The Influence of Root Exudates on the Uptake of PCDD/PCDF by Plants

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Introduction

As extremely hydrophobic substances with a high affinity to soil organic matter, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF) are very immobile in soils and, thus, scarcely available for uptake by plants[1]. Taking into account their high octanol/water-partition coefficients (log K_{ow}>6), a translocation within plants was believed to be unlikely, even over long time periods[2-4].
These assumptions based on the physico-chemical properties of PCDD/PCDF are in agreement with results in the recent literature which consistently show that the main entry pathway of PCDD/PCDF into plant shoots is atmospheric deposition[5-8].
However, for zucchini and pumpkin, both belonging to the genus *Cucurbita*, we were able to demonstrate an uptake of PCDD/PCDF *via* the roots and subsequent translocation to the shoots[9]. The release of root exudates with PCDD/PCDF "mobilizing" properties was discussed as a possible explanation. Certain compounds in these exudates may desorb PCDD/PCDF from soil particles in the rhizosphere of *Cucurbita* and thus possibly enhance their availability for root uptake.

In order to verify the hypothesis that zucchini roots release PCDD/PCDF "mobilizing" substances to the rhizosphere, we used root exudates of zucchini, and for comparative purposes of tomato (a plant species with proven minimal soil-plant transfer of PCDD/PCDF) as extraction agents for a highly PCDD/PCDF contaminated soil.

Experimental

Collection of root exudates. Zucchini and tomato plants were cultivated in plastic tubes (2.5 l) with quartz sand (particle size 2.5-3.0 mm) and a constant supply of nutrient solution. Root exudates were collected six and eight weeks after sowing, for zucchini and tomato respectively. The tubes were water logged with 1l of doubly destilled water for 10 min. and subsequently percolated. The percolate was filtered (Whatman GF/D) and concentrated by a rotavapor (6 l → 100 ml). The same procedure was performed with tubes containing sand only, but no plants (= "blank").
Soil extraction. 100 ml of the concentrated root exudates and of the "blanks" were each seperately mixed with 40 g of a highly contaminated soil (PCDD/PCDF concentration 14530 ng I-TEq/kg dry matter). The soil was air-dried and sieved to 2 mm. Each extraction was done with three replicates. After two hours of agitating the soil suspensions were centrifugated and filtered (Whatman GF/D). Finally, PCDD/PCDF concentrations of the solutions were determined.

PCDD/PCDF concentrations in the various samples were determined by ERGO-Forschungsgesellschaft mbH, Hamburg.

Results

PCDD/PCDF concentrations in the various "extraction agents" are summarized in Figure 1. Extraction of the soil with tomato root exudates does not result in elevated PCDD/PCDF concentrations compared to the extraction with water ("blank"), whereas the use of zucchini root exudates as extraction agent leads to a fourfold increase of the amount of PCDD/PCDF in the solution.

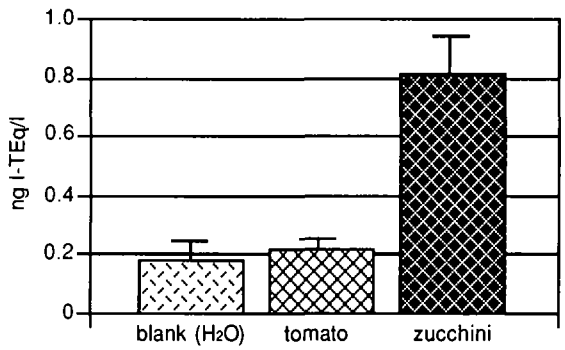

Figure 1: PCDD/PCDF concentrations in the various extraction agents (zucchini root exudates, tomato root exudates and H_2O)

Figure 2 clearly demonstrates that the application of tomato root exudates or water as the extraction agent not only results in similar PCDD/PCDF concentrations in the solutions but also in almost identical homologue profiles. Soil extraction with zucchini root exudates, however, leads to distinctly different profiles which show a close correspondence with the homologue profile of the extracted soil.

PCDD/PCDF extraction from the aqueous solutions was performed with dichloromethane. Based on their high octanol/water-partition coefficients the PCDD/PCDF should partition mainly into the dichloromethane phase. This was well observed for the solutions extracted with tomato root exudates and water, but when using the zucchini exudate extracted soil solution, a large decrease in the recovery of the internal PCDD/PCDF standards was observed. Additional analyses showed that this finding could be attributed to a lack of partitioning of the PCDD/PCDF (internal standards and native compounds) into the dichloromethane phase.

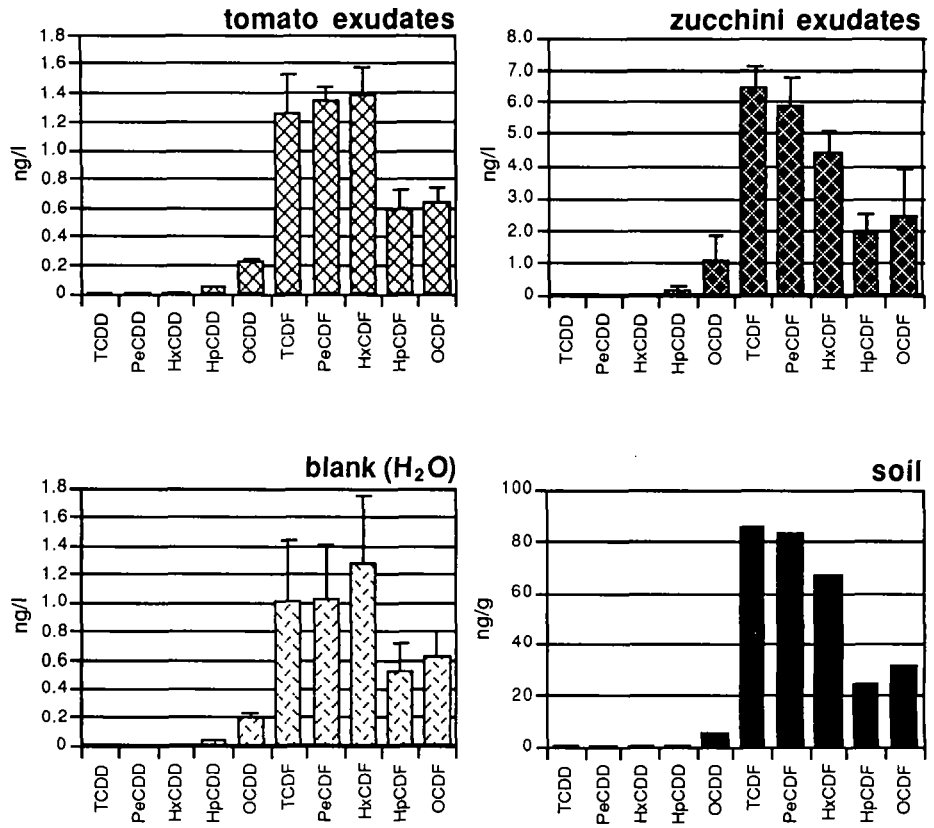

Figure 2: Homologue profiles of the soil extracts in dependence of the extraction agent (root exudates of zucchini and tomato, H_2O) compared to the soil profile

Conclusions

- In contrast to root exudates of tomatoes (a plant species with proven minimal soil-plant transfer of PCDD/PCDF), exudates released by zucchini roots are capable of extracting PCDD/PCDF from a contaminated soil (Figure 1); this capacity seems to be unselective for all congeners occurring in the soil (Figure 2).
- The lack of partitioning of the PCDD/PCDF into the dichloromethane phase during the extraction of the solutions suggests that certain compounds in zucchini root exudates probably attach to PCDD/PCDF molecules forming hydrophilic complexes, thus facilitating root uptake as well as transport within the plant of the *per se* extremely hydrophobic PCDD/PCDF.

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