Synergisms between Fe acquisition strategies

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Plants, bacteria and fungi have developed strategies to acquire Fe from their external environment. These strategies include exudation of reductants to facilitate reductive Fe dissolution and exudation of complexing agents (e.g. siderophores) to solubilize soil-Fe through ligand-promoted dissolution. In environments with a circum-neutral pH (7-8.5; e.g. calcareous soils), these Fe acquisition strategies can fail as a result of a low Fe activity in solution, slow dissolution kinetics and rapid re-oxidation of Fe(II).

We hypothesized that Fe acquisition strategies based on a combination of reductive and ligand-promoted dissolution may be more effective as a result of a synergistic effect. This synergistic effect implies that Fe mobilization by a reductant and a ligand combined is larger than the sum of Fe mobilization for the ligand and the reductant separately.

In the present study we explored this potential synergistic effect on Fe mobilization from goethite and from a calcareous clay soil from Santomera (Spain) for the biogenic reductant ascorbate and three biogenic chelating agents: desferrioxamine B (bacterial), esculetin (plant, strategy I Fe acquisition) and deoxymugineic acid (plant, strategy II Fe acquisition).

Synergistic effects on mobilization were observed for Fe and also for other metals; the nature of the synergistic effect in terms of duration and concentration increase strongly varied per ligand. For deoxymugineic acid, addition of a reductant could both have a synergistic and an adverse effect. The magnitude of the synergistic effect depended on the concentration of both the reductant and the chelating ligand. The effect of ascorbate addition on metal mobilization by ligands persisted after the ascorbate had reacted away, as was demonstrated by introducing a lag time between addition of the reductant and the ligand.

Our results contribute to a better understanding of chemical synergisms in nutrient acquisition, with possible implications for beneficial effects from intercropping and plant microbe interactions in agriculture.