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Green Synthesis of ZnO, CuO and ZnO-CuO Nanoparticles from Nigella sativa L. Extract and Effect of Nanoseed priming on Chickpea under Salinity Stress

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Abstract

Nigella sativa is a medicinal plant commonly referred to as "black cumin" and belongs to the family Ranunculaceae. Nanotechnology, a field that operates at the nanoscale, has numerous practical applications. Due to the unique properties of nanoparticles—including their large surface area, high reactivity, aggregation tendencies, penetration capability, small size, and distinct structure—nanotechnology has enabled a wide range of applications in agriculture. Biosynthesis offers a safe and environmentally friendly method for producing non-toxic, biodegradable nanoparticles (NPs). The objective of the present study was to synthesize ZnO, ZnO-CuO, and CuO NPs from *N. sativa* and to evaluate the impact of seed priming with these nanoparticles on the overall morphology, germination, and growth of chickpea (*Cicer arietinum*) under salt stress conditions. The synthesized NPs were characterized FTIR, XRD, DLS, SEM, and UV-Vis. For nanoseed priming, chickpea seeds were soaked in ZnO, CuO, and ZnO-CuO nanocomposite solutions at varying concentrations (100 ppm, 250 ppm, 500 ppm). The effects of ZnO, CuO, and ZnO-CuO NPs on germination, growth, and biochemical parameters of chickpea under salt stress were analyzed. Salt stress was applied in two phases. Various physiological and biochemical parameters were assessed, including catalase and peroxidase activities, hydrogen peroxide levels, seedling root and shoot lengths, fresh and dry weights, number of leaves, and lateral root development. Chickpea exhibited tolerance to salinity during the flowering stage, contributing to its stability and enhanced productivity. Following data collection, raw data were analyzed using the statistical software STAR. Nanoseed priming showed potential benefits in improving germination rates, enhancing seedling growth, and increasing stress tolerance, making it a promising approach for sustainable agriculture. The findings of this study suggest that ZnO, CuO, and ZnO-CuO seed priming can enhance chickpea growth under saline conditions. Improved seedling performance was associated with increased shoot and root lengths, fresh and dry biomass, and antioxidant enzyme activity, which collectively mitigated salt stress effects through nano-priming.

Key Words: