Protecting Crops from Abiotic Stress: Copper Oxide Nanoparticle Effects on Wheat and a Beneficial Rhizobacterium

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Full Abstract

CuO nanoparticles (NPs) have possible applications in agriculture as micronutrient sources, pesticides, and enhancers of crop stress tolerance. Here, three aspects of CuO NP agricultural applications are studied: 1) CuO-induced lignification, or formation of the structural polymer lignin, in wheat; 2) CuO NP-induced drought tolerance of wheat seedlings; and 3) the effects of CuO NPs on outer membrane vesicle (OMV) production by Pseudomonas chlororaphis O6 (PcO6), a plant-health promoting bacterium.

Wheat seedlings (Triticum aestivum v. Dolores) grown 7 d exposed to CuO NPs (300 mg Cu/kg) exhibited increased lignification in sclerenchyma cells, considered the strengthening cells of the plant. This increased lignification correlated with increases in the tensile strength and toughness of the wheat shoots, measured with tensile testing. CuO NP-induced lignification may be employed to prevent lodging, when crops irreversibly fall over, and reduce pathogen invasion.

Wheat seedlings (Triticum aestivum v. Juniper, bred for low rainfall conditions) exposed to PcO6 were grown 14 d then exposed to simulated drought for 8 d. Methods were developed to quantify drought tolerance with chlorophyll fluorescence parameters of #PSII and Fv/Fm, which represent operating and maximum photosystem II efficiencies respectively. Drought tolerance was unaffected by low CuO NP dosages (0, 0.5, 5, 15, and 30 mg Cu/kg) in the growth matrix. However, CuO NPs did not exhibit toxic effects to the wheat nor PcO6 showing that CuO NPs may be used for other agricultural applications without damage to wheat crops.

The effects of CuO NPs and H2O2, a metabolite involved in plant stress responses, on PcO6 and its subsequent production of OMVs under stress were quantified by Raman spectroscopy coupled with linear discriminant analysis (LDA). Raman spectroscopy coupled with LDA was able to discern between PcO6 cells and isolated OMVs according to stressor with 83.3% and 71.1% accuracy respectively. OMVs showed unique Raman spectra peaks compared to PcO6 cells, indicating that PcO6 cell components are selectively enriched or excluded from OMVs. These results show the power of Raman spectroscopy in accurately and precisely characterizing OMVs according to cellular abiotic stressor and thus understanding OMV roles in cell stress responses.