Zinc in the Soil-Plant Continuum

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INTRODUCTION

Most soils contain sufficient amounts of zinc (Zn) to support growth of many crops. Still, Zn deficiency is a constraint to crop production on one third of the world's agricultural soil. This means that understanding soil Zn bioavailability and mobilization of Zn by plant roots are relevant issues. We aim to understand biogeochemical interactions in the soil-plant continuum that are relevant to Zn mobilization by plants.

METHODS

Field experiments were done on low Zn soils with rice (*Oryza sativa* L.) in China and on Vertisols with teff (*Eragrostis tef* Zucc.) in Ethiopia. Batch and root box experiments allowing for rhizosphere sampling with rape seed, rice and wheat with a calcareous soil from Turkey were done to understand the effect of root exudates on Zn bioavailability in the rhizosphere. Chemical speciation modeling and analyses were combined with rhizosphere sampling.

RESULTS AND DISCUSSION

Our work on Vertisols showed that even on soils without any history in N and P fertilization, Zn can be a yield-limiting factor (Haileselassie et al. 2011). This implies that Vertisols are probably inherently low in Zn. In order to predict a yield response to Zn fertilization, we evaluated soil DTPA-Zn as an indicator for Zn bioavailability. There was a poor relationship between DTPA-Zn and Zn uptake, even at soils where DTPA-Zn was < 1 mg kg^{-1}. Further research on a soil indicator for Zn bioavailability of Vertisols is needed. Vertisols comprise 2.5 % of the world's total land area, with major areas in India, Africa and Australia. Latest results on Zn extracted in 0.01 M $CaCl_2$ as an alternative proxy will be presented.

Rice genotypes varied considerably in their capacity to mobilize Zn from low Zn soils. Zinc uptake from these soils could vary by a factor of 7 amoung 15 genotypes tested (Gao et al. 2005). This variation was found to be related to a variation in root malate exudation as a response to low Zn supply. On average, malate exudation increased by 64 % as a response to Zn deficiency (Gao et al. 2009). The increase in rhizosphere malate concentration, however, was too small to explain the increased Zn uptake, showing our lack of understanding rhizosphere processes involved in Zn mobilization.

Biogeochemical modelling showed that dissolved organic anions, pH and redox conditions were important determinants of Zn bioavailability and uptake. Modelling the effect of bulk soil conditions on Zn uptake, however, failed to predict the effect of management changes on Zn mobilization (Gao et al. 2009). We speculated that this discrepancy could be associated with the chemical conditions in the rhizosphere, where the local acidity, dissolved organic C, and redox conditions may deviate significantly from the bulk soil on which the geochemical analysis was based.

We are now working on an integrated experimental and modeling approach to identify processes controlling Zn bioavailability in the rhizosphere. A combination of a modelling framework

(ORCHESTRA), unbiased rhizosphere sampling, the Donnan Membrane Technique in combination with high resolution analyses of metals should elucidate the governing processes in the rhizosphere complex and lead to an integrative understanding of the concept of Zn bioavailability. Recent results will be presented.

CONCLUSIONS

Zinc deficiency is wide-spread, including regions without any fertization tradition. A good indicator is needed as a tool to predict the response to Zn fertilization.

Rhizosphere conditions are relevant to understand mobilization of Zn from low Zn soils. A new approach, combining chemistry, physics and biology of the rhizosphere, using experiments and models, should further increase our understanding of Zn bioavailability.

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