Effects of Zinc toxicity in sugar beet (*Beta vulgaris* L.) plants grown in hydroponics

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- *Antecedents and objectives*: Zinc is essential for cell physiological processes, has no redox activities but plays structural and/or catalytic roles in many processes, and it is the only metal present in all enzyme classes. However, at high concentrations Zn could be toxic. In most cases, an excess of Zn generates reactive oxygen species and/or displaces other metals from active sites in proteins. Zinc toxicity also induces chlorosis in young leaves, and this has been suggested to result from a Zn-induced Fe or Mg deficiency, based on the fact that the three metals have similar ion *radii*.
  The aim of the present study was to investigate the effects of high concentrations of Zn in the nutrient solution to establish a basis for studies of the mechanisms of heavy metal transport in this model plant species.
- *Materials and methods*: The effects of high Zn have been investigated in sugar beet (*Beta vulgaris* L. cv Orbis) plants grown in a controlled environment in hydroponics, with a. containing half-strength Hoagland nutrient solution with 45 µM Fe(III)-EDTA and higher concentrations of Zn sulphate (50, 100 and 300 µM). Different parameters were analyzed: growth, mineral nutrients, photosynthetic pigments, gas exchange and chlorophyll fluorescence.
- *Results*: High concentrations of $ZnSO_4$ in nutrient solutions decreased root and shoot fresh and dry mass, and increased root/shoot ratios. Plants grown with excess Zn had leaf edges rolled inwards and the root system appeared damaged and brownish, with short lateral roots. High Zn decreased N, Mg, K and Mn concentrations in all plant parts, whereas P and Ca concentrations increased only in shoots. Leaves of plants treated with 50 and 100 µM Zn developed some symptoms of Fe deficiency, including decreases in Fe, chlorophyll and carotenoid concentrations, increases in carotenoid/chlorophyll and chlorophyll a/chlorophyll b ratios and de-epoxidation of violaxanthin cycle pigments. Plants grown with 300 µM Zn showed decreased PSII efficiency and further growth decreases but did not show leaf Fe deficiency symptoms. Leaf Zn concentrations of plants grown with excess Zn were high but fairly constant (230-260 µg g-1 dry weight), whereas the total Zn uptake per plant decreased markedly at high Zn supplies.
- *Conclusions*: In general, excess Zn reduced plant growth, and leaves showed chlorosis symptoms and signs of damage. Photosynthetic rates, photosynthetic pigments and chlorophyll fluorescence were markedly different depending on the Zn concentration in the nutrient solution.
  Zinc homeostasis is tightly controlled in sugar beet, since when Zn concentration in the nutrient solution increased Zn shoot concentrations only increased marginally, and its allocation to the shoot was little changed. Therefore sugar beet can be used as good model plant to study Zn homeostasis in plants.