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Silicon-mediated enhancement of cucumber phytoremediation potential for manganese

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Manganese (Mn) is a naturally occurring element which is ubiquitous in the environment comprising 0.1% of the Earth's crust. Mn is an essential micronutrient for plant growth with a wide range of important physiological functions. Its availability in soil is directly proportional to pH and redox potential, so the reducing conditions (poorly drained and acidic soils) increase Mn bioavailability, uptake and tissue accumulation leading to toxicity symptoms such as chlorosis and brown spots, initially visible on older leaves. Although it is well established that silicon (Si) greatly improves Mn tolerance of many plant species, the physiological and molecular mechanism of this effect is poorly understood. In this regard, the effect of Si, when supplied as 1.5 mM silicic acid, on the plant growth and the appearance of Mn-toxicity symptoms in the leaves of cucumber plants (*Cucumis sativus* L. cv. Chinese long) grown at Mn excess (100 μM) was studied. In Mn treated plants, Si improved biomass production and alleviated symptoms of Mn toxicity compared with non-Si treated plants. Although bulk tissue Mn concentrations were similar in Si treated and non-treated plants, the apoplastic concentration of free Mn^{2+} and H_2O_2 of Mn-treated plants was signi?cantly decreased by Si treatment. These results suggest that Si nutrition does affect neither the metal uptake nor its translocation from root to shoot. Inert depositions of Si in the leaf cell walls of cucumber (known as Si-accumulating species), that enhanced cell wall stability, simultaneously are Mn^{2+}-binding sites which contribute to decrease of harmful free Mn activity within the plant tissue. The effect of Si nutrition on the compartmentation of leaf Mn was also veri?ed by the less destructive electron paramagnetic resonance (EPR) spectroscopy. Application of Si slightly decreased an EPR signal of free Mn^{2+} from the apoplastic ?uid and bulk tissue of plants subjected to high Mn concentrations. Hydroxyl radicals (OH) were recorded by EPR spin-trapping method using a reagent DEPMPO, where intensity of the EPR signals of DEPMPO/OH adducts of Si treated plants was lower regardless of the Mn supply. Additionally, Si supply led to a rapid suppression of guaiacol-POD activity under excess Mn in the leaf apoplastic ?uid which was visually confirmed by isoelectric focusing. Taking into account this Mn-Si interaction, phytoextraction process on sites contaminated with Mn could be significantly improved by Si application. Unfortunately, most metal hyperaccumulator plants are characterized with slow growth rate and low biomass. Addition of Si could elevate their biomass production combined with metal-toxicity protection without affecting metal uptake and the long-distance root to shoot translocation, so the excess Mn from the soil could be easily removed by harvesting shoot biomass.