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Green Synthesis of Nanoparticles for Insect Pest Management

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Nanotechnology offers a promising alternative to conventional pesticides, addressing challenges like environmental contamination and pesticide resistance. Green synthesis of nanoparticles utilizes biological entities to produce eco-friendly nanomaterials, eliminating the need for hazardous chemicals. This approach enhances sustainability, bioavailability and targeted pest management while minimizing ecological risks. This procedure involves selecting plant materials, extracting bioactive compounds and facilitating metal ion reduction for nanoparticle formation.

Introduction

Insect pests pose a significant threat to global agriculture, causing substantial losses in crop yield and quality. To mitigate these impacts, synthetic chemical pesticides have been widely used. However, their overreliance has led to several challenges, including environmental contamination, pesticide resistance, adverse effects on non-target organisms, and human health risks. The persistence of chemical residues in soil and water further exacerbates ecological imbalances, necessitating the development of safer and more sustainable alternatives.

Nanotechnology has emerged as a promising solution in modern pest management, offering enhanced efficacy, targeted delivery and reduced environmental footprint. Nanoparticles can improve the bioavailability of active ingredients, enable controlled release, and minimize unintended side effects. Their unique physicochemical properties allow for more effective interaction with pests while reducing the need for excessive chemical application (Stavitskaya *et al.*, 2022). However, conventional nanoparticle synthesis methods often involve hazardous chemicals, raising concerns about toxicity and sustainability.

Green synthesis of nanoparticles presents an eco-friendly alternative by utilizing biological entities such as plant extracts, bacteria, fungi and algae as reducing and stabilizing agents. This approach eliminates the need for toxic reagents and promotes biocompatibility, making it a sustainable strategy for developing nano pesticides (Tripathy *et al.*, 2010). The use of naturally derived compounds not only enhances environmental safety but also contributes to cost-effective and scalable production. As research in green nanotechnology progresses, it holds great potential for revolutionizing insect pest management while addressing the limitations of conventional pesticides.

Procedure for green synthesis of nanoparticles

Green synthesis of metallic nanoparticles offers an eco-friendly and sustainable approach to developing nanomaterials for insect pest management. This method utilizes biological entities such as plant extracts, bacteria, fungi and algae as reducing and stabilizing agents, eliminating the need for hazardous chemicals. The following is a generalized procedure for

the green synthesis of metallic nanoparticles using plant extracts, along with references to specific studies (Nadaroglu *et al.*, 2017).

1. Selection of Plant Material

- Choose a plant known for its rich phytochemical content, as these compounds facilitate the reduction of metal ions. Commonly used parts include leaves, peels, roots or seeds. For instance, *Annona squamosa* (custard apple) leaves have been employed for silver nanoparticle synthesis.

2. Preparation of Plant Extract

1. Collect the selected plant material and wash thoroughly with distilled water to remove impurities.
2. Air-dry the material in the shade to preserve active compounds.
3. Grind the dried material into a fine powder.
4. Mix a specific amount of the powder with distilled water and heat (e.g., at 60–80°C) for a designated time to extract the bioactive compounds.
5. Filter the extract using Whatman No. 1 filter paper to obtain a clear solution.

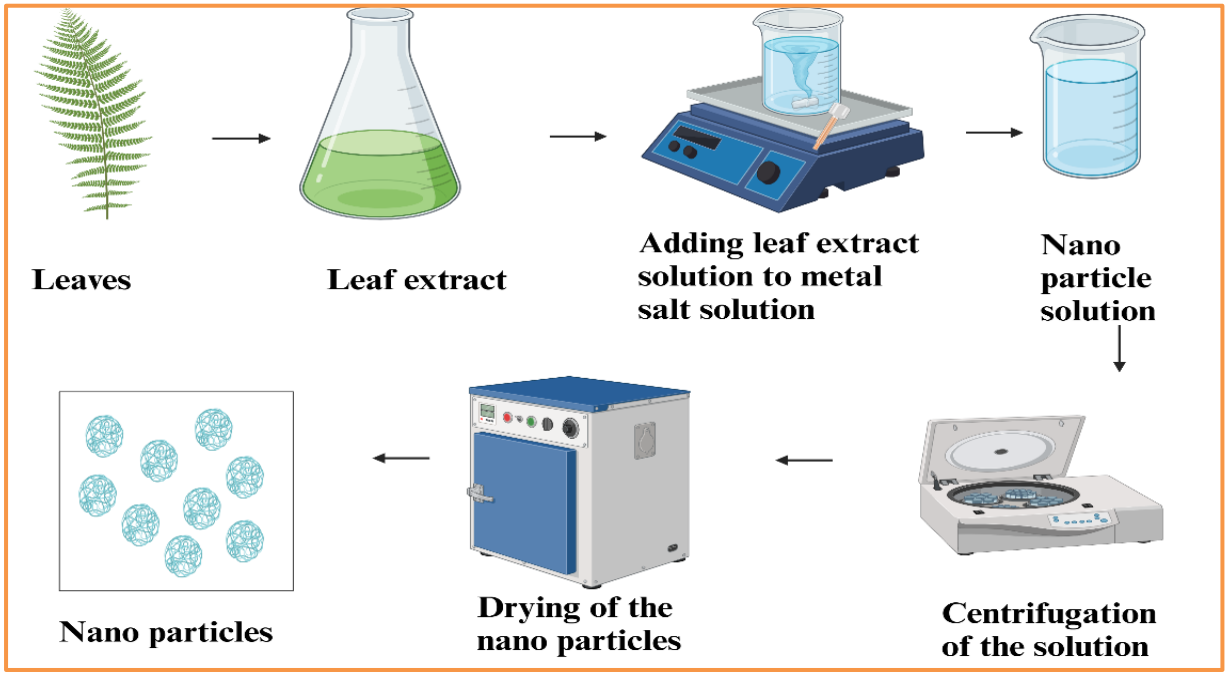

Fig: Procedure for the green synthesis of nano particles

3. Preparation of Metal Salt Solution: Prepare an aqueous solution of the desired metal salt (e.g., silver nitrate for silver nanoparticles) at an appropriate concentration, typically in the millimolar range (Rehman *et al.*, 2021).

4. Synthesis of Nanoparticles

- Mix the plant extract with the metal salt solution in a specific ratio under continuous stirring.
- Incubate the mixture at room temperature or under controlled conditions.
- Observe the color change, indicating nanoparticle formation. For example, the reduction of silver ions often results in a yellowish-brown color due to surface plasmon resonance (Arjunan *et al.*, 2012).

5. Characterization of Nanoparticles

- Use techniques such as UV-Vis spectroscopy to monitor the synthesis process by detecting characteristic absorption peaks.
- Employ X-ray diffraction (XRD) to determine the crystalline nature of the nanoparticles.
- Utilize scanning electron microscopy (SEM) or transmission electron microscopy (TEM) to analyze particle size and morphology.
- Perform Fourier-transform infrared spectroscopy (FTIR) to identify functional groups involved in the reduction and stabilization processes.

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