Chemosphere 131 (2015) 192–200

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Plant uptake, translocation, and return of polycyclic aromatic hydrocarbons via fine root branch orders in a subtropical forest ecosystem

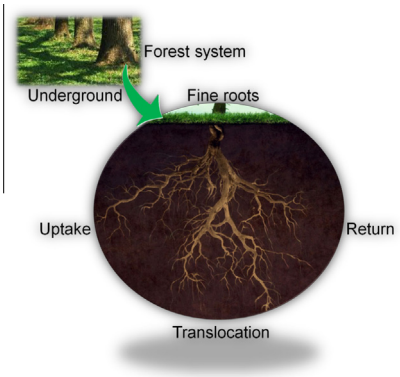
Zheng-Xia Chen [a,b], Hong-Gang Ni [a], Xin Jing [b], Wen-Jing Chang [a], Jian-Lin Sun [a,b,*], Hui Zeng [a,b,*]

[a] Shenzhen Key Laboratory of Circular Economy, Shenzhen Graduate School, Peking University, Shenzhen 518055, China
[b] Department of Ecology, College of Urban and Environmental Sciences, Peking University, Beijing 100871, China

HIGHLIGHTS

- Levels of PAHs with 2–3 rings in fine roots are higher than PAHs with 4–6 rings.
- There are obvious translocations of PAHs between adjacent fine root branch orders.
- The distal lower order roots contributed greatly to the total PAH return flux.
- Fine roots turnover is an effective pathway to remove toxicants absorbed into them.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 December 2014
Received in revised form 20 March 2015
Accepted 22 March 2015
Available online 7 April 2015

Handling Editor: Caroline Gaus

Keywords:
Plant uptake
Fine root
Polycyclic aromatic hydrocarbons
Root branch order
Belowground ecology

ABSTRACT

Fine roots of woody plants are a heterogeneous system differing markedly in structure and function. Nevertheless, knowledge about the plant uptake of organic pollutants via fine roots is scarce to date. In the present study, plant uptake, translocation, and return of polycyclic aromatic hydrocarbons (PAHs) via fine roots in a subtropical forest ecosystem were investigated. Levels of Σ_{15}PAHs in different fine root branch orders of *Michelia macclurei*, *Cryptocarya concinna*, *Cryptocarya chinensis*, and *Canthium dicoccums* varied from 5072 ± 1419 ng g^{-1} to 6080 ± 1656 ng g^{-1}, 4037 ± 410 ng g^{-1} to 6101 ± 972 ng g^{-1}, 3308 ± 1191 ng g^{-1} to 4283 ± 237 ng g^{-1}, and 3737 ± 800 ng g^{-1} to 4895 ± 1216 ng g^{-1}, respectively. Overall, concentrations of low-molecular-weight PAHs with 2–3 aromatic rings were higher than high-molecular-weight PAHs with 4–6 aromatic rings in all fine root branch orders. There were obvious translocations of PAHs between adjacent branch orders and a net accumulation of PAHs may occur in the fourth- and fifth-order roots. The storage of PAHs in the fine root system showed an obvious increasing trend along the branch orders ascending for all tree species. The return flux of PAHs via fine roots mortality showed an obvious decreasing trend with the branch orders ascending across the four tree species. Lower order roots contributed greatly to the total PAHs return flux. Our results indicated that fine roots turnover is an effective pathway for perennial tree species to remove environmental toxicants absorbed into them.

1. Introduction

Fine roots (<2 mm in diameter) in woody tree species have been proven to be not a homogenous unit, but a much more

* Corresponding authors at: Shenzhen Key Laboratory of Circular Economy, Shenzhen Graduate School, Peking University, Shenzhen 518055, China. Tel.: +86 755 26033019 (J.-L. Sun), +86 755 26035585 (H. Zeng).
E-mail addresses: sunjl@pkusz.edu.cn (J.-L. Sun), zenghui@pkusz.edu.cn (H. Zeng).

http://dx.doi.org/10.1016/j.chemosphere.2015.03.045
0045-6535/

heterogeneous system differing markedly in structure and function (Guo et al., 2004, 2008a; Hendricks et al., 2006; Wang et al., 2006). The first five branch orders within the fine root system (Fig. 1) were identified to investigate their distinct structure and functional roles (Pregitzer, 2002a,b; Guo et al., 2008a,b). The first- and second order roots, undergoing only primary development with an intact cortex and a higher mycorrhizal colonization rate, are generally considered to serve as absorptive functions (Guo et al., 2008b; Li et al., 2010; Xia et al., 2010; Kong et al., 2014). The fourth- and fifth-order roots that undergo secondary development with no cortex or mycorrhizal colonization, showing limited capacity for resource uptake, mainly serve as transport functions. The third-order roots undergoing both primary and secondary development indicate a shift of their function from absorption to transport. Overall, lower order roots (first- and second-order roots) mainly serve as absorptive functions while higher order roots (fourth- and fifth-order roots) mainly serve as transport functions (Pregitzer, 2002a,b; Guo et al., 2008b). Nevertheless, existing knowledge about how these different branch orders within the fine root architecture respond to environmental stresses is limited to date (Ma et al., 2013).

Plants have been considered to play an important role in the biogeochemical cycle of environmental pollutants (Burken and Schnoor, 1998; Sorek et al., 2008; Carter et al., 2014; Houben et al., 2014; Li and Chen, 2014). There is increasing evidence showing that root uptake and accumulation of environmental pollutants can readily occur in the soil–plant system (Moeckel et al., 2007; Dettenmaier et al., 2009; Luo et al., 2010; Wu et al., 2013; Zhao et al., 2013). However, most of these studies focus on the root of vegetables and other herbaceous plants (Tao et al., 2004; Gao and Collins, 2009; Desalme et al., 2013; Wu et al., 2013; Zhao et al., 2013). Knowledge about the root uptake of environmental pollutants by woody plants is comparatively limited, except for poplar trees (Burken and Schnoor, 1997, 1998; Newman et al., 1997; Thompson et al., 1998; Yoon et al., 2002; Wang et al., 2004; Widdowson et al., 2005; Zhai et al., 2014). Recently, plant uptake of heavy metals via fine roots of woody trees in a subtropical forest ecosystem was investigated (Wang et al., 2012; Guo et al., 2013). The authors showed that different fine root branch orders contribute differentially to the uptake, allocation, and return of heavy metals. Nevertheless, knowledge about the uptake, translocation, and return of organic pollutants via fine roots of woody plants was scarce to date.

Understanding the processes of plant uptake of polycyclic aromatic hydrocarbons (PAHs) from soils via roots is of great importance (Limmer and Burken, 2014). That is because plants are the beginning of food chains in an ecosystem, providing an initial source of energy for all life. Existing knowledge about the root uptake of PAHs focus on vegetables, such as cabbage, spinach, celery, soybean, and carrot (Gao and Zhu, 2004; Tao et al., 2004; Collins et al., 2006; Dettenmaier et al., 2009). In addition, the root uptake of PAHs in white clover and tea plants had been investigated (Lin et al., 2006; Gao and Collins, 2009). Nevertheless, very little information about the plant uptake of PAHs through the branching fine roots of woody plants is available to date. In the present study, we investigated the plant uptake, translocation, and return of PAHs via fine roots of four perennial tree species in a subtropical forest ecosystem. The main objectives were to (1) determine concentrations of PAHs along different fine root branch orders; (2) explore the translocation and storage patterns of PAHs within the fine roots; (3) estimate the return flux of PAHs via fine roots mortality. Our results may shed some new lights into the biogeochemical cycle of PAHs belowground.

2. Materials and methods

2.1. Sampling

Samples were collected from Dinghu Mountain National Nature Reserve (the first nature reserve in China), which was established in 1956 near Zhaoqing city in Guangdong province

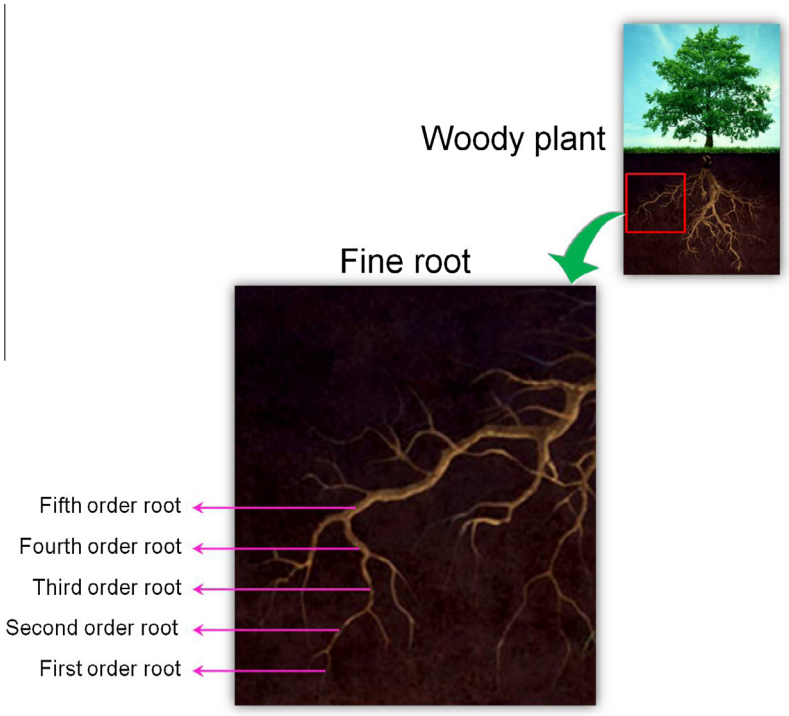


Fig. 1. The first five branch orders within the fine root system of woody plants. The ordering rules are: (1) the distal roots with no branches were defined as the first order; (2) the root from which two first order roots branched was classified as second order; (3) the rest of the branch root orders were determined in the same manner.