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A REVIEW ON PLANT PATHOLOGY IN THE ERA OF NANOTECHNOLOGY

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ABSTRACT

Plant diseases are a significant agricultural productivity constraint. Pesticide resistance and environmental contamination are issues that come from widespread pesticide use. It has been estimated that 20–40% of the crops are lost each year as a result of plant infections and pests. The use of hazardous pesticides in the present plant disease control strategy might be damaging to both humans and the environment. Plant pathogens have begun to be affected by the use of nanoparticles; a field of cutting-edge technology known as nanotechnology. An efficient method for controlling harmful bacteria was demonstrated by using nanoparticles as an alternative to chemical pesticides. The current approach of controlling plant diseases uses potentially harmful pesticides, which might have negative effects on both people and the environment. The use of nanoparticles in nanotechnology, a cutting-edge area of study, has started to have an impact on plant diseases. Nanoparticles have been shown to be an effective alternative to chemical pesticides for the control of dangerous microorganisms. The nanoparticles have an advantage over other commonly used chemical treatments since they are very stable and naturally biodegradable, which are linked to eco-toxicity. This study is centered on the application of nanotechnology in plant pathology for the identification and management of plant diseases, interactions between hosts and pathogens, and the microbial generation of nanoparticles, which offers plant pathologists and nanotechnologists a wide variety of prospects.

KEY WORDS: Plant pathogen, Toxic pesticides, Nanoparticles, Nano – biosensor, Disease management.

INTRODUCTION

The scientific study of plant diseases caused by pathogens (infectious organisms) and environmental conditions (physiological factors), also known as phytopathology, is known as plant pathology. Viruses, phytoplasmas, protozoa, nematodes, viroids, bacteria, oomycetes, and parasitic plants are some examples of infectious disease-causing organisms. Researchers are eager to confront the advantages of Nanoparticles by resolving any potential downsides that were discovered in the currently available diagnostic instruments (Banik and Sharma, 2011). A more complex, speedy, and accurate solution to improve phytopathology diagnostic procedures may be provided by nanotechnology (Shoala, 2019). When the size of the nanoparticles is lowered to a nano size (1-100nm), they can have certain features that make them appropriate for the creation of diagnostic probes (Banik and Sharma, 2011). Enhancing the speed and accuracy of phytopathogenic detection procedures with nano diagnostic equipment and techniques, such as Nano sensors, became vital (Shoala, 2019).

Fluorescent silica nanoprobes may make it easier

([2]Junior Scientist,*Assistant Professor) to identify plant diseases quickly. *Xanthomonas axonopodis pv. vesicatoria*, a bacterial pathogen that causes spots on solanaceous plants, was identified using fluorescent silica nanoprobes coupled with the secondary antibody of goat anti-rabbit IgG. An organic dye (Tris-2, 2'- bipyridyl) dichloro-ruthenium hexahydrate [Ru (BPY)] was injected into a silica nanoparticle with a diameter of 50 (+/-) 4.2 nm on average. The result was that the silica nanoparticles become fluorescent and photostable (Shoala, 2019). Beginning in the 1980s, The use of nanoparticles in managing plant diseases has extended to encompass plant disease detection and boosting plant immunity (Bhargava *et al.*, 2018; Elmer and White, 2018). By encouraging farming, especially when it is suffering a great loss owing to a variety of phytopathogens, nanotechnology plays a significant role in delivering healthier food (Meena *et al.*, 2021).

The properties of Nanoparticles include (Bhargava *et al.*, 2018);

1. Small size (1–100 nm) and a high surface–to–volume ratio
2. Physical qualities that can be changed by chemicals
3. Change in chemical and physical characteristics with regard to size and form
4. Despite atomic granularity, the structure is robust
5. Enhance or postpone particles

Detection and other uses of nanotechnology in plant pathology

Nanoscale biosensor/ nano sensors

Small and portable nano sensors would offer quick reaction and real-time processing with precise, quantitatively, dependably, reproducibly, robust, particular, and stable outcomes. A key part of precision farming would be the diagnosis of infection in plants that are not displaying any symptoms, followed by the targeted administration of therapy. Using micromechanical cantilever arrays, fungal spore detection was accomplished by Nugaeva *et al.* (2005) in *Aspergillus niger* and *Saccharomyces cerevisiae*. On micro-fabricated uncoated as well as gold-coated silicon cantilevers, proteins such as concanavalin A, fibronectin, or immunoglobulin G were surface grafted. It was shown that these proteins had variable degrees of affinity for the molecular structures on the fungal cell surface. Dynamically driven cantilever arrays were employed to measure the resonant frequency shift brought on by the immobilization and spore germination of the test fungus. Instead of taking many days with usual methods, this just took a few hours (Banik and Sharma, 2011). The finding that shift was proportionate to the mass of a single fungal spore may be used to make a quantitative estimate. In the research, the biosensors found the target fungus between 10 to the power 3 and 10 to the power 6 $CFUml^{-1}$ (Nugaeva *et al.*, 2005).

Nano biosensors are the fusion of biosensors with nano technology. The biosensor is a diagnostic device that transforms an electrical signal from a biological response. Nano biosensors are a mix of nano sensors and target analytic molecule-specific immobilized bioreceptor selective probes (Attaallah *et al.*, 2020). It may be utilized to detect and estimate the existence of trace amounts of phytopathogens, their metabolites, toxins, and other biohazardous elements in the agriculture and food systems. Additionally, these Using GPS links, nano sensors may be dispersed throughout several fields for real-time disease monitoring, crop health, and soil condition monitoring (Shivashankarappa, *et al.*, 2022). Additionally, it can pinpoint the ideal conditions for phytopathogen growth and spread, which will aid in managing plant pathogens and raising agricultural yields. Nano sensors may be used to identify phytopathogens or substances released by pathogens. They were created with copper nanoparticles and a gold electrode to detect phytopathogenic fungi *Sclerotinia sclerotioriim.* The created nano sensors measured the salicylic acid production rate in accordance with the anticipated fungus infection (Nugaeva *et al.*, 2005).

Enzymatic Nano Biosensors

By improving biosensing capabilities, advancements in nanotechnology have a significant influence on enzyme immobilization technology. The stability and sensitivity of biosensors have increased because to the combination of nanoparticles and enzymes. Additionally, the protection of the enzyme system inside the nano environment structure is caused by the interaction between nanoparticles and the enzyme system. Many enzymatic nanoparticle-based biosensors, including graphene, nanocomposite, nanofibers, and nanotubes, have been created as a result. Acetylcholinesterase was trapped in liposomes to create nanoparticle-enzymatic biosensors that efficiently detected the organophosphorus insecticides dichlorvos and paraoxon (Elmer *et al.*, 2018). To distinguish between pesticides including and excluding organophosphorus, these nanoparticle-enzymatic biosensors were developed (Yu Zhang *et al.,* 2018). For the detection of pesticides and aflatoxin oxidase, a biosensor immobilised on multi-walled carbon nanotubes was also developed. The detection sensitivity, stability, and repeatability of pesticide residue are improved by nanoparticle-immobilized enzyme-based biosensors as a result of enhanced surface area catalytic mode. increasing to 50 pg/liter the sensitivity and detection threshold of an enzyme biosensor for pesticides (Wu *et al.,* 2017).

Quantum Dots

With a diameter of a few nm, quantum dots are light, crystalline semiconductor particles that normally have spherical shapes (although some QDs have rod-like structures). They also have excitons that are restricted in all three spatial dimensions. QDs are the most crucial instrument for the very accurate identification of a particular biological marker in the medical profession. They have been utilised in DNA detection, in vivo imaging, cell labelling, and cell tracking (Sharon *et al.,* 2010).

Quantum dots are semiconductor crystals with nanoscale dimensions that may glow when activated by light and have special conducting qualities that depend on their size, ranging from 2 nm to 10 nm. A QD's bulk semiconductor's unusually high surface to volume ratio causes it to emit distinct electrical characteristics and molecules. Additionally, one of QDs' most notable characteristics is fluorescence, which changes depending on the nanoparticle size. These fluorophores are more accurate than organic fluorophores at determining the concentration of nucleic acids or proteins. The photo bleach resistance, preservation of 10-100 times larger molar extinction coefficient, longer fluorescence life expectancy, and low emission peak are only a few of the unique properties that QDs have (Shoala, 2019).

Carbon Nano Material as a Sensor

For electrochemical analysis, Carbon nanostructures are produced to serve as electrodes. They have been created as an electrochemical sensor to find pesticide residue in plants. Although no patent for the sole purpose of diagnosing plant illnesses using nanotechnology has yet been filed, the techniques created for diagnosing animal diseases can also be used to diagnose plant diseases (Banik, 2011).

Nanofabrication

To examine the pathogen infection process and behaviour inside host plants, nanofabrication techniques have been employed to create fake plant parts including stomata and xylem vessels. such as *Colletotrichum graminicola*, which causes anthracnose in maize, and *Uromyces appendiculatus*, which causes rust disease in beans (Basavaraja *et al.,* 2008). Breeders could benefit from this research as they look for specific stomatal traits to prevent entry into the host through stomata, leaf surface traits to stop the development of appressoriums before fungus penetration, or vascular traits to stop the movement of vascular pathogens like bacteria, fungi, etc. Or, to put it another way, it would help in the establishment of a successful breeding plan to locate or produce disease-resistant agricultural plants (Banik, 2011).

Smart Delivery

The field of nanoparticle technology is an attractive and promising one for drug delivery that is "smart" or targeted inside the biological system. This is actively being pursued in the fight against cancer (Yao *et al.,* 2020). P. Ehrlich proposed the using of nanoparticles in "smart" distribution as "magic bullets" over a century ago. *Cucurbita pepo* was treated in vitro using carbon-coated Fe nanoparticles to create a smart treatment-delivery system for plants. The Fe nanoparticle-based magnetic core allows itself to lead to a site of interest in the body (affected area) of an organism by using small magnets to create a magnetic field. In addition to providing biocompatibility, the carbon coating may be used to adsorb a wide range of molecules, including pharmaceuticals, DNA, chemicals, and enzymes.

Nanomaterial for Management of Plant Diseases

Utilising the advantages of nanomaterials for the control of plant diseases was a late development for plant pathologists. By creating nanoparticles of various metals, insecticides, and growth boosters, intriguing findings, particularly in plant disease management regards affecting fungus, bacteria, and parasite, have been attained (Banik, 2011; Bhargava, 2018).

A) Nanosized Silver

In both its ionic and nanoparticle forms, silver (Ag) is recognised to possess an antibacterial activity.

Enzyme inactivation is thought to be the cause of silver's most potent antibacterial activity, particularly in unicellular microbes (Agrawal and Rathore, 2014). The most studied and utilised nanoparticle is nanoscale silver, whose antibacterial properties have been tested against a number of pathogens that cause illness in both plants and animals. Silver is a fantastic stimulant of plant growth. Researchers examined the antifungal effects of nano silver colloids, that has a diameter of 1.5 nm, on the powdery mildew of rose by a pathogen named *Sphaerotheca pannosa var. rosae.* Silver is now a generally accepted alternative to agrochemicals, and the biggest number of patents are being submitted for "nano silver" for the preservation and treatment of diseases in the agricultural sector (Banik, 2011).

Nanosized Silica-Silver

Through the stimulation of plant physiological activity and development, silica is widely recognized to improve stress tolerance in plants, including resistance to plant diseases, although it has no specific antibacterial effects. However, as was said above, silver is well renowned for having great antibacterial properties. As a result, a novel nano silica-silver combination was created. The production and testing of the nanosized silica-silver (Si-Ag) particles against various bacterial and fungal diseases. At a concentration of 10 ppm, silica-silver nanoparticles demonstrated greater efficiency against fungus, completely inhibiting vegetative development. Silver nanoparticles of a lower size were discovered to be more efficient against fungus. Only 100 ppm of silica-silver nanoparticles totally inhibited the majority of the tested microorganisms (Wang *et al.,* 2017).

Nano-Copper

Bacterial blight of rice was one disease that nano-copper was said to be very good at combating (*Xanthomonas oryzae pv. oryzae*) and Mung leaf spot (*X. campestris pv. phaseoli*) (Varympopi *et al.,* 2022).

Nano-Iron

More research involving just humans is being done on the movement, behaviour, and therapeutic effects of nanoparticles. Similar research has been done to transport nanoparticles to the specific area of a sick plant. To cure a specific sick plant section, they sprayed iron nanoparticles coated in carbon to pumpkin plants (Patra *et al.,* 2018).

Carbon Nanotubes

Tomatoes cultivated in soil with carbon nanotubes have demonstrated an increase in growth. It is thought the carbon nanotubes that penetrated the tomato seeds as they were germinating, promoting water intake and plant development.

There are mainly two roles of nanotechnology in plant pathology

A bio barcoded DNA, quantum dots, and nano biosensors are first utilised in illness detection, and then disease control. By targeting medication delivery to pathogens through nanotubes, by enhancing plant resistance, and other methods, nanoparticles are utilised directly as antimicrobial agents to manage a variety of illnesses (Bhargava *et al.,* 2018).

Nanoparticles used in Plant Pathology: Numerous nanoparticles are employed in plant pathology. These are usually divided into the following three categories:

- **(a) Biopolymer nanoparticles:** It only has nanoparticles that are derived from living things. For instance, chitosan biopolymer, a linear polysaccharide produced from the chitin shells of prawns and other crustaceans, is made of D-glucosamine and N-acetyl D-glucosamine through alpha (1-4) glycosidic linkage.
- **(b) Metallic nanoparticles:** These are the only ones that contain metallic nanoparticles, such as mesoporous silica nanoparticles, silver nanoparticles, copper nanoparticles, zinc nanoparticles, etc.
- **(c) Nanocomposite:** It comprises composites or mixes of several nanoparticles, including carbon-coated iron nanoparticles, nano alumino-silicate, and chitosan-silver nanoparticles (Bhargava *et al.*, 2018; Kamle *et al.*, 2020).

Plant Pathogens in Biosynthesis of Nanoparticles

Production and application of nanoparticles that are made from different elements and compounds are the main components of nanoscience and nanotechnology study. Nanoparticles have a variety of functions, including the treatment of plant diseases through the use of antimicrobial compounds. There are a number of physical or chemical procedures that may be used to create nanoparticles. The synthesis of nanoparticles using biological systems, particularly microbes, is safe. Microorganisms have a number of benefits, including;

1. Biotechnology maneuverability for desired results;
2. Ease of handling, particularly with fungus
3. Production costs are low
4. Simple process scaling up
5. High efficiency
6. Eco-friendliness or green chemistry's simplicity and nature.

Metallic nanoparticles have been produced by microorganisms, which have been referred to as "Bio factories." (Shivashankarappa, 2022).

i) **Fungi:** The use of fungi in the manufacture of nanoparticles is relatively new. Fungi have replaced bacteria as the preferred natural "nano factories" due to their simplicity in the process of downstream and handling as well as the capacity to release a wide variety of enzymes. In contrast to prokaryotes, fungi are eukaryotes, making them less susceptible to genetic modification. Therefore, it would be difficult to change the genetic makeup of fungus to produce more nanoparticles. Up till now, several fungi have been used to create metallic nanoparticles. To better control the form, size, and other desirable features of the synthesised nanomaterials, its very crucial to understand the mechanism of nanoparticle synthesis in the microbial systems (Elmer and White, 2018).

ii) **Bacteria**: Prokaryotes have drawn the greatest interest among microorganisms for their role in the production of nanoparticles. Most often, silver, gold, iron sulphide (FeS), Quantum dots and magnetite nanoparticles are made up of cadmium sulphide (CdS), zinc sulphide (ZnS), and lead sulphide (PbS) have been biosynthesized by bacteria (Elmer and White, 2018).

iii) **Plant viruses:** Naturally occurring nanoparticles are plant viruses, particularly spherical/icosahedral viruses. Satellite is the tiniest plant virus discovered to date i.e, *Tobacco necrosis* virus measuring only 18nm in diameter.

Plant viruses should be employed to progress nanoscience and nanotechnology, as this is how they were intended to work by nature. They are utilised in nanotechnology because of their capacity to infect, transmit the genome to a specified location in the host cell, multiply, fuse with the nucleic acid, and leave the host cell without harming precisely and in an ordered fashion. Several different kinds of nanomaterials have been created using plant viruses as a template (Yu Zhang *et al.,* 2018).

CONCLUSION

The second craze in India after biotechnology for new research is nanotechnology, which has already had an impact in several areas of plant pathology. However, plant pathogen nanotechnological applications are still in their infancy. There are several instances of how to detect animal/human pathogens using nanosensors. There are an increasing number of papers describing the utilisation of microorganisms and plant pathogens in the production of nanoparticles. More bionanotechnological research into the physiology of the host and the pathogen, the process of infection, and illness detection will aid in developing creative disease management techniques.

By using a "smart" delivery strategy in plant systems and thoroughly defining the processes of penetration, transport, and aggregation of nanoparticles at the desired place, precision crop protection would be much improved. However, the high toxicity of nanoparticles mistakenly discharged into the environment may do more harm to people and other living creatures. The use of nano formulations to treat plant diseases is regarded to be a safer and more sustainable option. Consequently, it is important to take caution as nanotechnology develops.

Nano diagnostic methods may be successfully used to swiftly identify or diagnose phytopathogens in a short amount of time. Additionally, it could displace another cutting-edge diagnostic method. For a variety of plant infections, nano biosensors could be the rapid and effective diagnostic solution. By addressing sample collecting and transit issues and utilising on-site detection instead of changing the RNA, DNA, or protein of any samples, nano diagnostic methods have the potential to address a wide range of issues. Results were also discovered on-site without having an impact on crop output. Additionally, since lab-on-a-chip and lab-in-a-box are readily available, there is no need to transport certain equipment or facilities. "The Nano diagnostic Era" will be the following era's moniker.

Given that they may be applied directly to the target plant, nanoparticles are employed far less frequently to manage illnesses than conventional pesticides, which lowers the cost of cultivation. The using of nanoparticles by pathologists for purpose of identification and control of various pathogens is being influenced by their long-term stability, high efficacy, environmentally benign nature, and simplicity of pathogen detection.

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