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Effects of Nitrogen Application on Soil Nitrification and Denitrification Rates and N_2O Emissions in Greenhouse

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ABSTRACT

Nitrous oxide (N_2O) has significant impact on global warming and leads to the depletion of ozone in the stratosphere. Agricultural soil is regarded as a major source of N_2O emissions. In recent years, greenhouse grown vegetables have rapidly developed in China. Although excessive fertilizer application in greenhouse vegetable production can result in increased N_2O emissions, research data on such emissions from greenhouse vegetables, such as cucumber, remains limited. In this study, four nitrogen (N) fertilizer treatments including 1,200 (N_{1200}, traditional N amount), 900 (N_{900}), and 600 kg N ha^{-1} (N_{600}) and the control (N_0) were carried out on cucumber in a greenhouse in the North China Plain. Results showed that N_2O emissions mainly occurred in the first five days after topdressing, and accounted for 75.8%-95.2% of total N_2O emissions produced in the whole interval (10 days). Significant exponential correlations were observed between N_2O flux and nitrification or denitrification rates ($P< 0.01$). The results also indicated that nitrification dominated and played a more important role in N_2O emissions than denitrification under the irrigation conditions of the study (water-filled pore space was 40.0 to 66.6%). Cumulative N_2O emissions were 0.48-5.01 kg N ha^{-1} in the cucumber growing season, accounting for 0.28-0.38% of nitrogen input. Compared to N_{1200}, treatment N_{600} significantly reduced the rate of N_2O emissions by 53.4%, and also maintained cucumber yield. Based on this study, 50% of the traditional N fertilizer rate (N_{600}) was considered sustainable for greenhouse cucumber production in the North China Plain.

Keywords: Cucumber, Environmental factor, Nitrogen fertilizer, N_2O flux. Soil NO3$^-$N.

INTRODUCTION

Nitrous oxide (N_2O) emissions significantly impact global warming and the depletion of ozone in the stratosphere (Akimoto *et al*., 2005; Meade *et al.,* 2011). Over recent years, due to intensive human practices, the rate of global N_2O emissions has increased by 17% from 1990 to 2005 (Kroeze *et al*., 1999; IPCC, 2007). Agricultural soil is a major source of N_2O emissions, releasing 6.3 Tg N_2O–N yr^{-1} into the atmosphere, accounting for 58% of total N_2O emissions (Mosier *et al*., 1998; IPCC, 2007). Nitrification and denitrification are two major processes producing N_2O, representing approximately 70% of total global N_2O emissions (Moiser *et al*., 1996; Malla *et al*., 2005). Therefore, environmental factors (e.g. soil moisture, temperature, pH, and rainfall) and human factors (e.g. irrigation and nitrogen fertilization) (Smith *et al*., 2003; He *et al*., 2007; Baggs *et al*., 2010; Sanchez-Marti *et al*., 2010) related to nitrification and denitrification can affect N_2O emissions. Nitrogen fertilizer application and irrigation are regarded as two of the most important

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elements influencing N_2O emissions (Zhang *et al*., 2008). Wang *et al.* (2011) and He *et al.* (2009) reported that seasonal N_2O emissions from vegetable fields increased significantly with nitrogen fertilizer application ($P< 0.0001$). Increased N availability can increase microbial nitrification and denitrification rates, thereby escalating N_2O emissions (Liu *et al*., 2011). In China, the rate of fertilizer-induced N_2O emissions from agricultural soils was 198.9 Gg N_2O–N in 1997, with 66.9 Gg N_2O–N produced by vegetable fields in 2009 (Lu *et al*., 2006; Wang *et al*., 2011). Additionally, the N_2O flux from irrigation was 1.17 times more than that without irrigation in greenhouse conditions (Zhang *et al*., 2002).

Vegetable production has developed rapidly in recent years, but excessive fertilization has become a common phenomenon in China. In greenhouse vegetable cropping systems, nitrogen fertilization rates in Hebei Province are about 1,269 kg N ha^{-1}, which are 2.8 times that of the recommended rate (Zhang *et al*., 2005). In cucumber fields, the accumulated nitrogen in Shandong Province was above 1,500 kg ha^{-1} after a growing season, which was sufficient for the occurrence of soil nitrification and denitrification (Ma *et al*., 2000). In addition, the temperature inside greenhouses is always higher than that outside, and soil usually lacks plowing and insolation. All of these factors exacerbate N_2O emissions (Zhang *et al*., 2002; Xiong *et al*., 2006; He *et al*., 2009; Alomran *et al*., 2013). The N_2O emissions from China crop fields varied from 275 to 292 Gg N_2O–N yr^{-1} during the 1990s, with vegetable crops accounting for about 20% of that amount (Zheng *et al*., 2004; Lu *et al*., 2006; Wang *et al*., 2011). Further, the background N_2O emissions (emissions induced by factors other than fertilization) from vegetable fields increased from 6.76 Gg N_2O–N in 1990 to 19.6 Gg N_2O–N in 2009 (He *et al*., 2009; Wang *et al*., 2011).

A number of studies have been carried out on N_2O emissions in wheat fields (Meade *et al*., 2011), maize fields (Liu e*t al*., 2011), rice paddies (Pramanik *et al*., 2013) and grasslands (Liu *et al*., 2010); however, no studies have reported on N_2O emissions from greenhouse cucumber crops. In this study, four N fertilization levels under the same irrigation conditions in a greenhouse in the North China Plain were established. The aims of this study were to: (i) monitor the nitrification and denitrification rates, (ii) compare the effects of different N rates on N_2O flux during the cucumber growing season, (iii) determine the factors impacting N_2O emissions, and (iv) identify reasonable nitrogen fertilizer application rate.

MATERIALS AND METHODS

Study Site

The study site was located at Mazhuang Experimental Station in Xinji County of Hebei Province (115°17′37″E, 37°47′53″N) in the North China Plain. The selected greenhouse was 39 m long and 7.5 m wide, with a wall made of brick-concrete, and brackets constructed with welded metal wires. The soil texture was sandy loam, containing 8.93 g kg^{-1} of organic carbon (by H_2SO_4–$K_2Cr_2O_7$ oxidation), 1.55 g kg^{-1} of total nitrogen (by Kjeldahl digestion), 32.4 mg kg^{-1} of available phosphorus (Olsen-P method), 165.3 mg kg^{-1} of available potassium (with NH_4OAc extraction), at a pH of 6.6 (1:2.5 soil-water ratios) and bulk density of the 0-20 cm topsoil of 1.35 g cm^{-3} (average fertilization and non-fertilization belts) (Lu, 2000). The cucumber variety used in the experiment was Bomei 11, and the cucumbers were planted on 18 February, 2009, and harvested on 3 July, 2009.

Experimental Design and Management

Four nitrogen treatments with three replications (Plot size: 6×1.8 m) were applied as urea: (1) traditional, nitrogen fertilizer input 1,200 kg N ha^{-1} (N_{1200}); (2) 900 kg N ha^{-1} (N_{900}); (3) 600 kg N ha^{-1} (N_{600}), and (4) the control, no nitrogen input (N_0). Traditional nitrogen amount was determined as per previous research in Hebei Province (Zhang *et al*., 2005). Triple superphosphate (300 kg P_2O_5 ha^{-1}) and potassium sulfate (525 kg K_2O ha^{-1}) were applied for each treatment. Furrow irrigation (5,190 m^3 ha^{-1} in total) was applied, and the irrigation frequency was consistent with the schedule of local farmers (Table 1). The plot was isolated by 1 m deep polyvinyl chloride (PVC) boards. Three rows of cucumbers were planted in each plot, with a row space of 60 cm and an interplant distance of 30 cm.

N_2O Flux Measurements

The width of the experimental plot was 1.8 m, with three fertilized furrows (fertilized belts). Each furrow was 0.30 m wide, and cucumbers were planted in the furrows. The areas (0.45 m wide) between fertilized furrows were regarded as the non-fertilization belts (Figure 1). N_2O flux of the fertilized and non-fertilized belts were monitored synchronously (plants were not included in chambers). The average flux emitted from the fertilized and non-fertilized belts was considered as the statistical value

Table 1. Nitrogen input rates, irrigation rates and date of sampling in greenhouse cucumber experiment (2009).[a]

Date	Growth stage		N rate (kg ha^{-1})[b]			Irrigation (m^3 ha^{-1})	Dates of N_2O sampling
			N_{600}	N_{900}	N_{1200}		
16 Feb.	Seedling period	Basal	120	180	240		16 Feb, 18 Feb, 22 Feb, 1 Mar,
28 Feb.		fertilizer				270	9 Mar, 16 Mar, 22 Mar, 29 Mar,
9 Mar.						360	
1 Apr.	Blooming period	Topdressing	60	90	120	480	1 Apr, 3 Apr, 5 Apr, 7 Apr, 10 Apr,
11 Apr.			60	90	120	480	11 Apr, 13 Apr, 15 Apr, 17 Apr, 20 Apr,
22 Apr.	Initial fruit period		60	90	120	480	22 Apr, 24 Apr, 26 Apr, 28 Apr, 1 May,
4 May			60	90	120	480	4 May, 6 May, 8 May, 10 May, 13 May,
15 May	Full fruit period		60	90	120	480	15 May,17 May,19 May,21 May,24 May,
26 May			60	90	120	480	26 May, 28 May, 30 May, 1 Jun, 4 Jun,
5 Jun.	End fruit period		60	90	120	480	5 Jun, 7 Jun, 9Jun, 11Jun, 14 Jun,
16 Jun.			60	90	120	480	16 Jun, 18 Jun, 20 Jun, 22 Jun,25 Jun
21 Jun.						480	
25 Jun.						480	
Total			600	900	1200	5190	

[a] Day of fertilization was "the first day of N_2O sampling". [b] N_{600}, N_{900} and N_{1200} representing 600, 900 and 1,200 kg ha^{-1} of N application amount, respectively.

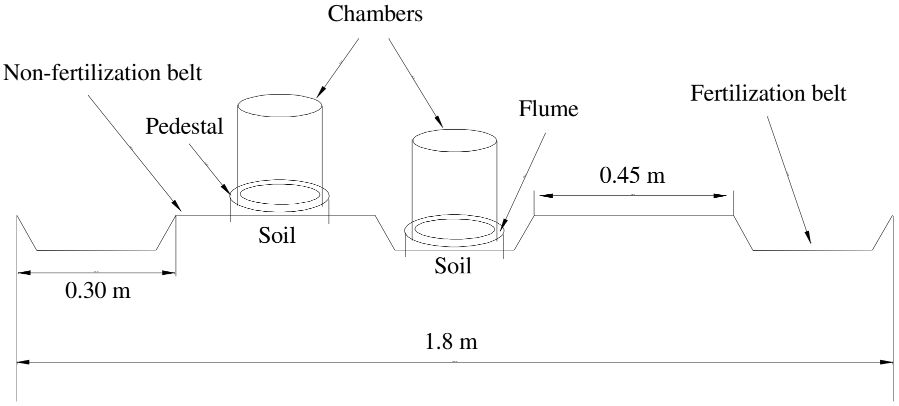

Figure 1. Schematic of experimental plot (fertilization and non-fertilization belts) and location of the chambers.

for each plot.

N_2O samples were collected using closed static chambers. Chambers (20 cm diameter×25 cm height) consisted of a chamber cap and a pedestal made of polyvinyl chloride (PVC) materials. The ring pedestal with a flume around the top was inserted to a depth of 5 cm into the soil before sampling to keep the chamber sealed (Figure 1). N_2O samples were collected at 1 or 2 day (d) intervals in the first 10 days after fertilizer application, and then at 7 day intervals in the other periods (Table 1). Sampling was carried out from 10:00 to 12:00 every day. Gas samples were taken using a 50 mL airtight syringe attached to a three-way stop cork at fixed intervals of 0, 10, 20, and 30 min after chamber closure, and then stored in evacuated bags made of inert aluminum-coated plastic. The N_2O samples were analyzed using a gas chromatograph (GC7890, Agilent Technologies Inc., USA) fitted with an electron capture detector (ECD) set at 300 °C. The column temperature was maintained at 40°C and the carrier gas was argon-methane (5%) at a flow rate of 30 mL min^{-1}. Details for this method were described by Zhang *et al.* (2011). N_2O fluxes were calculated according to Li *et al.* (2009).

Determination of Nitrification and Denitrification Rates Using BaPS System

The nitrification and denitrification rates were determined using Barometric Process-Separation (BaPS), which is based on measuring O_2, CO_2, and total gas balances inside an isothermal and gas-tight soil system. Nitrification (consumption of O_2 by ammonia oxidizing bacteria and archaea bacteria), denitrification (production of nitrogen containing gases such as NO, N_2O, and N_2), and soil respiration (consumption of O_2 and generation of equivalent volume of CO_2) are the main biological processes responsible for gas pressure changes in this system. The gross nitrification and denitrification rates and respiration can be calculated based on the gas and inverse balance. The basic principle of BaPS and relevant measuring processes are discussed in Muller *et al.* (2004) and Liu *et al.* (2005). Many studies have shown consistent gross nitrification and denitrification rates by BaPS and ^{15}N–pool dilution (Ingwersen *et al.*, 1999; Breuer *et al.*, 2002). In this study, undisturbed soil (10 cm depth) was sampled and sealed four times per month in the cucumber growing season, from February to June, by circular stainless rings equipped with the BaPS. At the same time, N_2O samples were collected simultaneously. All soil and gas samples were transported to the laboratory for analysis.

Auxiliary Measurements

Topsoil samples (10 cm depth) were randomly collected on the same day as N_2O sampling. Analysis of NO_3^--N concentrations in the soil was measured by extracting 10 g of mixed topsoil with 100 mL of 2 M KCl solution. The topsoil moisture content was determined gravimetrically by oven-drying samples at 105°C for > 12 hours. The water-filled pore space (WFPS) was calculated by *WFPS* (%)= (Soil bulk density×Soil moisture content)/(1-soil bulk density/ 2.65). The topsoil (5 cm) and air temperatures in the chamber as well as in the greenhouse were measured simultaneously when N_2O was sampled. Cucumber fruits were harvested and weighed by an electronic scale.

Statistical Analysis

Differences between treatments were determined by analysis of variance (ANOVA) and Tukey's multiple comparison tests using SPSS 18.0 statistical software. The significance levels for linear or non-linear regression curves were determined using *F*-test. Pearson correlation analysis was applied to investigate the associations of nitrification and denitrification rates and

N_2O fluxes with *WFPS*, mineral N content, soil temperature, and air temperature.

RESULTS AND DISCUSSION

N_2O Flux of Fertilization and Non-fertilization Belts

Details of soil temperature and soil moisture content (WFPS) are outlined in Figure 2-a. Soil temperature ranged from 8.6 to 33.8°C, with a mean of 24.4°C. *WFPS* changed strongly with irrigation, and ranged from 40.0 to 66.6%, with a mean of 55.8%.

Similar temporal trends in N_2O fluxes for the fertilized and non- fertilized belts were observed for each treatment during the growing season [Figure 2 (b and c)]. The N_2O fluxes varied from 5.99 to 1,098.7 μg m^{-2} h^{-1} and from 4.61 to 538.0 μg m^{-2} h^{-1} for the fertilized and non-fertilized belts, respectively. The peaks mainly appeared following N fertilization and appeared on the fourteenth day after base nitrogen application, at first irrigation and when the soil temperature was high (19.6°C). The rise in both temperature and soil moisture led to the significant increase in N_2O flux (Castaldi, 2000; Smith *et al.*, 2003). He *et al.* (2009) also reported that no N_2O emission peak occurred, even after fertilization, when soil temperatures were below 15°C.

N_2O flux peaks in the fertilized (Figure 2-b) and non-fertilized (Figure 2-c) belts appeared after topdressing. The N_2O fluxes decreased notably over a week and gradually tended to be stable after the peak appeared. Similar peaks in N_2O fluxes were observed by Malla *et al.* (2005) on application of nitrogen fertilizer. For different nitrogen treatments in the present study, N_2O emissions on the first five days were higher than that of the non-fertilized belts after topdressing. N_2O emissions on the first day, the first three days, and the first five days in the fertilized belts accounted for 41.4 to 80.0%, 76.8 to 91.4%, and 90.6 to 95.2% of total N_2O emissions over the 10 days, respectively, while the corresponding proportions in the non-fertilized belts were 18.0 to 68.6%, 52.1 to 86.2%, and 75.8 to 95.0%, respectively. These results illustrated that N_2O emissions were concentrated in the

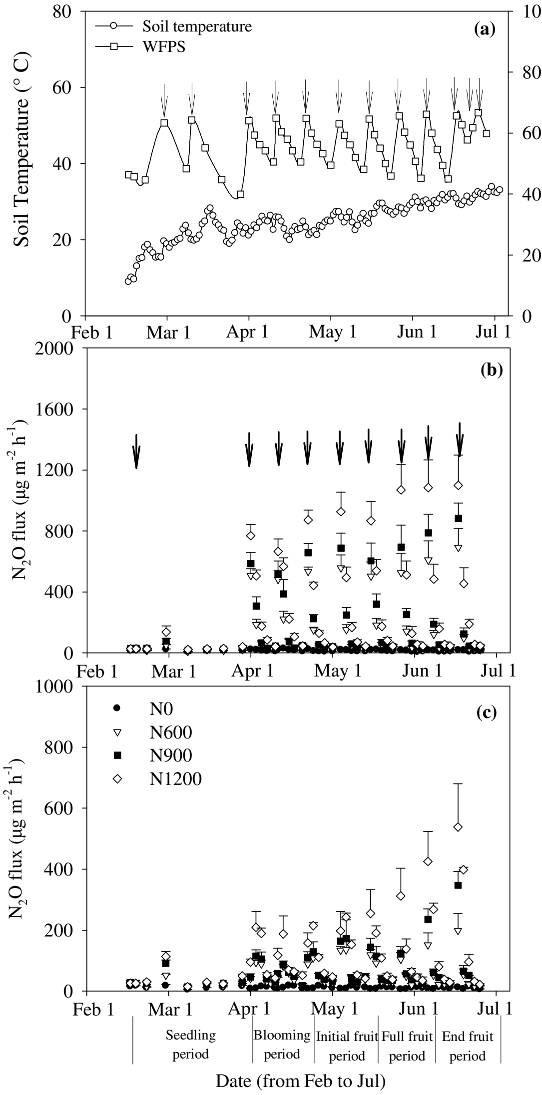

Figure 2. Temporal courses of soil temperature (5 cm depth), soil moisture (WFPS: Water-Filled Pore Space) (a), and N_2O fluxes for different N treatments in the fertilized (b) and non-fertilized belts (c) during cucumber growing seasons. *Vertical bars* denote the standard errors of the means (n= 3). Solid and bold arrows indicate irrigation and fertilizer N application, respectively. N_0, N_{600}, N_{900}, and N_{1200} are the treatments fertilized with 0, 600, 900, and 1,200 kg N ha^{-1}, respectively.

first five days for both the fertilized and non-fertilized belts, especially in the first three days after topdressing. These observations were consistent with He *et al.* (2007), who found a peak in N_2O emissions on the first or second day after fertilizer application in greenhouse tomatoes.

Nitrification and Denitrification Rates

The rates of nitrification and denitrification increased with the extension of the cucumber growing season and increase in air temperature; however, they decreased significantly with the decrease in N fertilizer application (Figure 3). The rates of nitrification and denitrification under N_{600} treatment were reduced by 24.8 to 34.0% (average of 30.2%) and 15.7 to 31.8% (average of 22.5%), respectively, compared to these under N_{1200} treatment. Soil moisture, air temperature, and soil temperature were correlated positively with both nitrification and denitrification rates (Table 2). Increases in suitable soil moisture (WFPS of 40.0 to 66.6%) or temperature (8.6 to 33.8°C) improved the nitrification and denitrification rates (Breuer *et al.*, 2002; Cao *et al.*, 2006). Correlation analysis demonstrated significant exponential relationships between the rates of nitrification and denitrification and N_2O flux (Figure 4). Similar findings were observed by Chen and Huang (2006). The nitrification of treatments N_0, N_{600}, N_{900}, and N_{1200} accounted for 72.3, 64.5, 66.7, and 69.8%, respectively, of total nitrification and denitrification, with an average value of 68.3%. This indicated that nitrification was

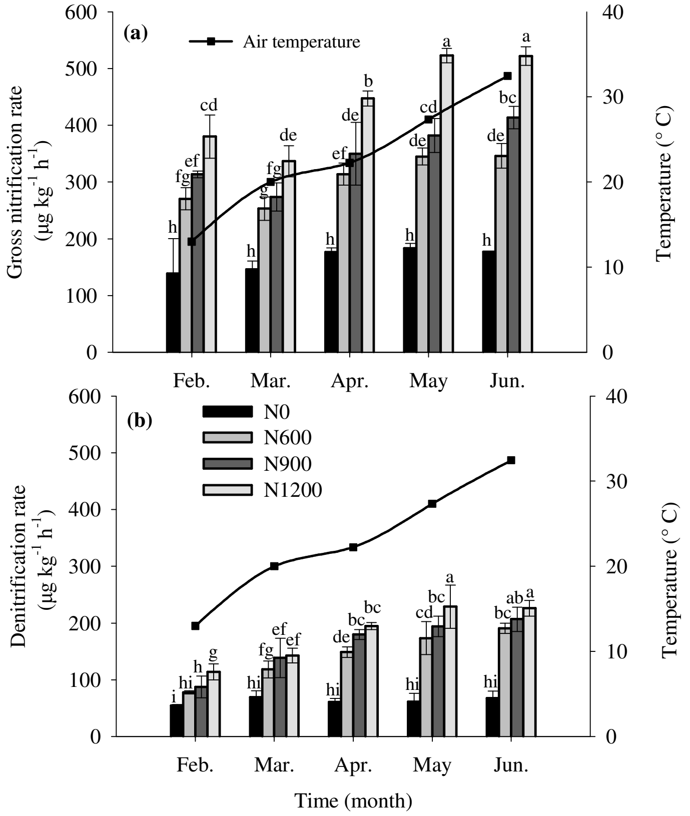

Figure 3. Monthly variation of gross nitrification rate (mean value±standard deviation) (a) and denitrification rate (mean value±standard deviation) (b) of greenhouse soil under different nitrogen conditions and the monthly temperature (curve with the square symbol). Different letters (a, b) denote significantly different between treatments at $P< 0.05$. N_0, N_{600}, N_{900}, and N_{1200} are the treatments fertilized with 0, 600, 900, and 1,200 kg N ha^{-1}, respectively.

Table 2. Correlation between the rate of nitrification and denitrification and environmental factors.

		WFPS (%)	Air temperature in greenhouse (°C)	Soil temperature (°C)
		n [a] = 33	n= 33	n= 33
Nitrification rate (μg kg^{-1} h^{-1})	N_0	0.439*	0.388	0.443*
	N_{600}	0.626**	0.359	0.657**
	N_{900}	0.541**	0.386	0.645**
	N_{1200}	0.499*	0.683**	0.688**
Denitrification rate (μg kg^{-1} h^{-1})	N_0	0.223	0.200	0.264
	N_{600}	0.630**	0.359	0.857**
	N_{900}	0.403	0.696**	0.726**
	N_{1200}	0.656**	0.555**	0.799**

[a] Number of observations; * Significant at $P< 0.05$, ** Significant at $P< 0.01$.

the dominant process producing N_2O in soil (WFPS of 40.0 to 66.6%). This is in agreement with Sanchez-Martin *et al.* (2010), who found that nitrification was more important in the production of N_2O compared with denitrification when *WFPS* was 56 to 75%.

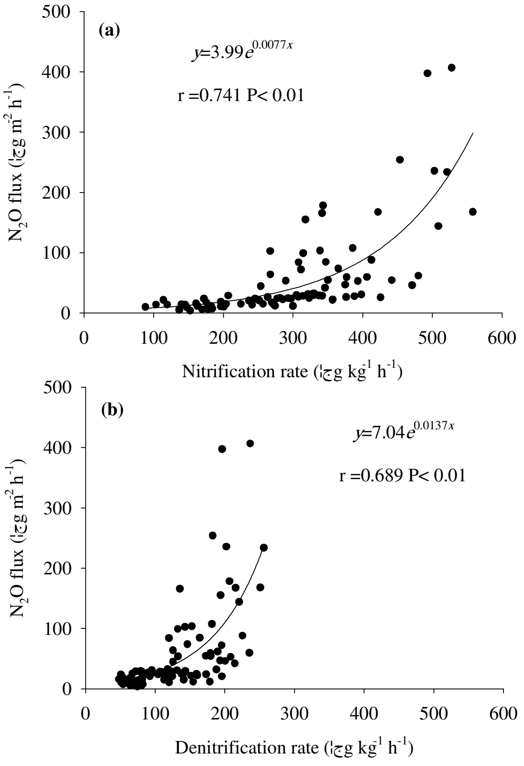

Figure 4. Relationship between the nitrification rate (a), denitrification rate (b) and N_2O flux.

N_2O Emissions and Environmental Factors

N_2O emissions are significantly influenced by farming activities such as nitrogen application and irrigation, which can alter the NO_3^--N concentrations and moisture in the soil (Laville *et al.*, 2011). Compared to the control, nitrogen application increased the rates of nitrification and denitrification and, consequently, led to a significant increase in N_2O emissions. We observed significant correlations in soil NO_3^--N with N_2O emissions in the cucumber season (Figure 5), which is in agreement with other studies that

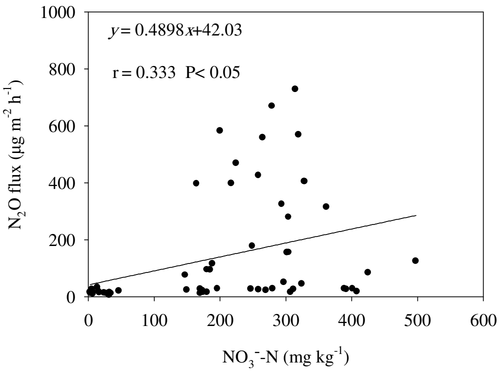

Figure 5. Relationship between N_2O fluxes and soil NO_3^--N content (average fertilization and non-fertilization belts).

have reported increased emissions with increasing soil NO_3^--N (Stevens *et al.*, 1998; Laville *et al.*, 2011).

Irrigation often causes the soil pores to fill with water, which aggravates the anaerobic environment and intensifies denitrification (Clemens *et al.*, 2008). Bateman and Baggs (2005) and Baggs *et al.* (2010) stated that the optimum *WFPS* for ammonia oxidation was around 65% *WFPS*. At a *WFPS* of between 30 and 70%, the relationship between aerobic microbial processes and *WFPS* appeared linear (Linn and Doran, 1984). Generally, N_2O emitted under 35 to 60% *WFPS* is produced during nitrification, while denitrification is the main process producing N_2O under 70-90% *WFPS* (Bateman and Baggs, 2005; Liu *et al.*, 2007; Zhang *et al.*, 2009; Laville *et al.*, 2011). According to Lan *et al.* (2013), the effects of moisture on N_2O emissions were probably masked by the effects of fertilization. When mineral N content of the soil is low, irrigation does not affect N_2O emissions significantly (He *et al.*, 2009). In this study, fertilizer was dissolved and flushed with furrow irrigation water during the topdressing period, and a significant positive relationship was found between N_2O flux and *WFPS* (Table 3). These findings are supported by a number of previous studies (Lin *et al.*, 2010; Laville *et al.*, 2011). Soil temperature also significantly affects N_2O emissions when soil nitrate content and soil moisture are relatively constant (He *et al.*, 2009). Cao *et al.* (2006) also found a highly significant positive correlation (r= 0.781) between soil temperature (from 5 to 32°C) and N_2O emissions during the growing season of Chinese cabbages. In this study, soil temperature during the cucumber growing season ranged from 8.6 to 33.8°C, and N_2O emissions showed a significant positive relationship with soil temperature, except for the control (Table 3).

Cumulative N_2O Emissions and Cucumber Yield

The effects of nitrogen application on cumulative N_2O emissions and cucumber yield were significant (Table 4). N_2O emissions from the fertilized and non-fertilized belts were calculated by integrating the linearly interpolated data in the cucumber growing season, and the cumulative N_2O emissions ranged from 0.48 to 5.01 kg N ha^{-1}. Taking N_2O emissions from the N_0 treatment as the background emissions, the fertilizer-induced N_2O emission factors for N_{600}, N_{900} and N_{1200} were 0.30, 0.28 and 0.38% of nitrogen input, respectively. Less N_2O emissions were produced when less nitrogen fertilizer was used (Table 4). Compared to the N_{1200} treatment, cumulative N_2O emissions were reduced by 53.4% in the N_{600} treatment. At the same time, cucumber yield increased by 6.02%, which showed that an appropriate reduction in nitrogen application reduced cumulative N_2O emissions significantly without lowering the cucumber yield.

Table 3. Correlation between N_2O flux and environmental factors.

		WFPS (%)	Air temperature in greenhouse (℃)	Soil temperature (℃)
		n^a = 33	n= 33	n= 33
N_2O flux ($\mu g\ m^{-2}\ h^{-1}$)	N_0	0.385*	-0.037	0.084
	N_{600}	0.667**	0.463**	0.497**
	N_{900}	0.707**	0.392*	0.428**
	N_{1200}	0.693**	0.765**	0.756**

^{a} Number of observations; * Significant at $P< 0.05$, ** Significant at $P< 0.01$.

Table 4. Cucumber yields, N_2O emission and emission factors under different nitrogen conditions.

Treatments [a]	Yield (10^4 kg ha^{-1})	Increasing ratio (%)	N_2O emissions		Cumulative N_2O emissions (135 d) (kg N ha^{-1})	Emission factor (%) [c]
			Fertilizer belts	Non-fertilizer belts		
N_0	11.9 b [b]	—	0.28 d	0.20 d	0.48 d	—
N_{600}	16.5 a	22.9	1.56 c	0.74 c	2.30 c	0.30
N_{900}	15.5 a	18.8	2.06 b	0.95 b	3.01 b	0.28
N_{1200}	15.4 a	15.9	3.37 a	1.64 a	5.01 a	0.38

[a] N_0, N_{600}, N_{900}, and N_{1200} are the treatments fertilized with 0, 600, 900, and 1,200 kg N ha^{-1}, respectively; [b] Values with the same letter means no significant different among different treatments by Tukey with three replications ($P>$ 0.05); [c] Emission factor induced by total applied N from chemical fertilizer.

CONCLUSIONS

We investigated the N_2O emissions and soil nitrification and denitrification rates under different nitrogen fertilization treatments including traditional nitrogen (N_{1200}), 75% of traditional nitrogen (N_{900}), 50% of traditional nitrogen (N_{600}), and no nitrogen treatments (N_0) in a cucumber growing greenhouse in the North China Plain. N_2O emissions and nitrification and denitrification rates in the greenhouse soils were strongly related to fertilizer nitrogen inputs. Compared to the N_{1200} treatment, N_2O emissions and nitrification and denitrification rates of N_{600} were reduced by 53.4, 30.2 and 22.5%, respectively. High N_2O emissions occurred in the first five days after topdressing, which accounted for more than 75.8% of total emissions during the 10-day study period. Water-filled pore space (*WFPS*), air temperature, and soil temperature affected the nitrification rate, denitrification rate, and N_2O emissions, especially after nitrogen fertilizer application. The nitrification and denitrification rates presented an exponential relationship with N_2O emissions ($P<$ 0.01), and nitrification was the main biological process producing N_2O under the traditional irrigation conditions in this experiment (WFPS of 40.0 to 66.6%). N_2O emissions ranged from 0.48 to 5.01 kg ha^{-1} during the cucumber growing season, and 0.28-0.38% (average 0.32%) of the nitrogen application rate was emitted as N_2O-N. The improved N-fertilizer management reduced the nitrogen application rate by 50% (N_{600}), increased cucumber yield by 6.02%, and significantly decreased N_2O emissions ($P<$ 0.01).

Based on this study, for the present greenhouse cucumber production in Hebei Province in the North China Plain, appropriate reduction in nitrogen fertilizer application significantly reduced N_2O emissions without any negative effect on cucumber yield. Compared to the traditional nitrogen application rate i.e.1,200 kg N ha^{-1}, a 50% reduction is suggested.

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اثر کار برد نیتروژن روی نیترات سازی و نیترات زدایی و تصعید N_2O در گلخانه

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چکیده

اکسید نیتروژن(N_2O) اثر مهمی روی گرم شدن زمین دارد و به تخلیه اوزن در استراسفر منجر می شود.زمین های کشاورزی به عنوان منبع اصلی تصعید و انتشار این گاز شناخته می شوند. در سال های اخیر، کاشت گلخانه ای سبزیجات به سرعت در چین توسعه یافته است. با وجود مصرف بیش از حد کودهای شیمیایی در گلخانه ها برای تولید سبزی های مختلف که می تواند تصعید N_2O را افزایش دهد، داده های پژوهشی در زمینه انتشار این گاز در فرایند تولید سبزیجاتی مانند خیار همچنان محدود است. در این رابطه، در پژوهش حاضر، چهار تیمار کود نیتروژن شامل ۱۲۰۰ کیلو گرم در هکتار(N_{1200}، مقدار رایج وسنتی)، ۹۰۰ (N_{900})، ۶۰۰ کیلو گرم در هکتار (N_{600})، و شاهد (N_0) روی محصول خیار در دشت شمالی چین بررسی شد. نتایج نشان داد که بیشتر تصاعد گاز N_2Oکه نزدیک به ۹۵/۲٪ -۷۵/۸٪ کل تصاعد گاز طی دوره اندازه گیری (۱۰ روز) بود طی پنج روز اول بعد از کودپاشی سرک رخ داد. از تحلیل داده ها، رابطه های معنی دار نمایی ($P< 0.01$)بین جریان انتشارN_2O **و** نرخ نیترات سازی و نیترات زدایی به دست آمد. همچنین، نتایج نشان داد که در انتشار و تصاعد گاز مزبور در شرایط آبیاری (تخلخل پر شده از آب در خاک بین ۴۰٪ تا ۶۶/۶٪) فرایند نیترات سازی غالب بود و نقش مهم تری از نیترات زدایی در این مطالعه داشت. انتشار تجمعی N_2Oطی فصل رشد خیار بین ۰/۴۸-۵/۰۱ کیلو گرم در هکتار بود که معادل ۰/۳۸٪ - ۰/۲۸٪ از نیتروژن افزوده شد به خاک را شامل می شد. در مقایسه با تیمار N_{1200}، تیمار N_{600} به طور معنی داری نرخ انتشار N_2Oرا در حدود ۵۳/۴٪ کاهش داد و سطح عملکرد خیار را حفظ کرد. بر پایه این پژوهش، مصرف نیتروژن در حد(N_{600}) معادل ۵۰٪ مقدار رایج و سنتی در دشت شمالی چین میتواند به عنوان مصرف پایدار برای تولید خیار گلخانه ای در این منطقه تلقی شود.