Carbon dioxide flux in constructed wetland with/without plant

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Abstract. To investigate the effect of plant presence on the carbon dioxide flux, we established nine constructed wetlands using two plant species. Results showed that carbon dioxide emissions have no difference between constructed wetlands with and without plants, 88.90 mg CO₂ m⁻² h⁻¹ and 34.73 mg CO₂ m⁻² h⁻¹ respectively (P > 0.05), in accordance with microbial biomass carbon and total organic carbon content (P > 0.05). The carbon dioxide emissions in constructed wetlands planted with Phragmites australis and Lythrum salicaria had no significant differences (P > 0.05), but they were significantly higher than in constructed wetlands without plant (P < 0.001). Similar with carbon dioxide emissions, the total organic carbon concentration and microbial biomass carbon in constructed wetlands with and without plant was not significant differences (P > 0.05). The total organic carbon concentration 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 plant aboveground biomass and total organic carbon removal but not affect carbon dioxide emission 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]. Despite of many advantages, constructed wetlands also release certain amount of carbon dioxide due to their higher carbon loadings [2]. Carbon dioxide is the largest greenhouse gas in causing the climate warming [3]. Carbon dioxide produced in constructed wetlands by plant roots and microbes [3]. Carbon dioxide emission is highly variable and regulated by many factors, such as plant, organic carbon content and dissolved oxygen [4]. Plants are the main driver of these factors [5]. Labile carbon including organic acids, amino acids and sugars are released into the soil through plant roots, where the quality and
quantity of these organic carbons depends on plant species [6]. Besides, plant root respiration produces carbon dioxide directly [7].

Some researchers have studied carbon dioxide emission in constructed wetlands, but the effects of plant on the carbon dioxide emission in constructed wetlands have been in debates. Some researchers find that planted constructed wetlands emit lower carbon dioxide levels than unplanted systems [8], while others have claimed that planted constructed wetlands emit higher carbon dioxide levels than unplanted systems [9]. 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 carbon dioxide emission and carbon removal; (2) if plant presence does affect carbon dioxide emission, whether the carbon dioxide 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 [10] 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 carbon dioxide samples using static chamber on the 26th of August in 2017. The carbon dioxide concentrations were detected through gas chromatography technique (Agilent 7890B, USA).

Plant aboveground samples from each constructed wetlands were collected after collecting the carbon dioxide samples and dried at 65 °C for 48hr. After plant aboveground harvesting, the soil of each constructed wetland was sampled using a sampling spade. Microbial biomass carbon (MBC) in soil was determined by the chlororm fumigation-extraction technique. Effluent total organic carbon content was measured using automated discrete analyzers (Smart Chem 200, Italy).

A one-way ANOVA was used to test for differences in carbon dioxide emission, plant aboveground biomass, microbial biomass carbon, total organic carbon 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 carbon dioxide fluxes

There was no significant difference in carbon dioxide emissions between constructed wetlands with and without plants, 88.90 mg CO\(_2\) m\(^{-2}\) h\(^{-1}\) and 34.73 mg CO\(_2\) m\(^{-2}\) h\(^{-1}\) respectively (Fig.1A, \(P > 0.05\)), showing no significant effect of plant presence on the carbon dioxide emission in this study. Similarly, the microbial biomass carbon in constructed wetlands with and without plant was not significant differences (Fig.2A, \(P > 0.05\)). Soil microbes release carbon dioxide through microbial respiration [11]. So, the carbon dioxide emission with plant presence may be explained by the microbial processes.
Figure 1. Effects of plant presence (A) and species (B) on carbon dioxide emission. Species abbreviations are: Pa, *Phragmites australis*; Ls, *Lythrum salicaria*.
3.2 Effects of plant species on carbon dioxide fluxes

In Fig. 1B, the carbon dioxide emissions in constructed wetlands planted with *Phragmites australis* and *Lythrum salicaria* had no significant differences ($P > 0.05$), but they were significantly higher than in constructed wetlands without plant ($P < 0.001$). One reason might be that the microbes related to carbon dioxide processes had no differences, because microbial biomass carbon had no significant differences between *Phragmites australis* and *Lythrum salicaria* systems (Fig. 2B, $P < 0.05$). In addition, the plant belowground biomass in the constructed wetlands planted with *Lythrum salicaria* were lower than that in the constructed wetlands planted with *Phragmites australis* (Fig. 3, $P < 0.05$). It is possible that the carbon dioxide production mainly depend on microbial processes but not plant root respiration.
3.3 Effects of plant presence and plant species on total organic carbon
Similar with carbon dioxide emissions and microbial biomass carbon, the total organic carbon concentration in constructed wetlands with and without plant was not significant differences (Fig. 4A, $P > 0.05$). Microbial transformation is the major removal pathway of carbon in constructed wetlands [12]. So we think microbial transformation is responsible for the total organic carbon removal in this study.
Similar with carbon dioxide emissions and microbial biomass carbon, the total organic carbon concentration in constructed wetlands planted with *Phragmites australis* and *Lythrum salicaria* had no significant differences (Fig. 4B, *P* > 0.05). However, contrary to carbon dioxide emissions and microbial biomass carbon, the total organic carbon concentration in constructed wetlands planted with *Phragmites australis* and *Typha orientalis* were lower than that in constructed wetlands with plant (Fig. 4B, *P* < 0.05). Microbes convert organic carbon into carbon dioxide [13], the total organic carbon removal was consistent with the carbon dioxide release and microbial processes.

4. Conclusions
In conclusion, our study demonstrated that plant presence and plant species had no effect on carbon dioxide emissions, but plant presence enhanced total organic carbon removal, indicating that plant presence is important factors in regulating total organic carbon removal but not affect carbon dioxide emissions in constructed wetlands.

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