Smart Nanomaterials Technology

Azamal Husen *Editor*

Sustainable Uses of Aromatic Plants in Nanotechnology

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Contents

Effects of Metal-Based Nanoparticles (Au, Ag, Zn, and Cu) on Aromatic Plants

Ayeesha Khatoon, Sazia Siddiqui, and Aisha Kamal

Abstract Aromatic and medicinal plants are rich reservoirs of essential oils and bioactive phytochemicals with wide applications in the food, cosmetic, and pharmaceutical sectors. Recent advances in nanotechnology highlight the potential of metal-based nanoparticles (NPs) particularly Au, Ag, Zn, and Cu to modulate growth, stress tolerance, and secondary metabolite production in these species. Their nanoscale size, high surface reactivity, and tunable physicochemical properties enable unique interactions with plant tissues, influencing nutrient uptake, photosynthetic efficiency, antioxidant defenses, and phytochemical biosynthesis. At optimal concentrations, NPs act as bio-stimulants, enhancing enzymatic and nonenzymatic antioxidant activity, improving essential oil yield, and enriching compounds such as phenolics, flavonoids, and terpenoids, thereby elevating both therapeutic and commercial value. However, their effects are strongly dose- and species dependent. While low to moderate NP levels stimulate plant defense mechanisms and metabolic pathways, excessive accumulation can induce oxidative stress, DNA damage, impaired photosynthesis, and growth inhibition, underscoring the importance of defining threshold concentrations. This chapter synthesizes current evidence on the uptake, transport, and mechanistic actions of Au, Ag, Zn, and Cu NPs in aromatic plants, highlighting their dual role as stimulants or stressors. It emphasizes the need for optimized application strategies and biosafety assessments to harness nanotechnology for sustainable cultivation and enhanced medicinal value of aromatic crops.

Keywords Aromatic plants · Metal-based nanoparticles · Essential oils · Phytochemical modulation · Antioxidant activity · Phytotoxicity thresholds

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