Constraints to synergistic effects between ligands and reductants in plant iron acquisition from soil

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Iron (Fe) is an essential micronutrient to plants. For acquiring Fe from the soil, plants employ Fe acquisition strategies that are based on the exudation of ligands and reductants to enhance Fe dissolution. Co-exudation of ligands and reductants can lead to synergistic Fe mobilization (i.e. the mobilized Fe concentration by a ligand and a reductant combined is larger than the sum of Fe concentrations they mobilize separately). This synergistic effect may be vital to plants for coping with conditions of low Fe availability (e.g. on soils with a circum-neutral pH). However, also the mobilization of other metals, such as nickel and cobalt, that compete with Fe for complexation by ligands can be synergistically enhanced. This enhanced competition can reduce the timespan that Fe remains mobilized. Because of this adverse competition effect and the short residence time of Fe(II) under oxic soil conditions at circumneutral pH, we hypothesized that matching the exudation of ligands and reductants in time and concentration is prerequisite for plants to optimally benefit from synergistic Fe mobilization.

To test this hypothesis a series of kinetic batch experiments were done with a calcareous clay soil to which a plant ligand (the phytosiderophore 2'-deoxymugineic acid (DMA)) and a reductant (ascorbate) were added, either separately or combined, simultaneously or with a lag time, and under oxic or anoxic conditions. It will be shown and discussed that, with increasing ascorbate concentration, the free DMA ligand became depleted faster and the decline in Fe solution concentation as a result of competition started earlier. An increase in DMA concentration had the opposite effect. DMA and ascorbate did not need to be applied simultaneously to induce synergistic Fe mobilization, despite the high reactivity and short life-time of ascorbate in the soil. The synergistic effect on Fe mobilization did become smaller with increasing lag time between ascorbate and DMA application. Synergistic Fe mobilization was comparable under oxic and anoxic conditions, demonstrating that fast Fe(II) reoxidation by oxygen from the atmosphere did not compromise the size of the synergistic effect. Our results suggest that matching ligand and reductant exudation may be essential for optimizing Fe acquisition by plants.

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