



Nanotechnology: Miniscule Management of Plant Parasitic Nematodes

(Rupak Jena¹, *Subhashree S Paikaray², B K Sahoo² and SD Mohapatra¹)

¹Division of Crop Protection, National Rice Research Institute, Cuttack, Odisha

²Department of Entomology, Siksha O Anusandhan University, Bhubaneswar, Odisha

*Corresponding Author's email: subhashreepaikaray25@gmail.com

A major challenge in future is the uphill movement of world's population requiring food security. Although a 35% population increase is projected by 2050, an increase in food demand in the order of 75% is anticipated, due to economic development and changes in food preferences. The food production has significantly increased but is constantly threatened by the everchanging abiotic conditions and resurgence of various biotic insects and pests. In biotic challenges plant - parasitic nematodes cause an estimated annual US78 billion-dollar crop - yield loss worldwide, which makes effective control strategies highly essential. The parasitic nematodes are among the major soilborne crop pests, and their control relies on highly toxic compounds that have an impact on the whole soil community. Phytochemical-based approaches offer promising alternatives, with numerous plant-derived compounds showing antinematicidal properties.

Nanotechnology is the design, characterization, production and application of structures by controlling shape and size at nanometer scale that has a great influence on biological science, medicine, pharmacy and agriculture. Nanotechnology in crop protection offers innovative solutions for sustainable agriculture and food production in the face of climate change and population growth. In agriculture it encompasses crop protection, tackling pest management issues, and promoting sustainable agriculture. Through targeted and regulated administration, nanoparticles can improve the effectiveness of fertilizers and insecticides while lowering chemical use and their negative effects on the environment. The nanomaterials in form of organic, inorganic and combined formulations serving as herbicides, fungicides, bactericides, and insecticides benefits agriculture and its various nano biosensors assist detection of plant diseases and environmental monitoring

Recent developments in nanotechnology against plant parasitic nematodes

Nowadays, the rapid development of nanotechnology presents a new way to improve the performance of conventional pesticide formulations through the construction of nanotechnology based agricultural system such as drugs carriers and a controllable drug targeting and releasing system. Also, independently nano-products or nanomaterials are used against plant parasitic nematodes in form of nano-silver and nano-sulfur. Nanoparticles can enhance the efficacy and delivery of anthelmintic drugs, improving target selectivity and reducing environmental impact. Biologically synthesized nanoparticles show potential as an eco-friendly and cost-effective method for nematode control. Various nanoparticles, including metals, metal oxides, and non-metals, have demonstrated effective nematicidal properties, often surpassing economically important nematodes. These nanoparticles can directly toxify nematodes, reduce plant infection, and inhibit parasite reproduction.

Mechanisms of action include generating reactive oxygen species and affecting gene expression related to oxidative stress and DNA damage repair.

Silver nanoparticles against plant-parasitic nematodes: Silver has been generating a lot of interest lately because of its high conductivity, chemical stability, catalytic properties, and antibacterial properties. Recently silver nanoparticles (AgNP's) have gained popularity due to the physiochemical and agricultural productive activities. As a result of their well-established antibacterial properties, AgNP's were first studied in the treatment of plant diseases. Using AgNP's to combat *Meloidogyne incognita* attacking tomatoes in greenhouse scenarios dramatically reduced the nematode population while simultaneously enhancing plant development indices. AgNP's have nematode-killing characteristics against root-knot nematodes, but they also affect other PPN species, plant pathogenic bacteria, and fungi. AgNP's are thought to be broad-spectrum antibacterial, antifungal, and antitumor agents. AgNPs toxicity impaired the development and reproduction of root-knot nematodes at doses of 0.05–0.5 mg/ml for 72 hours and 5–50 mg/ml for 1–3 days, respectively. AGNP's against *M. graminicola* revealed 0.1 µg/ml as the minimum concentration for 100% irreversible nematode mortality. The effective dosage to kill nematodes in field soil assays was determined to be 3 µg/ml,

Gold Nanoparticles against plant-parasitic nematodes: Nanoparticles have been utilized in controlled laboratory and field environments to manage plant-parasitic nematodes. Gold is classified as a precious metal known as a noble metal. However, there is currently no substantiated information about its significance for the survival and functioning of living macro-organisms and microorganisms. Various techniques have been employed for the synthesis of gold nanoparticles (GNPs), encompassing both biological and chemical approaches. Studies conducted demonstrated that the use of GNPs immediately resulted in the mortality of nematodes. Furthermore, the researchers observed that the effectiveness of GNPs in killing nematodes was enhanced when used in conjunction with nematicides.

Copper nanoparticles against plant-parasitic nematodes: Copper nanoparticles (CuNP's) has reported to successfully manage root-knot nematodes and various plant diseases due to its natural antibacterial properties. Also, it is documented as a fungicide/bactericide and nematicides while studying its impact on grape vine nematode *Xiphinema index*. Under lab conditions CuNP's concentration of 0.2 g/L is reported to be sufficient to cause 100% mortality in *Meloidogyne incognita* juveniles. The root and shoot parameters of the tomato plant showed enhanced root and shoot parameters. *Meloidogyne javanica* and *Meloidogyne graminicola* are effectively managed by the CuNP's at a lower dose of 20 µg/ml that prevented the egg hatching and caused mortality under lab conditions.

Green synthesized nanoparticles against plant-parasitic nematodes: The synthesis of nanoparticles from biological means i.e. bacteria, yeast, fungi, plant or plant products in the range of 1-100 nm with the help of biotechnological tools. Green nanoparticles are eco-friendly, less energy consumable, cost effective, non-toxic and pollution-free It also has good characteristics such as stability and biodegradability. According to reports, the silver nanoparticles produced by *Euphorbia tirucalli* latex extract are deadly to *M. incognita* juveniles and also prevent egg hatching in vitro. Biological approaches use the various parts of a plant, including a stem, root, fruit, seed, callus, peel, leaves, and flowers, to create metallic nanoparticles in a variety of sizes and shapes.



Fig 1: Synthesis of Green silver nanoparticles

Advantages of nanotechnology in agriculture

- Nanotechnology offers numerous advantages in agriculture, including enhanced crop productivity and sustainability.
- Nanomaterials can improve seed germination, nutrient delivery, and stress tolerance in plants.
- Nanotechnology enables precision agriculture through advanced sensors for monitoring soil quality, plant diseases, and stress.
- Nanotechnology aids in water conservation through nanoscale irrigation systems and soil water retention enhancement.
- Nanoparticles can deliver nutrients and pesticides with unprecedented precision, optimizing resource use and minimizing environmental impact.

Future prospects and Conclusion

Plant parasitic nematode are considered a destructive pest for many major crops. There is a lot of promise for employing nanoparticles to identify and eliminate plant diseases. Both synthetic and biosynthesized nanoparticles offer intriguing and difficult management prospects for commercially significant plant-parasitic nematodes. Nanotechnology is an effective alternative solution for this problem as it is considered eco-friendly and is less toxic against nontarget organisms. Hence more research and scientific intervention are required regarding the effects of various nanoparticles and their mechanism in plant growth and protection against pests and nematodes under various abiotic and biotic stresses.

Table 1: Referenced nanoparticles and green materials combination for the management of plant-parasitic nematodes:

Sl no	Green Materials (NP)	Nematodes	Crop	Effect
1.	Organic extract of <i>Urtica urens</i> (Ag)	<i>M. incognita</i>	<i>In vitro</i>	Increase the nematode mortality and reduce the egg hatchability.
2.	Milled Corn Residue (Ag)	<i>H. Sacchhari</i>	Rice	Improved rice plant growth with a reduction in nematode population.
3.	Aqueous extracts of Ficus mucoso bark (Ag)	<i>M. incognita</i>	Groundnut	Increase the tolerance to nematodes by enhancing growth and yield. Reduce the nematodes population.
4.	<i>Streptomyces plicatus</i> (ZnO)	<i>M. incognita</i>	Tomato	Deformation of the nematode cuticle and causes immobilization leads to mortality.
5.	Strawberry seed powder (MgO)	<i>M. incognita</i>	<i>In vitro</i>	Induces nematode mortality and inhibits egg hatching by altering the morphology.
6.	Jatropha curcas Leaf extract (CuO)	<i>M. incognita</i>	Chickpea	Reduction in nematode population and galling percentage by altering the root exudates which attract the nematodes.
7.	<i>Euphorbia tirucalli</i> latex (Cu)	<i>M. incognita</i>	Tomato	Reduced gall formation, egg masses on roots, number of eggs per egg masses and the J2 population in the soil. It repels the nematodes by altering the root exudates.
8.	<i>Cladophora glomerata</i> extract (Ag)	<i>M. javanica</i>	Tomato	Reduction of systemic acquired resistance Reduction in nematode population and gall formation.

References

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