Arsenic uptake and translocation via xylem sap – the cucumber model

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Understanding the processes involved in the arsenic uptake by plants from contaminated soils to the roots and the subsequent arsenic translocation from roots to fruits are of fundamental importance either for food safety aspects or phytoremediation purposes.

In this work, cucumbers were chosen because not only they are easily and rapidly grown but they also produce high amount of xylem sap. The xylem is a tissue network that transports water from the roots up to the leaves and is thus an important pathway for metal transport. Cucumbers were grown hydroponically in a nutrient Hoagland solution for three weeks before being subjected to different concentrations (100, 500 and 1,000 µg/kg) of inorganic (As(III) and As(V)) and organic (MMA and DMA) arsenic for 24h. After decapitating the cucumbers, the excreted xylem sap was collected for 1 hour. Roots, shoots and leaves were separated and digested. Electrochemistry was used to monitor the concentration of As(III) and total inorganic arsenic in the Hoagland solution during the contamination period. The total As concentration in the Hoagland, roots, stems and leaves were measured by ICP-MS. The arsenic speciation in sap and nutrient solution was determined by anion HPLC-ICP-MS while complexes from the root extracts were analyzed by RP-HPLC-ICP-MS/ESI-MS.

When subjected to As(V), As(III) was detected in the nutrient solution after c.a. 30 minutes suggesting a reducing mechanism either within the plants by arsenate reductase and subsequent excretion or within the rhizosphere. The total arsenic concentration in the different parts of the cucumber was dependent on the arsenic species in the Hoagland solution. Inorganic arsenic was found at higher levels in the roots but less in the shoots and leaves compared to plants subjected to organic arsenic. High levels of arsenic were always found in the roots as phytochelatins PC_3 and PC_4 complexes when subjected to inorganic arsenic. While less organic arsenic is taken up by the roots, it is transported more into shoots and leaves than inorganic arsenic which remains immobilized as PC complexes in the roots. Interestingly, the amount of collected sap was found to decrease significantly in presence of increasing levels of inorganic arsenic in the Hoagland solution. In the sap, it was found that plants subjected to organic arsenic transport unchanged species in the sap whereas plants subjected to either As(V) or As(III) transport arsenic as As(III). In that case, no complexes but only the free As(III) were detected by HPLC-ICP-MS/ESI-MS, as observed in previous studies (1).
Is As(III) really free or is it present as weak complexes which are unstable in the chromatographic column ? It is hoped that electrochemistry will shed some light on this fundamental question.

Reference:

(1) Raab, A.; Schat, H.; Meharg, A. A.; Feldmann, J., Uptake, translocation and transformation of arsenate and arsenite in sunflower (Helianthus annuus): formation of arsenic-phytochelatin complexes during exposure to high arsenic concentrations. *New Phytologist* **2005,** *168*, (3), 551-558