International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 5, July-August 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Recent Advancements in Antifungal Agents for Sustainable Agriculture

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ABSTRACT

In order to prevent phytopathogenic fungi in agriculture, the use of metal nanoparticles is thought to be a suitable solution. Numerous metal nanoparticles have been created and employed as possible antifungal agents to date, including Ag, Cu, Se, Ni, Mg, and Fe. As a result, this proposal provides a thorough and critical analysis of the use of these nanoparticles to the management of phytopathogenic fungi. Due to their effective antifungal properties, Ag nanoparticles have received the greatest research attention, followed by Cu nanoparticles. It was also discovered that various metal nanoparticles, including Se, Ni, Mg, Pd, and Fe, have been studied as antifungal agents with notable outcomes. These nanoparticles, which have exhibited exceptional antifungal properties, have been created using a variety of synthetic techniques and come in a variety of forms and sizes. The effectiveness of using metal nanoparticles to control phytopathogenic fungi in agriculture is demonstrated in this review.

KEYWORDS: *Antifungal, Nanoparticles, Sustainable Agriculture*

How to cite this paper: Rahul Sinha "Recent Advancements in Antifungal Agents for Sustainable Agriculture" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-5, August 2022, pp.2161-2163, URL: www.ijtsrd.com/papers/ijtsrd51751.pdf

IJTSRD51751

1. INTRODUCTION

Since the dawn of agriculture, insects, bacteria, fungus, and other environmental pathogens have been the primary cause of pests and illnesses. This results in significant crop losses, which are represented in production with poor profitability, thus affecting earnings. Phytopathogenic fungi are one group of pathogens that cause a variety of illnesses in agriculture. Fungi can adapt to any medium with ease and may colonise a variety of substrates or media in harsh or unstable climatic circumstances. They can have an impact on the crop at several phases, including sowing, growth, production, and postharvest.

The majority of phytopathogenic fungi are now managed with inexpensive, readily available chemical agents. However, their indiscriminate usage has led to a number of issues, including environmental contamination, animal and human illnesses, and ecological imbalances. Fungi have also grown more resilient and more potent against chemical products as a result of the use of chemical agents. Biological control, plant extracts, and essential oils are being employed to manage phytopathogen fungus as effective and environmentally safe alternatives. Such choices have proven useful, thus they are regarded as wise decisions. These alternatives do have significant difficulties, though, including the impact of delays, high acquisition prices, and continuous applications that leave them open to attack [1-3].

Alternatively, the use of nanomaterials, which have been effectively employed in other industries including energy, health, and electronics, is another newly discovered and implemented option in agriculture. Because they have significantly distinct physicochemical characteristics from bulk materials, nanomaterials have grown in significance. Additionally, the physicochemical characteristics of nanomaterials depend on their size, shape, and composition. Because of these characteristics, nanomaterials are now useful in a variety of fields. Numerous uses of nanomaterials exist in the realm of agriculture, specifically in the production, processing, storage, packaging, and transportation of agricultural goods. Due to their simplicity of handling and manufacture, nanoparticles provide environmentally friendly, effective, and contemporary options that can be extremely helpful for the control of phytopathogenic diseases that can be employed as bio-manufacturing agents [4].

Numerous nanomaterials have demonstrated remarkable antifungal properties, making them a viable alternative to conventional methods of controlling phytopathogenic fungi. In particular, metal nanoparticles have received extensive research; as a consequence, they have been examined and have produced noteworthy outcomes because of their exceptional antifungal capabilities. Numerous metal nanoparticles have been created and put to use so far to manage phytopathogenic fungus. However, given that the already available studies only partially evaluate the use of metal-based nanoparticles for controlling these infections, there is currently a shortage of critical and in-depth assessments of recent advancements in the use of metal nanoparticles to control phytopathogenic fungi. As a result, this study provides a thorough and in-depth examination of the development of the use of metal nanoparticles for the management of phytopathogenic fungi in agriculture. First, a review of the potential processes by which nanoparticles affect phytopathogenic fungi is done. The development of using metal nanoparticles as possible antifungal medications is then thoroughly examined. Finally, recommendations for the future are given [5].

2. Mechanisms Involved in Antifungal Activity of Nanoparticles

Due to their excellent antifungal efficacy against a diverse range of phytopathogenic fungi, nanoparticles are a unique method for controlling phytopathogenic fungi in agriculture. Their size distribution, shape, composition, crystallinity, agglomeration, and surface chemistry are only a few of the elements that have an impact on their antifungal activity. For instance, the surface area-to-volume ratio of tiny nanoparticles favours their antifungal activity. The ability to change and regulate the aforementioned variables through synthesis pathways is well established.

Additionally, it has been shown that the method of synthesis might have a significant impact on the antifungal activity since occasionally metal precursors or surfactants are difficult to remove from nanoparticles. The surface chemistry of the nanoparticles can therefore be altered by the production residues, which will therefore have an impact on their antifungal efficacy. Finally, because each species of phytopathogenic fungus has a distinct morphological structure, this issue should not be overlooked [6].

3. Future Directions

The application of metal-based nanoparticles for the management of phytopathogenic fungi in agriculture was critically and thoroughly examined in this review. The following conclusions and suggested future directions are based on this review. The use of metal nanoparticles for the control of phytopathogenic fungi has advanced tremendously, and studies conducted to date clearly demonstrate that these nanoparticles can be an ideal substitute for conventional fungicides in the management of phytopathogenic fungi in agricultural settings [7].

The majority of research on metallic nanoparticles used as antifungal agents has focused on Ag and Cu nanoparticles. These nanoparticles have demonstrated encouraging action against a variety of phytopathogenic fungus species. Various synthesis techniques have made it feasible to create nanoparticles of various sizes and forms. The majority of the nanoparticles, nevertheless, are spherical and have a wide range of sizes. Since it is widely recognised that these characteristics affect antifungal activity, we think it vital to synthesise and analyse nanoparticles of various sizes and forms (for example, octahedrons, icosahedrons, and faceted ones). There is limited study on the other metallic nanoparticles, such as Ni, Se, Mg, Pd, and Fe. Therefore, it may be assumed that even if the synthesis techniques that have been evaluated for them have shown positive results, their antifungal activities are not well recognised. Because there are so many potential for research in this area, it is crucial to keep studying these metallic nanoparticles [8, 9].

4. Conclusions

The majority of the nanoparticles tested today as antifungal agents are monometallic. Since it has been established that bimetallic or trimetallic nanoparticles have quite different features from monometallic nanoparticles, we believe it is crucial to synthesise and test these nanoparticles for the control of phytopathogenic fungus. The majority of the investigations were examined in vitro, according to this review. To understand how phytopathogens behave outdoors, it is crucial to use the in vivo technique. Since the settings in the lab and the field are different, it is best to apply the nanoparticles directly to the pathogens. The use of metal nanoparticles in agriculture is significantly facilitated by the lack of in vivo investigations.

Acknowledgements

Author is very much gratified to Principal, Smt. Radhabai Sarda Arts, Commerce & Science College, Anjangaon Surji, Dist. Amravati, Maharashtra – 444705 for providing necessary academic help.

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