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# Does the combination of two plant species improve removal efficiency in treatment wetlands?

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ABSTRACT

We explored the effect of combining two plant species with complementary traits (*Phragmites australis* and *Phalaris arundinacea*), planted sequentially, on the performance of treatment wetlands (TWs). We performed a year-long experiment in mesocosm-scale TWs, aiming to answer the following question: will the combined removal efficiency of the two species equal the average efficiency of the separate monocultures, or will it outperform both monocultures, thus supporting the hypothesis that plant diversity improves pollutant removal in TWs? Root and shoot density and morphology particular to each plant species influenced the redox conditions of the rhizosphere; *Phragmites* rhizosphere oxidizing conditions enhanced nitrification and ammonification processes, while possibly limiting denitrification rate. On the other hand, *Phalaris* reducing conditions seemed to limit nitrification and enhance denitrification and sulfate reduction. Our results revealed that *Phragmites* was equal to or more efficient in removal than *Phalaris* for all pollutants except for nitrate. We found no evidence that combining both species would improve treatment efficiency for any pollutant taken individually, the best monoculture being always as efficient as or more efficient in removal than the combination of two plant species. However, combining both plant species may represent the best tradeoff between overall high pollutant removal and low nitrate level in the effluent.



## 1. Introduction

Treatment wetlands (TWs) are simplified ecosystems designed for the purpose of wastewater treatment. Their removal efficiency is determined by the biological and physicochemical processes that take place between wastewater and the main components of TWs—substrate, plants and microbial communities. Plants play an important role in TW performance (Brix et al., 2002; Kadlec and Wallace, 2009). They uptake and store nutrients, and enhance microbial mediated processes by increasing the attachment surface area, supplying oxygen to the rhizosphere and providing organic carbon through root exudates (Coleman et al., 2001; Bais et al., 2006; Kadlec and Wallace, 2009; Vymazal, 2011). Given this influential role, the identity and number of plant species in a TW may have an impact on its treatment efficiency. It is generally assumed that plant species should be selected for TWs based on fast growth rate; rapid establishment, usually by clonal propagation; large biomass with a well-developed belowground system and good tolerance of TW conditions. While a wide variety of species possess these traits, in reality, macrophyte species selection for TWs mostly follows established practices and commonly considers only a limited number of species, and TWs are predominantly planted with a single species (Brisson and Chazarenc, 2009; Vymazal, 2011).

It has been hypothesized that combining different plant species in TWs can improve treatment efficiency by means of functional complementarity (Coleman et al., 2001; Fraser et al., 2004; Picard et al., 2005; Zhang et al., 2010; Zhu et al., 2010; Liang et al., 2011). Plant diversity in TWs may increase tolerance to changing conditions as well as stability in biogeochemical process (Eviner and Chapin, 2003). Furthermore, differences in seasonal plant activity, root affinity for microorganism colonization and ability to take up nutrients and organic compounds could result in temporal and spatial compensation, which might improve TW removal efficiency (Coleman et al., 2001; Allen et al., 2002; Zhang et al., 2010; Liang et al., 2011). However, only a few well-replicated experiments have measured the advantages of combining plant species, often with contradictory conclusions. For example, findings by Coleman et al. (2001), Fraser et al. (2004) and Picard et al. (2005) did not support the hypothesis that polycultures would be more efficient than monocultures for nutrient removal, while Zhu et al. (2010) and

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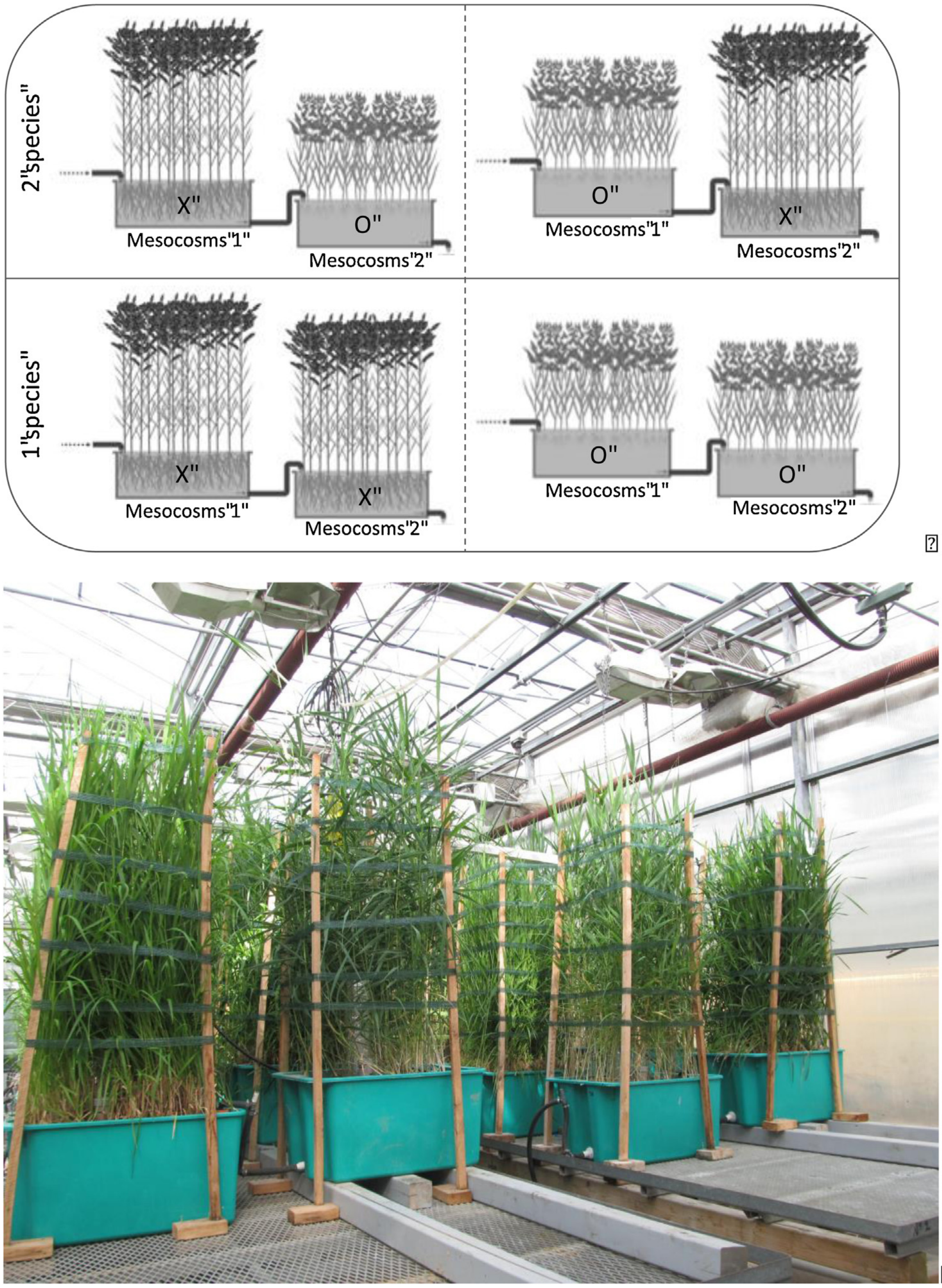


**Fig. 1.** Schematic representation of the different treatments and the experimental systems (Top). Photo of the experimental set-up. Greenhouse, Montreal Botanical Garden. May 2013 (Bottom).

Zhang et al. (2010) found a positive correlation between nitrogen removal and number of plant species in TWs.

We explored the effect of combining two plant species with complementary traits, planted sequentially, on the performance of TWs. Based on the assumption that greater morphological or temporal dissimilarities in plant species may have a better chance of producing complementary interactions, we selected *Phragmites australis* (common reed) and *Phalaris arundinacea* (reed canarygrass) for this mesocosm-scale TW. These two species are commonly used for wastewater treatment (Vymazal, 2011). Both species are from the Poaceae family, and form dense, nearly monospecific stands. Their ability to concentrate nitrogen, phosphorus and trace metal in tissues is also comparable (Vymazal et al., 2007; Vymazal and Kröpfelovaí, 2008). However, prior studies comparing them in TWs revealed differences in seasonality and growth development that suggest they may show some complementarity in functions. While *Phalaris*' growing season begins early in spring, *Phragmites* starts growing later but continues until autumn (Vymazal and Kröpfelovaí, 2005). *Phalaris*' root system is very dense but superficial, while *Phragmites*' root zone is less dense but grows deeper with longer rhizomes (Gagnon et al., 2007). *Phragmites* has more aerenchymae than *Phalaris* (Bernard, 1999), and up to three times the cross-sectional gas space in its rhizomes (Coops et al., 1996). The greater capacity for internal gas transport in *Phragmites* may explain its higher tolerance to deep flooding when compared to *Phalaris* (Waring and Maricle, 2012). $N_2$ and $N_2O$ gas emissions also differ greatly between the two species (Augustin et al., 2001; Maltais-Landry et al., 2007). Root distribution and gas exchange capacity may in turn affect bacterial activity. In one microcosm experiment,