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Phytotoxicity of carbon nanotubes in soybean is associated with disturbances of zinc homeostasis

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The effect of short-term seed treatments with multi-walled carbon nanotubes (CNTs, 0 – 500 $\mu\text{g seed}^{-1}$ during 36 h) on germination and seedling development of soybean was studied. CNTs decreased speed of the water uptake by soybean seeds and therefore reduced imbibition damages, which finally improved germination rate. However, at 8 days after sowing and even after 23 days of growth on a calcareous soil, plants developed from seeds treated with CNTs, showed stunted growth and poor fine root development associated with zinc (Zn) deficiency. The growth of affected plants was recovered by foliar applications of 0.5 mM ZnSO_4 or by cultivation in nutrient solution. Since Zn is an important co-factor for antioxidant enzymes, stunted plant growth in response to Zn limitation has been related to excessive oxidative degradation of auxin as growth hormone. We hypothesize that CNT seed treatments may affect re-mobilisation of Zn seed reserves, leading to the development of Zn-deficient seedlings with stunted root growth and lacking the ability to acquire sparingly soluble Zn forms in soils but with restoration of normal growth by external application of soluble Zn.

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