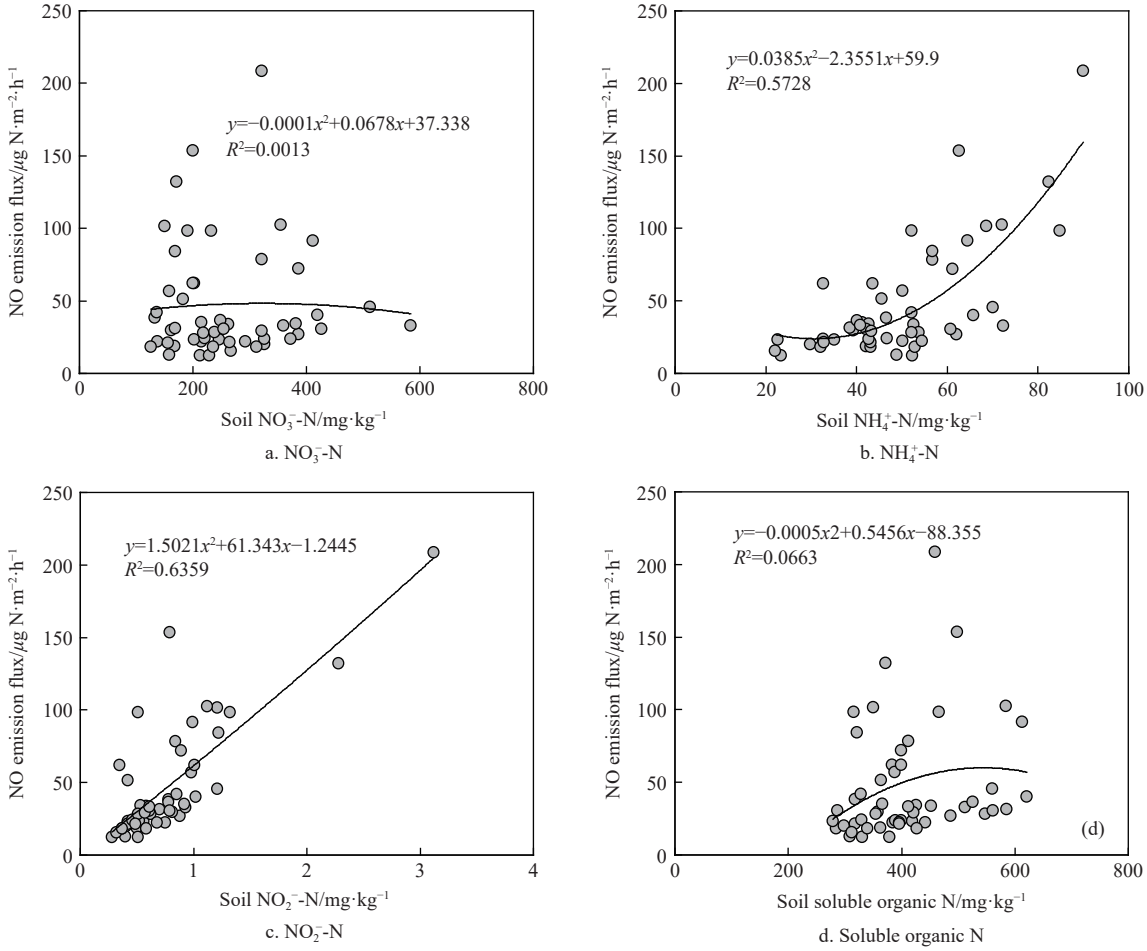


Figure 8 Correlation between NO emission and possible impact factors including soil NO_3^--N, NH_4^+-N, NO_2^--N and soluble organic N

4 Discussion

4.1 N_2O and NO emission in response to different irrigation schemes

Soil moisture regulates the nutrient content in soil pore and affects the nitrification and denitrification processes[28,29]. In this study, the N_2O and NO emissions under DR1 treatment were lower than that under DR3, which was in line with the results by Zhang[18]. This might be due to the fact that the soils in DR3 experienced a more intense dry-wet alternation process, leading to: (1) the promotion in the mineralization of soil N and the formation of more substrates (NH_4^+-N or NO_3^--N)[30,31]; (2) the more intension in the alternating nitrification and denitrification process[32]. Both the two results will increase the emission of N_2O and NO. In addition, the reason responsible for the higher NO emission under DR3 might be that NO was mainly caused by nitrification process driven by autotrophic and heterotrophic nitrifying bacteria[33], the soil WFPS under DR3 was in a lower level among the three drip treatments (Figure 3), this was conducive to the occurrence of the nitrification process. Abalos et al.[34] also found that compared with high-frequency irrigation, the low-frequency irrigation increased NO emission.

In this study, it was found that under the same irrigation regime, drip irrigation decreased the N_2O and NO emissions compared to furrow irrigation, which agreed with most previous studies[35-37]. Andrew et al.[38] found that the drip irrigation reduced soil N_2O by up to 62%. Wang et al.[39] used three irrigation modes including surface drip irrigation, sprinkler irrigation and furrow irrigation for the winter wheat in north China plain, and found that the N_2O emission from drip irrigation treatment was 14.6% lower than that from furrow irrigation. Laura[35] compared the difference of N_2O emission from soil under furrow irrigation and drip irrigation during melon cultivation season, and showed that the drip irrigation reduced 70% of total N_2O emissions compared with furrow irrigation. The reason might be that the water rapidly filled the soil voids in a short time under furrow irrigation, forming an anaerobic environment, strengthening denitrification process and promoting N_2O emission; meanwhile, the soil treated by furrow irrigation obtained greater wetted volume and more microorganisms with stronger activity[40], which might also be another reason for promoting denitrification thus increasing the N_2O emission. After furrow irrigation, soil water was easier to downward infiltrate compared to drip irrigation, and the soil in the cultivated layer dehydrated faster[41], conversely forming a nitrification environment conducive to NO emission. On the contrary, some researchers achieved different conclusions. For example, Guo et al.[42] found that

the average N_2O emission flux reached 74.81 $\mu g/m^2 \cdot h$ under drip irrigation in wheat field, and was increased by 25.87% compared with furrow irrigation. According to the analysis by earlier researchers, there might have two main reasons: firstly, drip irrigation reduced the leaching of N, and the total amount of mineral N in surface soil was greater, and correspondingly, the substrate concentration for N_2O and NO emissions was higher[43]; secondly, under drip irrigation, the soil structure was more intact and the available oxygen content was higher, which strengthened the mineralization of organic N[44] and then promoted the nitrification and denitrification processes, finally increased the production and emission of N_2O and NO from the soil.

4.2 Impact factors responsible for N_2O and NO emission

In this study, it was found that different lower irrigation limits have different degrees of impact on soil N (NO_3^--N, NO_4^+-N, NO_2^--N. etc), and DR3 treatment was at the highest level of mineral N in the whole growth period among the three drip irrigation treatments. There might be two reasons for this: (1) DR3 has the lowest irrigation volume and frequency, which reduced the downward leaching amount of N from the arable soil[45]; (2) the soil under DR3 was in a drier state (Figure 3), the diffusion of soil nutrients and ions was limited, less energy could be provided to microorganisms, thus the microorganisms were in a "hungry" state. After rehydration, microorganisms might grow and reproduce compensatorily, and their number and activity were significantly increased, thus promoting the mineralization of soil N[46]. The higher soil mineral N detected under DR3 (Figure 6) could support the above presumption.

The driving pathways for the soil N_2O and NO emissions included the above-mentioned nitrification and denitrification, as well as the denitrification by the nitrifying bacteria and the dissimilatory reduction of nitrate nitrogen to ammonium[47,48]. However, it was generally believed that nitrification and denitrification were the two main pathways[49]. Soil NO_2^--N was the product of ammonia oxidation during the nitrification process[50]. A significant positive correlation was observed between N_2O/NO emission and soil NO_2^--N or NH_4^+-N, indicating that NO_2^--N or NH_4^+-N were the key factors to explain the changes of N_2O and NO emission. Therefore, it could be speculated that N_2O and NO emissions were dominated by the nitrification. Moreover, from the perspective of soil WFPS (Figure 3), the lower WFPS corresponded to the higher N_2O or NO emission, which also supports that the driven pathway of N_2O/NO emission was nitrification.

The study quantitatively compared the emission differences of N_2O/NO under different drip irrigation lower limits, as well as under different irrigation modes. Furthermore, the correlation between N_2O/NO emission and possible influencing factors was also analyzed. However, different irrigations may cause different distribution of water and N in soil profile[19]. Soil capillary action will promote water and nitrogen to accumulate to the surface soil, therefore affecting the NO_x emission. Whether and to what extent, the movement of soil water and N in profile soil affects the emission of nitrogen oxides, need to be studied. In addition, irrigation influences the development of crop roots then impacts the plant absorption for soil N[51]. Does plant N consumption have an impact on N_2O/NO emission? This is worthy to be investigated in future.

5 Conclusions

The overall results concluded that under the same irrigation regime, N_2O and NO emissions from furrow irrigation treatment increased by 36.8% and 45.2% respectively compared to that from drip irrigation treatment. Among the drip irrigation treatments, the cumulative N_2O or NO emission was the lowest in DR1 and the highest in DR3. The cumulative N_2O and NO emissions under DR3 were 30.2% and 28.6% higher than under DR1, respectively. Moreover, DR1 was also the lowest among the four treatments in soil NO_3^--N concentration. Both N_2O and NO emission fluxes were positively correlated to soil NO_4^+-N (r=0.88 and 0.76) or NO_2^--N (r=0.90 and 0.80) concentration, while not obviously correlated to NO_3^--N and soluble organic N, indicating that N_2O and NO were mainly produced by the soil nitrification process. It was concluded that the N_2O and NO emissions under drip irrigation were lower than under furrow irrigation, when the irrigation regime was the same. Besides, drip irrigation with "small quota but high frequency" reduced N_2O and NO emission compared to that with "large quota but low frequency".

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