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Iron uptake from manufactured nanomaterials: obscured mechanism, controversial effect

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Transition metals in nanomaterials such as iron, manganese or zinc are essential microelements for plants. When these metals are present in suboptimal concentration for the plants, deficiency syndromes develop that causes reduced crop production or poor fruit quality. Low mineral content of plant products has a major role in human malnutrition. Most stable Fe-chelates for the correction of Fe deficiency are not biodegradable and expensive so applying manufactured nanomaterials may serve as a cheap and eco-friendly alternative. Newly designed, transition metal containing nanomaterials stabilized in colloid suspension have been characterised and then applied in hydroponic cultures to cucumber model plants in a wide range of concentration. The uptake and distribution of the elements from the nanomaterials and their utilization were investigated by microXRF mapping, ICP-MS, enzyme activity tests, gene expression measurements and the changes in some basic physiological parameters were followed. Nanoferrihydrite and nano-Mn-Zn-ferrite colloid suspensions with 3-8 nm particle size applied in 0.01-0.02 mM concentration and at slightly acidic pH proved to be a good source of Fe, Mn and Zn in various experimental conditions. Mn-Zn-ferrite has also been tested at pH 7.5 and Fe deficient cucumber plants showed a significant recovery after 3 days of application in terms of chlorophyll concentration and photosynthetic efficiency but not at pH 8.5. Mn and Zn deficient plants also showed recovery upon addition of the ferrite. Ferric chelate reductase assays showed that it is not the normal reduction-based uptake pathway that plays a role in the iron utilization of these nanoparticles. Analysis of root ferric chelate reductase expression pointed out a quick utilisation of Fe content of the nanoferrihydrite particles. Elevated concentrations of the nanoferrite at the millimolar range as compared to equal concentrations of micronutrient salts proved to be significantly less toxic. However, another nanomaterial, an insoluble nano FeCo powder applied to the nutrient solution of cucumber in high concentration causes severe chlorosis due to cobalt toxicity, pointing on that the composition of the nanoparticles is highly important for their bioactivity.

Keywords: nanomaterial, ferrite, ferrihydrite, fertilizer, ferric chelate reductase, toxicity

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