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The effect of the application of cell cultures and supernatants of PGPR (Arthrobacter oxydans) as soil additives on the phytoextraction of germanium and rare earth elements

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Phytomining is a promising method for the exploitation of sources with sub-economical mineralization. Germanium (Ge) and rare earth elements (REEs) occur widespread in soils and are therefore of particular interest in phytomining research. Besides total concentrations in soils, availability of elements in plants requires the elements to be mobile in the rhizosphere in a chemical form that can move towards the plant root and can be taken up by roots. In general, availability in the rhizosphere is affected by direct interactions between root-exudates and soil particles as well as indirectly by plant-microbe-soil-interactions that strongly influence physico-chemical properties of the rhizosphere. Bacterial siderophores are low molecular organic ligands which form stable complexes with some micronutrients such as Fe(III) as well as with REEs and Ge. Therefore bacterial siderophores may play an important role in the rhizosphere of plants controlling the availability of target elements in phytomining research. The aim of the present study was to evaluate the effect of cell cultures and siderophore containing supernatants of Arthrobacter oxydans and Kocuria rosea on the mobility and accumulation of REEs and Ge in Avena sativa, Brassica napus und different genotypes of Phalaris arundinacea. In this experiment all plants were cultivated for eight weeks on soils and sand. On soil, all plants were treated weekly with cells and supernatants of the abovementioned bacteria in order to investigate the effect of the plant growth promoting rhizobacteria (PGPR) on the accumulation of REEs and Ge. On sand, all plant received supernatants of the bacteria together with Ge- and REE-containing watering solutions 24 h before harvest. As a reference, sand-cultured plants also received the elements without supernatants in order to evaluate the effect of the chemical binding form on the uptake of the target elements in plants. In summary, this experimental design makes it possible to distinguish between effects of mobilization in the rhizosphere and changes in uptake through changes in the chemical forms. Additionally, the commercial siderophore DFOB (desferrioxamin-B) was used as a control treatment. After harvest the biomass of shoots and roots was measured and trace element concentrations were measured by means of ICP-MS. As a result we could show that the culture supernatants of Arthrobacter oxydans significantly improved the growth of Brassica napus ($p < 0{,}001$) and Phalaris arundinacea ($p < 0{,}01$). Addition of DFOB as well as well as of the culture supernatant of Kocuria rosea significant increased the Ge concentrations in the shoot of Avena sativa and the concentrations of REEs in Phalaris arundinacea ($p < 0{,}05$). Our results suggest a high potential of PGPR in phytomining and phytoremediation research; however, the investigation of processes involved, the evaluation of the best forms of application as well as the evaluation of the phytoextraction-efficiency under field conditions remain a field of our ongoing research.