Root Release of Organic Carbon by Three Emergent Wetland Plants

Xu Zhai & Hans Brix
Plant Biology, Department of Bioscience, Aarhus University, Aarhus C, Denmark

Introduction

- The most important nitrogen removal pathway in constructed wetlands (CWs) is sequential nitrification and denitrification. Endogenously derived dissolved organic carbon (DOC) in root exudates from plants may provide the denitrifying bacteria with energy for the denitrification process and hence stimulate the conversion of nitrate (NO_3) into N_2 gas.
- CWs take advantage of plants, which convert inorganic carbon into organic carbon via photosynthesis. The quantity of C released in root exudates varies among species and is influenced by temperature, light-regime as well as the developmental stage and nutritional status of the plants.

Objectives

The aims of this study were

- to quantify the amount of DOC released in root exudates by three species of wetland plants
- to evaluate the effects of temperature and light-regime on DOC release
- to assess the relationship between DOC release and nutrient uptake (NH_4, NO_3, PO_4 and K) by wetland plant roots.

Materials and Methods

The amount of DOC released and nutrient uptake rates by roots of *Phragmites australis, Iris pseudacorus* and *Juncus effusus* were quantified at two temperatures (10 and 20°C) and three light-regimes (Light:dark 14:10h, 24:0h and 0:24h). The DOC release rates of each plant (n=6) were quantified from the increase in DOC concentration in the nutrient solution. The nutrient uptake rates were caculated from decrease in solution concentrations over time.

Results

Table 1. Results of ANOVA (*P*-values) showing the effects of growth temperature (T: 10°C and 20°C), species (S: *P. australis, I. pseudacorus* and *J. effusus)*, and light-regime (L: 14h, 24h and 0h light per day) on RGR, DOC release rate and nutrient uptake rates.

	Main effects				Interactions			
	T (Df=1)	S (Df=2)	Pl (T×S) (Df=30)	L (Df=2)	T×S (Df=2)	T×L (Df=2)	L×S (Df=4)	T×S×L (Df=4)
RGR	**0.0000**[a]	**0.0000**	0.2645	**0.0000**	**0.0002**	**0.0348**	**0.0000**	0.3434
DOC release rate	**0.0010**	**0.0000**	**0.0000**	**0.0000**	0.2726	0.1131	0.0885	0.6412
NH_4 uptake rate	**0.0312**	**0.0000**	**0.0000**	**0.0000**	0.4488	**0.0000**	**0.0000**	**0.0445**
NO_3 uptake rate	**0.0049**	**0.0000**	**0.0000**	**0.0000**	0.8106	**0.0000**	**0.0000**	**0.0017**
PO_4 uptake rate	0.0681	**0.0123**	**0.0000**	**0.0046**	0.8751	**0.0000**	**0.0000**	**0.0004**
K uptake rate	0.4571	**0.0000**	0.1440	**0.0000**	0.0943	**0.0020**	**0.0004**	**0.0101**

Pl (T×S) is Plant nested in Temperature × Species.
[a] Figures in bold are statistically significant at the 0.05 probability level.

- Average DOC release rates from *I. pseudacorus* (12.2±0.7 µg g^{-1} root DW h^{-1}) and *P. australis* (9.0±0.9 µg g^{-1} root DW h^{-1}) were significantly (p<0.05) higher than the DOC release rates from *J. effusus* (4.3±0.4 µg g^{-1} root DW h^{-1}) (Fig.1).
- In light treatments, DOC release rates were consistently higher than in the dark treatment at both temperatures. *I. pseudacorus* DOC release rates were highest (15.8±0.9 µg g^{-1} root DW h^{-1}) at continuous light condition at 20°C (Fig.1b).
- The average DOC release rate from the plants grown at 20°C (10.2±0.7 µg g^{-1} root DW h^{-1}) was significantly higher than the release rate from the plants grown at 10°C (6.8±0.7 µg g^{-1} root DW h^{-1}), except for *J. effusus* at continuous light and dark (Fig. 1c).

Table 2. Results of regression analysis showing the relation of root release rate of DOC from three species with plant RGR, total plant DW and nutrient uptake rates.

	P. australis		*I. pseudacorus*		*J. effusus*	
	r	*p*	*r*	*p*	*r*	*p*
RGR	0.382	**0.022**[a]	0.329	0.050	0.796	**0.000**
Total dry weight	-0.408	**0.014**	-0.166	0.333	-0.323	0.055
NH_4 uptake rate	0.323	0.055	0.467	**0.004**	0.710	**0.000**
NO_3 uptake rate	0.285	0.092	0.258	0.129	0.651	**0.000**
PO_4 uptake rate	0.332	**0.048**	0.248	0.145	0.461	**0.005**
K uptake rate	0.383	**0.021**	0.327	0.052	0.726	**0.000**

[a] Figures in bold are statistically significant at the 0.05 probability level.

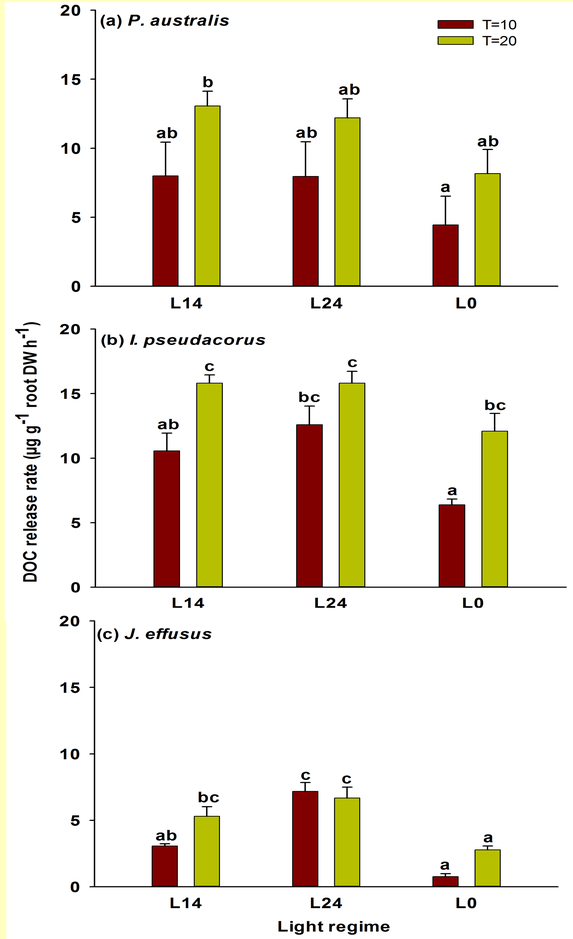


Fig.1 Release rates of DOC from roots of three species incubated at two temperatures(T=20 and T=10) and three light-regimes (L14, L24 and L0). Different letters above columns indicate significant difference between treatments in each species (P < 0.05). Values are means ± S.E. (n = 6)

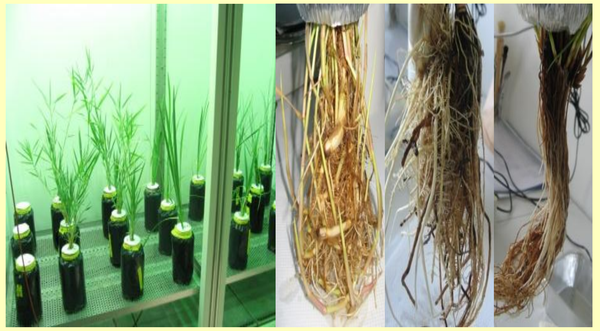
Conclusions

Extrapolation of measured DOC release rates indicate that:

- Root DOC may be in the range of **7-440 kg DOC $ha^{-1}year^{-1}$** which potentially can fuel a denitrification rate of **2-88 kg N ha^{-1} $year^{-1}$** (based on 250 g root dry weight m^{-2} and 5:1 as the required C:N ratio for denitrification).

As N loading rates of treatment wetlands may vary in the range of 200-5000 kg $ha^{-1}year^{-1}$, the results suggest that:

- Root exudates may be **a major carbon source for denitrification in low-loaded wetlands**
- Root exudates are of **minor quantitative importance for denitrification in highly-loaded wetland systems**.



Future Directions

- The compositions of the carbon compounds in root exudates from different wetland species, and the relations to growth conditions, will be analyzed.

Please contact
zhai.xu@biology.au.dk
for further information.