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# Green Nanotech for Seed Success: Enhancing Seed Quality with Silver Nanoparticles

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Seed is a basic tool for agriculture and ensuring its healthy germination is vital for crop growth. In recent years, nanotechnology has revolutionized seed science, offering innovative solutions to enhance seed performance. Among various nanomaterials, silver nanoparticles (AgNPs) have gained prominence for their antimicrobial, antioxidant, and growth-promoting properties. The emergence of green synthesis techniques which use plant extracts as natural reducing and capping agents has made AgNP production eco-friendly, safe, and cost-effective, avoiding toxic chemicals. This approach integrates beneficial phytochemicals into nanomaterials, creating a new frontier in green nanopriming. Priming seeds with green-synthesized AgNPs has shown to improve germination rates, seedling vigour, and resilience to biotic and abiotic stresses, ultimately supporting better crop establishment and productivity. This sustainable innovation marks a promising advancement in modern agriculture.

**Key words:** AgNPs, Green synthesis, Silver nanoparticles

## Green Synthesis: A Nature-Friendly Approach

Traditional methods of synthesizing nanoparticles involve harsh chemicals that can be toxic to the environment. Green synthesis, on the other hand, uses plant extracts such as Moringa, Neem, Tulsi or Guava as natural reducing and stabilizing agents. These plant-based methods are not only eco-friendly and cost-effective but also incorporate the nanoparticles with beneficial bio-compounds from the plants themselves.

## What Are Green Synthesized Silver Nanoparticles?

Green silver nanoparticles are produced through the bioreduction of silver salts ($AgNO_3$) using plant extracts (e.g., moringa, neem, guava, tulsi, etc.) as natural reducing and stabilizing agents. These extracts contain flavonoids, polyphenols, terpenoids, and proteins that contribute to the formation and stabilization of nanoparticles.

The resulting nanoparticles are:

- Non-toxic
- Uniform in size (typically 10–50 nm)
- Stable in suspension
- Biologically active

They exhibit strong antimicrobial and antioxidant activities, making them suitable for agricultural applications.

## Role of AgNPs in Seed Priming

Priming seeds with green AgNPs leads to the partial hydration of seeds and the uptake of nanoparticles into seed tissues. This nanopriming technique stimulates the seed's internal metabolism and prepares it for rapid and synchronized germination once sown.

## Key benefits include

- **Enhanced Germination Rate**: AgNP-primed seeds germinate faster and more uniformly due to improved enzymatic activity and water absorption.
- **Seedling Vigour**: Higher vigour index observed with increased shoot and root length.
- **Improved Metabolic Activity**: Boosts activities of α-amylase, catalase (CAT), superoxide dismutase (SOD), and peroxidase (POD), leading to better energy mobilization.
- **Stress Tolerance**: AgNPs help protect seeds from oxidative stress and support germination under salinity, drought, or pathogen-induced stress.
- **Antimicrobial Defense**: Green AgNPs reduce seed-borne and soil-borne infections by acting as antimicrobial agents.

## Mechanism of Action of Silver Nanoparticles in Plants

**Penetration and Uptake**

- **Seed Coat Entry:** When seeds are primed with AgNPs, the nanoparticles adhere to the seed coat and enter through micropores or cracks during imbibition (water absorption).
- **Cellular Uptake**: AgNPs can enter plant cells via endocytosis or through aquaporins and ion channels. Once inside, they move to various organelles (like the mitochondria, chloroplasts, and nucleus) where they interact with biomolecules.

**Controlled Generation of Reactive Oxygen Species (ROS)**

- AgNPs may induce a mild oxidative stress by generating ROS (e.g., $H_2O_2$, $O_2^-$).
- This controlled ROS burst acts as a signal to activate defense mechanisms and promote seed metabolism.

**At low concentrations, ROS:**

- Stimulate antioxidant enzyme activity (SOD, CAT, POD)
- Regulate cell wall loosening enzymes for radicle emergence
- Promote hormonal signaling for germination

## Activation of Antioxidant Defense System

**AgNPs upregulate antioxidant defense to balance ROS levels:**

- **SOD (Superoxide dismutase)**: Converts superoxide radicals into hydrogen peroxide
- **CAT (Catalase):** Breaks down $H_2O_2$ into water and oxygen
- **POD (Peroxidase):** Detoxifies peroxides and strengthens cell walls

This enhanced enzymatic activity protects plant cells from oxidative damage and supports healthy growth, especially under **abiotic stress** (e.g., salinity, drought).

## Stimulation of Hydrolytic Enzymes

**AgNPs prime seeds by increasing the activity of:**

- **α-Amylase**: Breaks down starch into simple sugars for energy during germination
- **Proteases**: Mobilize stored proteins
- **Lipases**: Help in lipid utilization

These enzymes supply the energy and building blocks required for **seedling development** and root-shoot elongation.

## Modulation of Phytohormones

**Silver nanoparticles influence the balance of plant hormones**:
**Abscisic Acid (ABA):** Reduces dormancy, allowing quicker germination
**Gibberellic Acid (GA):** Promotes enzyme synthesis and seedling growth
**Indole-3-acetic acid (IAA):** Stimulates cell elongation and root development**.**

**Advantages of Green AgNPs Over Conventional Priming Agents**

| Feature | Green AgNPs | Traditional Agents |
|---|---|---|
| Eco-friendly | Yes (plant-based synthesis) | No (often synthetic chemicals) |
| Antimicrobial properties | Strong | Limited or none |
| Antioxidant activity | High (due to plant phytochemicals) | Low to moderate |
| Residue toxicity | Minimal | Possible chemical residue |
| Cost-effectiveness | Moderate (reusable and scalable) | Depends on formulation |

## Challenges and Precautions

- **Dosage Optimization**: High concentrations can be phytotoxic; precise control is needed.
- **Regulatory Approval**: Needs compliance with biosafety and agricultural standards.
- **Scale-up Constraints**: Standardizing green synthesis protocols across crops is ongoing.

## Conclusion

Green synthesized silver nanoparticles offer a cutting-edge, eco-safe tool for improving seed germination, vigour, and stress resilience. Their ability to stimulate metabolism, enhance defense mechanisms, and suppress pathogens positions AgNPs as a valuable component in modern seed technology. Continued research, awareness, and adoption can integrate this nanobiotechnological innovation into mainstream agriculture, supporting sustainable and productive crop systems.

## References

1. Almutairi, Z. M. (2016). Influence of silver nanoparticles on seed germination and early seedling growth in tomato. *Saudi Journal of Biological Sciences*, 23(1), 44–48.
2. Kumari, A., & Yadav, S. K. (2014). Biocompatibility and seed germination efficacy of silver nanoparticles synthesized using neem (Azadirachta indica) extract. *Journal of Plant Biochemistry and Biotechnology*, 23(1), 34–42.
3. Raj, S., & Irudayaraj, J. (2020). Eco-friendly synthesis of silver nanoparticles using Moringa oleifera leaf extract and their effect on seed germination and seedling vigour. *Journal of Nanobiotechnology*, 18(1), 10–17.
4. Singh, R., & Sharma, P. (2021). Green nanotechnology for enhancing seed germination: A review. *Journal of Environmental Biology*, 42(3), 585–592.