Fate and Effects of Uncoated ZnO Nanoparticles on Nine Crops Exposed in Two Agricultural Soils, a Calcareous Soil and an Acidic Soil

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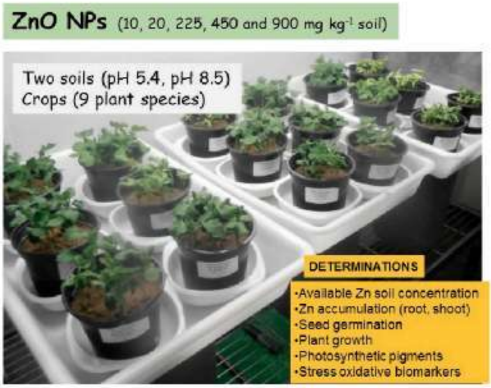

The nanotechnology has a wide range of applications including those that deliberately release nanoparticles (NPs) into the environment.
The use of nanoformulations containing agro-chemicals to soils provides an efficient way to apply pesticides and fertilizers in a controlled mode. The zinc oxide nanoparticles (ZnO NPs) are of particular interest due to their increasing incorporation into agricultural products [1].
Soil components and soil properties affect largely NPs behavior in the soil. Soil pH and organic matter mainly govern Zn chemical speciation, sorption/desorption process and its dis-tribution in the soil [2] and hence, its availability to plants. The increased amount of Zn in the plant tissue displays not only visible toxic impacts but also biochemical ones as the generation of reactive oxygen species (ROS) or enzymatic alterations [3].
This work collects the results of a pot trial conducted to evaluate seed germination, growth and biochemical parameters affectation in nine crops growing in two agricultural soils containing ZnO NPs at soil concentrations of 10, 20, 225, 450 and 900 mg Zn kg^{-1} (dry weight) (compared to controls non-Zn-treated soils). In addition, the behavior of Zn in these soils was studied by the determination of its potential availability, and by the Zn uptake in roots and later translocation of Zn to the aerial parts of the plants.
Two soils with different physicochemical features were used, a calcareous (pH 8.5) and an acidic soil (pH 5.4). The studied plants were wheat, maize, radish, bean, lettuce, tomato, pea, cucumber and beet. Seeds of the mentioned plants were sown and grown for 45 days under controlled conditions, 16 h light and 20±2 °C. Three replicates of control and treatments were used. After harvest, total and available concentration of Zn ([Zn]) in the soils were analyzed and correlated with [Zn] in plants (both roots and shoots).
As expected, the available [Zn] in the calcareous soil was very low (< 2 mg kg^{-1}) and phytotoxic effects were limited to a slight decrease of biomass of wheat, cucumber and beet at the highest Zn treatment and, an increase of biomass of maize and radish. As a whole, no pattern was found for biomarkers, only ascorbate peroxidase (APX) and catalase (CAT) seemed to decrease in most plant species and [Zn]. By contrast, in the acidic soil, the available [Zn] increased with total [Zn], reaching 35% of initial total Zn at the 450 and 900 mg Zn kg^{-1} soil treatments. The germination of seeds of bean, tomato, lettuce and beet was reduced and the growth of most of the crops was seriously affected except for maize and pea. The calculated EC_{50} (growth) values in acidic soil were in a range of 110-520 mg Zn kg^{-1}. The biomarkers as malondialdehyde (MDA) or protein contents increased only in maize. In pea, chlorophyll, MDA and CAT decreased and ROS and APX increased.
The toxic effects on germination and growth correlated better with total [Zn] than with the available [Zn] in both soils. [Zn] in aerial parts of plants showed good correlation with [Zn] in soil (total and bioavailable).
BCFs of most plants grown in the calcareous soil varied in the range 0.5-2 for both shoots and roots. However, under acidic conditions, BCF were in the range 2-6 also for both shoots and roots. Differences in BCF were more due to plant species than to the tested parts of the plants.

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References

[1] M. Rizwan et al., *Journal of Hazardous Material*, 322 (2016) 2.
[2] Monreal et al, in *The Application of Nanotechnology for Micronutrients in Soil-Plant Systems*. VFRC Report 2015/3. Virtual Fertilizer Research Center, Washington, D.C., 2015, 44.
[3] Garcia-Gomez et al., *Science of the Total Environment*, 589 (2017) 1.