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The interaction of phytosiderophores with soil as a function of time

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Graminaceous plant species (grasses) exude natural chelating agents, called phytosiderophores (PS) for the purpose of iron acquisition, in particular under conditions of iron deficiency stress. The biogeochemistry of phytosiderophores in the rhizosphere is still poorly understood. Processes like mobilization of iron or other metals by PS, and the degradation of the chelating agent were previously studied under conditions quite remote from those observed in the rhizosphere, e.g. in hydroponics systems or in soil suspensions with low soils to solution ratios. Such experimental conditions may lead to artifacts like for instance the depletion of available metal fractions. The aim of the present study is to contribute to a more accurate quantification of the source and sink terms determining PS concentrations in the rhizosphere.

The mobilization of iron and other metals from two clay soils and two sandy soils by the PS deoxymugineic acid (DMA) was studied as a function of time in a batch experiment with a soil-solution ratio of 1. Both soils causing iron deficiency stress in plants and a reference soil not doing so were included. To examine the effect of ligand biodegradation on metal mobilization, treatments with and without sterilant (azide) were included.

The fraction of added DMA mobilizing Fe ranged from 10 to 60% and correlates positively with Fe availability (DTPA-extractable Fe) and negatively with the clay content of the soils. In particular in soils of low Fe availability, Fe mobilization by DMA was severely compromised by mobilization of other metals including Cu, Zn, Ni and Co. The relative importance of Zn as competing cation decreases over time, while the importance of Cu increases. In the treatment without sterilant addition, metal-DMA complexes were removed from solution after 4 days in all soils; in the clay soils, Fe-DMA complexes were already removed before. The highest concentration of mobilized Fe did not depend on whether sterilant was added or not, except in one soil; this concentration was reached after 0.25 up to 8 hours. Also in treatments with sterilant addition, the FeDMA concentration eventually declined, but removal from solution was not complete when the experiment ended after one week. This indicates that besides biodegradation there are other processes significantly compromising the FeDMA concentration in the soil. In summary, these results emphasize the importance of the kinetics and thermodynamics of coupled rhizosphere processes for plant iron acquisition.