Innovative Bio-Nanoparticle Approaches for the Sustainable Management of Rhizoctonia solani in Agriculture

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ABSTRACT

Rhizoctonia solani is a species of fungus in the order *Cantharellales. Basidiocarps* (fruit bodies) are thin, effused, and web-like, but the fungus is more typically encountered in its anamorphic state, as hyphae and sclerotia. The inability of contaminated seeds to germinate, or "damping off," is the most typical sign of *rhizoctonia*. *R. solani* can destroy extremely young seedlings shortly after they emerge from the soil, or it can enter the seed before it has germinated to induce this pre-emergent damping down. Bio-nanoparticles can have positive environmental effects, such as reduced toxicity and increased solubility of pesticides. However, it's important to use nanotechnology responsibly, as there are concerns about environmental and non-target organism safety. Nanoparticles can help plants resist disease by activating their defense mechanisms or deactivating microbes.

INTRODUCTION

Rhizoctonia solani is a species of fungus in the order *Cantharellales. Basidiocarps* (fruit bodies) are thin, effused, and web-like, but the fungus is more typically encountered in its anamorphic state, as hyphae and sclerotia. The name *Rhizoctonia*

solani is currently applied to a complex of related species that await further research. *Rhizoctonia solani* is a facultative plant pathogen that has a wide host range and can be found all over the world. It causes root rot, damping off, and wire stem, among other plant diseases. It can also grow *mycorrhizal* relationships with orchids.

HOST AND PATHOGEN

Numerous serious plant diseases with substantial economic implications are caused by *Rhizoctonia solani*. It is one of the fungi that cause several harmful situations, such as the turfgrass disease brown patch, damping off in soybean seedlings, black scurf in potatoes, and barren patches in cereals, sugar beet root rot, belly rot of cucumber, banded leaf and sheath blight in maize (Yasmin *et al*., 2023) sheath blight of rice, and many more. *R. solani* mostly attacks plants' seeds, but it can also infect pods, roots, leaves, and stems. "Damping off," or infected seeds' inability to germinate, is the most typical *Rhizoctonia* symptom. *R. solani* has the ability to infect seeds before they germinate and induce pre-emergent damping off, or it can harm very early seedlings. Seedlings are most susceptible to disease in their early stages (MA. Cubeta *et al*., 1997).

ECONOMIC IMPORTANT

Rhizoctonia solani is found all over India, where the host crops are located an infection may be serious. Due to the soil adhering to the fungal mycelium, there are considerable yield losses (ranging from 25% to 100%), increased soil tare, and low industrial grade crops as a result of the elevated nitrogen, sodium, and potassium levels. This pathogen causes sheath blight, which is the second most dangerous disease after rice blast.

TRADITIONAL APPROACHES

Conventional techniques rely on well-documented fungal morphology for genus confirmation. Among the several quantitative methods are baiting with a vulnerable host legume crop, wet sieving, direct microscopic inspection, incubating immersion tubes in soil and plate profiling and qualitative detection techniques that have been studied. These methods only require basic lab equipment, but they are labor-intensive, so they are not good for large-scale environmental studies.

The accepted method for categorizing and splitting strains of this sexually obscure *R. solani* fungus is hyphal anastomosis. Cons of using conventional techniques. The usage of anastomosis reactions for a long time to categories *Rhizoctonia* isolates, despite the fact that this method has a number of drawbacks. Other features that helped identify R. solani AG and subgroups were thiamine need, optimal growth temperature, sclerotium type, host origin, and symptoms (Ogoshi *et al*., 1996). It is possible for anastomosis between two isolates of the same AGs to be prevented by instability in diet, environment, or genetics. Establishing a fusion reaction also takes time and might be hard to decipher.

SIGNIFICANCE OF BIONANOPARTICLE

- **Targeted applications-** Nanoparticles can perform specialized functions in a targeted area.
- **Biomedical applications-** Nanoparticles are important in the field of nanotechnology, and are used in the pharmaceutical industry to make medical preparations. For example, magnetic nanoparticles are used in cancer target therapy.
- **Antibacterial properties-** Nanoparticles have a significant antibacterial effect, and this effect increases with the concentration of nanoparticles.
- **Drug delivery-** Solid lipid nanoparticles (SLNs) are used in drug delivery and

research because of their size-dependent properties.

- **Green synthesis-** Green synthesis is an emerging method for synthesizing nanoparticles, and offers biological benefits, environmental benefits, and cost-effectiveness.

STRUCTURAL OF BIO-NANOPARTICLES

i. Spherical
ii. Cylindrical
iii. Tubular
iv. Conical
v. Hollow core
vi. Spiral
vii. Flat
viii. Wire

TYPE OF BIO-NANOPARTICLE

There are several types of bio-nanoparticles:

- Biological nanoparticles: These include lipoproteins, ferritin, magnetosomes, and viruses.
- Magnetic nanoparticles: These are used in nanomedicine, analytical chemistry, and biosensing.
- Inorganic nanoparticles: These can be produced from microorganisms and plant extracts.
- Gold nanoparticles: These are used in biosensors because of their high surface-to-volume ratio, conductivity, and stability.
- Ceramic nanoparticles: These are used as drug vehicles in cancer therapy.
- Protein nanoparticles: These are amphiphilic biopolymers that are made from amino acids.
- Aluminum nanoparticles: These are used in high-energy compositions, hydrogen generation in water processes, and the synthesis of alumina.

RATIONALE FOR USING BIO-NANOPARTICLES IN PLANT DISEASE MANAGEMENT

Role of Nanotechnology in Managing Bacterial Diseases. Nanoparticles are being employed to defy bacterial pathogens in three ways, mainly:

(i) as carriers of antibacterial chemicals,

(ii) to boost plants' defenses against bacteria, and

(iii) directly interacting with bacterial cells leading to cell death.

1. **Organic nanoparticles:** Natural or artificial organic compounds serve as templates for the creation of organic nanoparticles (NPs). Examples of organic nanoparticles seen in nature include protein aggregation, lipid bodies, milk emulsions, and viruses, among other more intricately organized structures.
2. **Inorganic nanoparticles:** They are composed of metals, metal oxide, carbon, or organic molecules. Inorganic nanoparticles are comparatively biocompatible, hydrophilic, and non-toxic, highly stable than organic particles. In response to different structures, nanoparticles have a large diversity of shapes, dimensions, and sizes.

BIO-NANOPARTICLES ARE USED IN AGRICULTURE:

I. Fungicides: Biogenic nanoparticles can be used as fungicides to control plant fungal diseases.

II. Stress alleviation: Nanomaterials can help reduce the impact of environmental stresses on plants, which can negatively affect their yield potential.

III. Crop production: Nanotechnology can help boost crop production, enhance crop tolerance, and decrease environmental pollution.

IV. Germination rates: Carbon nanotubes can increase germination rates and influence seedling growth.

V. Disease detection: Nanotechnology can help with rapid disease detection.

VI. Nutrient absorption: Nanotechnology can help enhance the ability of plants to absorb nutrients.

MECHANISM OF ACTION OF BIONANOPARTICLES:

The most reported modes of action of nanoparticles are antimicrobial activity, ROS-induced cytotoxicity, Geno toxicity, plant growth promotion, etc. It has been successfully demonstrated that actions of nanoparticles are governed by their size, shape, dose, and concentration.

ADVANTAGES AND DISADVANTAGE OVER CONVENTIONAL FUNGICIDES:

Advantage is that it will kill fungi that are destroying crops, such as parasitic fungi. Disadvantage is that these substances can kill all fungi, even fungi decomposers. This can destroy crops as well.

1. **Impact of *Rhizoctonia solani* on agriculture:** The *soilborne* fungus *Rhizoctonia solani* can cause significant yield losses in many crops, including:

- Damping-off: A disease that can affect many plants
- Bare patch disease: Can lead to stunted growth and reduced grain production
- Black scurf: A disease that affects potatoes
- Crown rot: A disease that affects sugar beets
- Root rot: A disease that can affect peanuts
- Limb rot: A disease that can affect peanuts
- Seed decay: A disease that can affect peanuts
- Pod root: A disease that can affect peanuts

2. Symptoms of *Rhizoctonia solani* include:

- Brown rot on stems starting at the soil line
- Brown lesions on roots
- Yellowing and falling off of lower leaves
- Wilting
- Stunting
- Plant death

SOME WAYS TO CONTROL *RHIZOCTONIA SOLANI* INCLUDE:

- Trichoderma: A soil-dwelling saprophyte that can suppress soil pathogens and promote plant growth
- Mycorrhizae: Can protect plants from pathogens
- Organic amendments: Can be added to soils to suppress disease.

ECONOMIC CONSEQUENCES: Yield losses and financial implications for farmers.

❖ **Weeds-** Weeds can cause yield losses of 10–80% depending on the crop, the type of weed, and the level of competition between the crop and the weed. In developing

countries, weeds can cause 90–95% crop failure or complete crop failure in some areas.

- **Pests and diseases-** Primary and secondary yield losses are two types of yield losses that can be caused by pests and diseases. Damage to plants from weed competition and other pests including bacteria, fungus, viruses, and insects severely reduces plant output and in certain cases can completely kill a crop.

- **Climate change-** Global food yields might be lowered by 3–12% by the middle of the century and by 11–25% by the end of it due to climate change. Climate change will alter pest, plant disease and weed distributions, with potential to reduce crop yields, including of staple crops like wheat, soybeans, and corn (maize). Warmer temperatures can increase the metabolic rate and number of breeding cycles of insect populations.

- **Disasters-** The effects of catastrophes on the economy and food security can be lessened with the implementation of effective disaster risk reduction (DRR) programs. Lower-than-expected productivity is one of the most immediate ways that catastrophes impact agriculture. Farmers suffer immediate financial losses as a result, which can have an impact on the sector's growth or the economy of entire countries. These losses can also ripple across the value chain.

METHODS OF SYNTHESIZING BIO-NANOPARTICLES.

Nanoparticles can be synthesized using a variety of methods, including chemical, physical, and biological methods. Some of these methods include:

- Biological synthesis- Also known as green synthesis, this method uses bacteria, fungi, viruses, or plant extracts to create nanoparticles. It's an economical, environmentally friendly, and sustainable way to produce nanoparticles, and it can be scaled up for large-scale production. Enzymes, proteins, polyphenols, flavonoids, and terpenoids are examples of biologically active substances found in the biological sources utilized in the green synthesis of nanoparticles. These substances can function as catalysing, reducing, stabilizing, or capping agents for one-step synthesis.

- Chemical methods- In nanoparticle synthesis by chemical reduction, metal-containing salts (denoted as precursors) are dissolved and chemically reduced in an appropriate solvent. In the first stage of the nucleation, the metal salt is reduced to give zero valent metal atoms.

- Physical methods- Evaporation-condensation and laser ablation are the most important physical approaches. The absence of solvent contamination in the prepared thin films and the uniformity of NPs distribution are the advantages of physical synthesis methods in comparison with chemical processes.

OTHER METHODS FOR STUDYING NANOPARTICLES INCLUDE:

- Scanning electron microscopy (SEM)- This method uses a focused beam of electrons to create an image of the nanoparticles, which can then be analyzed to measure their size.

- Fourier transform infrared spectroscopy (FTIR)- This technique can be used to determine the concentration of chemicals, the surface of nanoparticles, and the atomic arrangement of the nanoparticles.

- X-ray diffraction (XRD)-This technique is useful for studying the structure of

nanoparticles because the wavelength of X-rays is on the atomic scale.

- Atomic force microscopy (AFM)- This technique uses a sharp-tipped cantilever to scan the surface of an object and detect forces and displacement. It can be used to image and analyze the mechanics of biological specimens at the nanoscale.

DELIVERY SYSTEMS FOR BIO-NANOPARTICLES

As a matter of fact, the $5 trillion global agro-food business will only grow in tandem with the predicted 70% rise in world calorie consumption and the at least 100% growth in crop demand. Many now firmly believe that nanotechnology will have a major influence on the agro-food industry, particularly when it comes to issues of food sustainability and safety, such as boosting agricultural output and increasing nutritional and food security. Actually, since its introduction into the agricultural and food sectors in 2003, nanotechnology has applications in many different industries, including environmental monitoring, crop productivity enhancement, animal feed improvement, and food processing and preservation.

CONCLUSION

Bio-nanoparticles / Nanoparticles can have positive environmental effects, such as reduced toxicity and increased solubility of pesticides. However, it's important to use nanotechnology responsibly, as there are concerns about environmental and non-target organism safety. Nanoparticles can help plants resist disease by activating their defense mechanisms or deactivating microbes. They made from metal oxides, metalloids, nonmetals, and carbon nanomaterials can kill bacteria and fungi. Nanoparticles can carry antibacterial chemicals, pesticides, and RNA-interference molecules. They can be used as biostimulants to improve plant health. Nano-biosensors can detect plant viruses early, which is important for effective disease management. Nano-fertilizers can improve nutrient uptake and increase crop yields. Nano-biochar is a sustainable soil supplement that can be made from plant or animal biomass.

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