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Chapter 3

Biogenesis of nanoparticles from medicinal plants and their importance in agriculture

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Abstract: The biogenesis of nanoparticles from medicinal plants, also known as green synthesis, represents an eco-friendly and sustainable approach to nanoparticle production. These nanoparticles typically metal or metal oxide - based, are synthesized using plant extracts that contain a various phytochemicals that function as reducing and stabilizing agents. This method avoids the need for harmful chemicals, making it an environmentally benign alternative to conventional nanoparticle production. In agriculture, these plant - derived nanoparticles hold significant potential. They can enhance crop growth, improve nutrient uptake, and offer protection against pathogens through antimicrobial properties. Additionally, they can act as Nanofertilizers or pesticides, reducing the need for synthetic chemicals and promoting sustainable farming practices. Thus, biogenic Nanoparticles contribute to both environmental sustainability and agricultural productivity, providing an innovative solution to some of the challenges faced by modern agriculture.

Keywords: Nanoparticles, Green synthesis, Medicinal plants and Sustainable agriculture

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3.1. Introduction

The synthesis of nanoparticles (NPs) has gained significant attention due to their wide-ranging applications in medicine, electronics, and agriculture (Aisida et al., 2020). Traditional methods of NP synthesis involve energy-intensive physical and chemical processes that often use toxic reagents, harming the environment (Khan et al., 2019). To address these concerns, green synthesis or biogenic synthesis of NPs, especially from medicinal plants, has emerged as an eco-friendly and sustainable alternative (Roy et al.,

2019). Medicinal plants, rich in bioactive compounds, offer a natural and safe route for synthesizing NPs, which can transform modern agricultural practices (Malabadi et al., 2021).

3.2. Biogenesis of Nanoparticles from Medicinal Plants

Medicinal plants are a rich source of secondary metabolites such as flavonoids, alkaloids, phenols, and terpenoids, which are integral to the green synthesis of nanoparticles (Raut et al., 2010). These plant-based compounds act as reducing, capping, and stabilizing agents, enabling the formation of nanoparticles through a one-step process (Jagtap & Bapat, 2013). The biogenic synthesis process is simple, cost-effective, and eliminates the need for toxic chemicals.

Key Steps in Biogenesis:

1. **Preparation of Plant Extract**: Plant parts (leaves, stems, or roots) are ground into powder and extracted using solvents, typically water or ethanol (Kuppusamy et al., 2016).
2. **Reduction of Metal Ions**: Metal salts like silver nitrate ($AgNO_3$) or gold chloride ($HAuCl_4$) react with plant extracts. Phytochemicals in the extracts reduce metal ions to zero-valent nanoparticles (e.g., Ag^+ reduced to Ag^0 by phenolic compounds) (Singh et al., 2016).
3. **Stabilization and Capping**: Bioactive compounds stabilize nanoparticles and prevent aggregation, ensuring uniform size and dispersion (Sharma & Kumar, 2019).
4. **Characterization**: Characterization techniques include UV-visible spectroscopy, X-ray diffraction (XRD), and transmission electron microscopy (TEM) (Ahmed et al., 2016).

3.3. Importance of Nanoparticles in Agriculture

Nanoparticles enhance productivity and sustainability in agriculture by serving as eco-friendly alternatives to traditional fertilizers and pesticides (Khan et al., 2019).

1. **Nanofertilizers**: Improve nutrient delivery and reduce environmental harm by minimizing fertilizer use (Parveen & Banse, 2021).

2. **Nanopesticides**: Exhibit antimicrobial properties, controlling plant pathogens and reducing dependence on harmful synthetic pesticides (Bhattacharyya et al., 2010).

3. **Soil Remediation**: Zinc oxide nanoparticles can degrade organic pollutants, enhancing soil health (Roy et al., 2019).

4. **Stress Tolerance**: Nanoparticles help plants resist drought, salinity, and temperature stresses (Prasad et al., 2017).

3.4. Challenges and Future Prospects

Although promising, green synthesis of nanoparticles faces challenges like standardization of protocols and assessing their long-term impact on ecosystems (Malabadi et al., 2021). Future research should focus on optimizing synthesis processes and scaling up production to make plant-based NPs viable for widespread agricultural applications (Aljabali et al., 2018).

Conclusion

The biogenesis of nanoparticles from medicinal plants is a sustainable, cost-effective, and environmentally friendly approach to addressing agricultural challenges. By improving crop productivity and reducing dependency on harmful chemicals, plant-based NPs offer a revolutionary solution for sustainable agriculture.

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