



## **CuO nanoparticles effect on barley inner structure and its morphological responses**

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With the wide application and potential releases of various types of nano-based products without proper care in the environments: the majority of them end up in the soil, directly or through landfills from sludge and other wastes has drawn considerable attention to the public health. The interaction between plants and nanoparticles is a very important aspect for the risk assessment. Therefore, the experiment was conducted on barley by using 300 mg\*kg<sup>-1</sup> of CuO nanoparticles (particle size 30-50 nm) in the hydroponic and soil medium. Barley has been identified for efficient heavy metals accumulator and recommended to use for bio-testing. The well mixed and ultrasonicated nanoparticle solution was applied in a hydroponic system, and zeta potential was performed to check stability and hydrodynamic sizes of nanoparticles, whereas, nanoparticles spiked to the soil for one month prior to seed sowing. The samples were collected between the boot and head emergence phase of barley growth. Nanoparticles toxicity was observed to slow down the development of barley by changing parameters of leaf shape, size, and colour, root and shoot length in both media. The root and shoot lengths reduced by 29.4% and 11.9% in hydroponic, 5% and 3% in soil grown plants, respectively. The high accumulation of Cu contents in under- and aboveground tissues were determined. It was 3.7 and 7.16 times higher in the hydroponic, 10.3 and 5.2 times higher in the soil-grown plant's root and shoot than the control plants, respectively. The number and lengths of root hairs were also reduced, even disappeared than the control in hydroponic; however, no such symptoms were visual on the soil-grown plant roots. It is expected that the accumulation of Cu in root and shoot tissues may one of the causes for a decline to plant growth. The microscopic observations revealed several changes at the cellular and sub-cellular levels such as a disruption in the cell wall, cell membrane, chloroplast structure, thylakoids, sizes of plastoglobules and starch granules, destructive changes in peroxisomes, swollen mitochondrial cristae, deposition of electronically dense materials near the cell wall, and disturbed vascular bundles. Studying these effects at the inner structural level helps identify the cellular targets and primary impact points of nanoparticles toxicity in plants. The toxic effects of nanoparticles on barley were more pronounced in the hydroponic systems than in the soil. Plants growing in a contaminated medium either in soil or an aquatic system may pose a serious threat to human health via the food chain. Therefore, the results could help to increase the scientific understanding of nanoparticles toxicity to plants and the soil barrier function in the ecosystem.

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