Nitrous oxide flux in constructed wetland with/without plant

Hongying Sun1,2, Quanwei Xin1, Xingsheng Lin2, Zhihui Ma1, Liyun Xiao3, Dong Liu3 and Siren Lan1,a

1Forestry College, Fujian Agriculture and Forestry University, Fuzhou, 350002, China
2National Engineering Research Center of Juncao, Fujian Agriculture and Forestry University, Fuzhou 350002, China
3Regional Management Office for quality and Safety of Agricultural products, Anqiu, 262100, China
4Nanjing Institute of Environmental Sciences, Ministry of Environmental Protection, Nanjing, 210042, China

Abstract. To investigate the effect of plant presence on the nitrous oxide flux, we established constructed wetland using two common plant species. Results showed that nitrous oxide emissions have significant differences between constructed wetlands with and without plants, 7567.64 ug N₂O m⁻² d⁻¹ and 492.67 ug N₂O m⁻² d⁻¹ respectively (P < 0.001), contrary to microbial biomass nitrogen and total nitrogen content (P > 0.05). The nitrous oxide emissions in constructed wetlands planted with Phragmites australis and Lythrum salicaria had significant differences, 13328.72 ug N₂O m⁻² d⁻¹ and 1806.56 ug N₂O m⁻² d⁻¹ respectively (P < 0.001), and they were significantly higher than in constructed wetlands without plant (P < 0.001). The total nitrogen content in constructed wetlands planted with Phragmites australis and Lythrum salicaria had no significant differences (P > 0.05). Hence, plant presence and plant species are important factors in regulating nitrous oxide emissions and total nitrogen removal in constructed wetlands.

1. Introduction

Constructed wetlands are widely used for various wastewater treatments with many advantages, including low operation cost, easy maintenance and high removal performances [1, 2]. Despite of many advantages, constructed wetlands also release certain amount of nitrous oxide due to their higher nitrogen loadings [3]. Nitrous oxide is the third largest greenhouse gas in causing the climate warming [4]. Nitrous oxide produced in constructed wetlands mainly by microbes [5]. Nitrous oxide emission is highly variable and regulated by many factors, such as plant, dissolved oxygen and organic carbon [6]. Plants are the main driver of these factors [7]. Labile carbon including sugars, amino acids and organic acids are released into the soil through plant, where the quality and quantity of these organic carbons depends on plant species [8]. Besides, oxygen released from root systems effects soil microbial activities [9].

Some researchers have studied nitrous oxide flux in constructed wetlands, but the effects of plant on the nitrous oxide emission in constructed wetlands have been in debates. Some researchers find that planted constructed wetlands emit lower nitrous oxide levels than unplanted systems [9], while others have claimed that planted constructed wetlands emit higher nitrous oxide levels than unplanted
systems [10]. These conflicting results may be caused by the use of different plant species in constructed wetlands. In this study, we established constructed wetlands and assembled different community treatments (unplanted, *Lythrum salicaria* and *Phragmites australis*) to investigate: (1) whether plant presence has an impact on nitrous oxide emission and nitrogen removal; (2) if plant presence does affect nitrous oxide emission, whether the nitrous oxide emission is different between *Lythrum salicaria* systems and *Phragmites australis* systems.

### 2. Materials and methods

This study was conducted in constructed wetlands on Agriculture and Forestry University campus, in Fujian Province of China. The nine constructed wetlands were established using a vertical flow design for treating synthetic wastewater and filled with river sand to 30 cm deep. Two common local plant, *Lythrum salicaria* and *Phragmites australis* were selected for this experiment. In March of 2017, the seedlings were transplanted into constructed wetlands with a density of 12 individuals per constructed wetland.

The wastewater used in the experiment was the Hoagland's nutrient solution [11] with little modification. The nitrogen concentration is 112 mg L\(^{-1}\). The wastewater was introduced into the constructed wetlands, remained for 10 days, and then was drained.

We collected nitrous oxide samples using static chamber on the 26th of August in 2017. The nitrous oxide concentrations were detected through gas chromatography technique (Agilent 7890B, USA).

Plant samples from each constructed wetlands were collected after collecting the nitrous oxide samples and dried at 65 °C for 48hr. After plant harvesting, the soil of each constructed wetland was sampled using a sampling spade. Microbial biomass nitrogen (MBN) in soil was determined by the chloroform fumigation-extraction technique. Soil nitrogen was measured using automated discrete analyzers (Smart Chem 200, Italy).

A one-way ANOVA was used to test for differences in nitrous oxide emission, plant biomass, microbial biomass nitrogen, total nitrogen content. All analyses were performed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

### 3. Results and discussion

#### 3.1. Effects of plant presence on nitrous oxide emissions

There was significant difference in nitrous oxide emissions between constructed wetlands with and without plants, 7567.64 \(\mu g\) \(N_2O\) \(m^{-2}\) \(d^{-1}\) and 492.67 \(\mu g\) \(N_2O\) \(m^{-2}\) \(d^{-1}\) respectively (Fig.1A, \(P < 0.001\)), showing significant effect of plant presence on the nitrous oxide emission in this study. However, the microbial biomass nitrogen in constructed wetlands with and without plant was not significant differences (Fig.2A, \(P > 0.05\)). Plant allocates available organic carbon to the soil, which could further enhance microbial activity and nitrous oxide emission [12]. So, the positive effect of plant presence on nitrous oxide emissions, at least in part, from the positive response of plant biomass (Fig.3, \(P < 0.05\)) to plant presence.
Figure 1. Effects of plant presence (A) and species (B) on nitrous oxide emission. Species abbreviations are: Pa, *Phragmites australis*; Ls, *Lythrum salicaria*
3.2 Effects of plant species on nitrous oxide emissions
In Fig.1B, the nitrous oxide emissions in constructed wetlands planted with *Phragmites australis* and *Lythrum salicaria* had significant differences, 13328.72 µg N₂O m⁻² d⁻¹ and 1806.56 µg N₂O m⁻² d⁻¹ respectively (P < 0.001), and they were significantly higher than in constructed wetlands without plant (P < 0.001). A possible reason was that the microbes related to nitrous oxide processes might have significant differences. Although microbial biomass nitrogen had no significant differences between *Phragmites australis* and *Lythrum salicaria* systems (Fig. 2B, P < 0.001), microbial activity might be higher in constructed wetlands planted with *Phragmites australis* than in constructed wetlands planted with *Lythrum salicaria*.

3.3 Effects of plant presence and plant species on soil nitrogen
Contrary to nitrous oxide emissions, the soil total nitrogen content in constructed wetlands with and without plant was not significant differences (Fig. 4A, $P > 0.05$). Similarly, microbial biomass nitrogen and plant biomass in constructed wetlands with and without plant was not significant differences (Fig. 2A, $P > 0.05$). Microbial transformation and plant uptake is the two major removal pathway of nitrogen in constructed wetlands [6]. So we think plant uptake and microbial transformation is responsible for the total nitrogen removal in this study.

![Figure 4](image)

Figure 4. Effects of plant presence (A) and species (B) on soil nitrogen.

Contrary to nitrous oxide emissions, the soil total nitrogen content in constructed wetlands planted with *Phragmites australis* and *Lythrum salicaria* had no significant differences (Fig. 4B, $P > 0.05$). Similarly, contrary to carbon dioxide emissions and microbial biomass nitrogen, the total nitrogen content in constructed wetlands planted with *Phragmites australis* and *Typha orientalis* were lower than that in constructed wetlands with plant (Fig. 4B, $P < 0.001$). Microbes convert nitrogen into nitrous oxide partly and plant uptake nitrogen for growth and development [16], the total nitrogen removal was consistent with the nitrous oxide release, plant biomass and microbial processes.

### 4. Conclusions

In conclusion, our study demonstrated that plant presence and plant species had significant effect on nitrous oxide emissions. Similarly, plant presence enhanced total nitrogen removal. Thus, plant presence and plant species is important factors in regulating nitrous oxide emissions and total nitrogen removal in constructed wetlands.

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