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Evidence for the mechanisms of zinc acquisition by plants using isotope discrimination

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To investigate the mechanisms of Zn acquisition by grasses in general and rice in particular, and of differences between rice genotype in tolerance to Zn deficiency, we grew tolerant and intolerant genotypes in a highly Zn-deficient submerged soil, and measured growth, Zn uptake and fractionation of Zn isotopes at natural abundances. We found no isotope fractionation in either genotype under Zn sufficiency. But under Zn deficiency, the Zn-efficient genotype was enriched in heavy 66Zn relative to plant-available Zn in the soil. This was in contrast to our previous studies in solution culture in which we found light isotope enrichment in the plants. Heavy isotope enrichment is only explicable by chelation of Zn by a phytosiderophore released from roots and uptake of the Zn-phytosiderophore complex by a specific root transporter. The light isotope enrichment in solution culture is consistent with uptake of free Zn2+. Enhanced uptake of Fe(III) through excretion of phytosiderophores is well established for Fe acquisition by grasses, but hitherto this has not been conclusively demonstrated for Zn acquisition. In experiments in solution cultures we found greater excretion of the phytosiderophore deoxymugineic acid (DMA) by the efficient genotype and enhanced excretion of DMA under Zn deficiency. We show with a mathematical model that the rate of excretion of DMA and its Zn-solubilising effect in the soil are sufficient to account for the differences in Zn uptake by the field-grown genotypes, including an interaction with planting density.