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Review Article

NANOTECHNOLOGY IN PLANT DISEASE MANAGEMENT - AN OVERVIEW

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ABSTRACT

Generally, advancements in various branches of science and technology have had a significant impact on various aspects of plant pathology like efficient pathogen detection. Nanotechnology is found to have many applications of which plant pathology is the one important field. In recent years, nanotechnology has been increasingly applied to the development of novel antimicrobials for the management of pathogenic bacteria affecting agricultural crops. This review discusses the applications of different nanoparticles in plant disease management and their mode of action against the bacteria. The synthesis of nanoparticles (NPs) using biomolecules (protein, enzyme, DNA and plant extracts) have opened a new avenue of research in green nanobiotechnology. They are proved to be effective, cheap and eco-friendly in combating microbes. Reactive oxygen species production, lipid peroxidation, protein oxidation, ATP depletion and DNA degradation are some of the mechanisms by which nanomaterials used to kill bacteria.

Keywords: Nanotechnology, Plant pathology, Antimicrobial.

1. INTRODUCTION

Nanotechnology deals with the study of synthesis and applications of biomaterials between 1 nanometre and 100 nanometres in size. The term nanotechnology was initially used by Taniguchi [1] who is a professor at Tokyo University of Science during a scientific conference. Nanotechnology finds applications in different fields like medicine, industry and agriculture. Agriculture plays crucial role in nation's economy because it is the source of food supply and is the main source of raw materials for industries. The main limitation in agriculture for achieving food security is the plant disease management. Applications of nanoparticles in crop protection especially for combating the plant diseases are attributed to their unique physical and chemical properties of particles. Magnificent results were obtained in plant disease management and especially in treating bacterial and fungal diseases by using nanoparticles. The essentiality of nanotechnology lies in its ability to work at the molecular level as well as in creating large structures which are found to have new molecular organization. The main aim of nanotechnology is to exploit these properties and make use of them efficiently in various fields [2]. Nanotechnology has provided new solutions to problems in agriculture and food science (post-harvest products) and offers new approaches to enhance their applicability in plant disease management and also as a diagnostic tool in disease detection [3]. Silver, gold, silicon and other nanoparticles are identified for this purpose.

2. APPLICATION OF NANO PARTICLES IN DISEASE MANAGEMENT

Nanoparticles are synthesised in three ways *i.e.,* chemical, physical and biological methods. Biological methods are proved to be more advantageous these days. Plant-based synthesis is relatively fast and safe and works under room condition without the needs of high physical requirements [4]. Green synthesis of nanoparticles from plant extracts and microbes has become popular in these days. In the green synthesis, the biomolecules act as both reducing and/or stabilizing agents while producing (NPs). These metallic nanoparticles possess great potential and scope in plant disease management.

Several strategies are available to protect crops from the negative effects of pathogens. One such strategy is development of polymeric and lipid-based edible film layers [5]. Another strategy would be the use of metal ions, such as Zn^{2+}, Cu^{2+} and Ag^{+}, although the mechanisms are not fully understood [6]. Because of the low antibacterial activity of metal ions, many researchers have focused on the use of nanomaterials to increase antibacterial impact. This has led to the development of several types of nanomaterials, later categorized into inorganic (metallic nanoparticles such as Ag, Cu, O and TiO_2), organic (liposomes), carbon-based nanomaterials such as Carbon Nano Tubes (CNTs) and composite based nanoparticles. Here some of the applications of metallic nanoparticles in crop protection as antibiotic agents are discussed.

In the recent past, antibacterial, antifungal and antiviral properties of the metal nanoparticles such as silver, copper, zinc oxide and titanium dioxide have been intensively studied [7. 8]. Among the nanomaterials metal and metal oxides nanoparticles (NPs) that have demonstrated potential activity in combating plant diseases [9].

2.1. Gold nanoparticles

Biosynthesis and application of gold nanoparticles as antibacterial agent have become more popular due to their unique physico-chemical characteristics. Plant based synthesis of gold nanoparticles (GNPs) were reported from various plant species such as *Azadirachta indica* [10], *Emblica officinalis* [11], *Chenopodium album* [12], *Mangosteen* leaf [13] *Carica papaya, Catharanthus roseus* [14], *Garcinia mangostana* [15], *Salvia officinalis, Lippia citriodora, Pelargonium graveolens*, *Punica granatum* [16] and from the bark extract of *Mimosa tenuiflora* (Mt) [17].

Many scholars have established the potential antibacterial activity of gold nanoparticles synthesized from various plant species such as *Olea europaea* fruit extract and *Acacia nilotica* husk extract with potential antibacterial activity against *K. pneumoniae* and *Pseudomonas spp* [18]. Gold nanoparticles synthesized by *Fusarium oxysporum f. sp. cubense JT1 (FocJT1)* exhibited antibacterial activity against *Pseudomonas sp.* [19]. The mechanism of the inhibitory effects of Gold ions on microorganisms is partially known. Some studies have reported that the positive charge on the Gold ion is crucial for its antimicrobial activity through the electrostatic attraction between negative-charged cell membrane of microorganism and positive-charged nanoparticles [20].

2.2. Copper nanoparticles

Copper oxychloride and copper sulphate are in practice for the treatment of different fungal diseases of apple for many years. Many reports suggest that copper nanoparticles exhibit broad antimicrobial activity against many bacteria. But the application of copper bactericides over the time resulted in evolution of copper-tolerant strains found while controlling diseases such as bacterial spot caused by *Xanthomonas perforans* which is the most prevalent disease of tomatoes. In such case, nano copper was reported to be highly effective in controlling bacterial spot caused by *Xanthomonas perforans* [21]. For more than two centuries, due to its antimicrobial properties, copper-based nanostructures have become excellent alternatives to control plant diseases. Copper has been used in inhibiting the growth of microorganisms for more than two centuries and reportedly decreased the microbial concentration to least significant amounts [22, 23]. Bactericidal properties of copper nanoparticles are further established by many authors [24-26]. Reports obtained in support of the antimicrobial activity of nano copper oxide (CuO) against various bacterial species such as *E. coli* and *Bacillus subtilis* [27, 28]. The antibacterial activities of CuO NPs have also been confirmed against *S. aureus, Bacillus subtilis, P.aeruginosa* and *E. Coli* [29]. There are reports demonstrating effectiveness of copper nanoparticles extracted from Eucalyptus and Mint in treating the disease caused by *Colletotrichum capsici* [30].

2.3. Silver nano particles

Silver is known to have antimicrobial activity from ancient times and silver nanoparticles are applied vastly in treating unicellular microorganisms is believed to be brought about by enzyme inactivation [31]. Silver nanoparticles (AgNPs) are mostly plant-based, sources ranged from fungi, algae to higher plants. Examples of green synthesis of silver nanoparticles are available [32]. They possess unique physical and chemical properties over the other nanoparticles including large surface area and high electrical conductivity [33]. Owing to their distinctive features, they have been used in several fields, such as agriculture, industries, health and even in cosmetology. Silver nanoparticles are most investigated and best utilized against many disease-causing pathogens of plants. Usaually, precursors are used during the process of green synthesis. Silver nanoparticles synthesized using silver nitrate as the metal precursor and hydrazine hydrate as a reducing agent showed high antimicrobial activity against Gram positive bacteria [34].

Application of silver nanoparticles against microbial diseases was reported that leaf extracts of *Acalypha indica* can be used to synthesize silver nanoparticles which proved to be a potent antibacterial agent against *Alternaria alternate* [35]. Two medicinally important plants *Cucurbita pepo* and *Malva crispa* were also reported for synthesis of silver [36] and gold nanoparticles [37, 38] with potent antibacterial agent against pathogens. There were reports [39] suggested that silver nanoparticles (AgNPs) are also used to enhance seed germination and plant growth apart from being used as antimicrobial agents to control plant diseases.Similarly, silver nanoparticle is effective against citrus fruit fungal pathogen viz., *Alternaria alternata*, *Penicillium digitatum*, and *Alternaria citri* [40]. Nanosilver colloids showing antifungal activity against *Sphaerothecapannosa Var. Rosea* which causes powdery mildew in roses.

Application of silver in management of plant diseases has been tested by researchers [41] with reference to two fungal pathogens of cereals viz. *Bipolaris sorokiniana* (spot blotch of wheat) and *Magnaporthe grisea* (rice blast). AgNPs exhibit concentration-dependent anti-microbial activity against *Escherichia coli, Aeromonas hydrophila*, and *Klebsiella pneumonia* [42].

In recent years, nanotechnology has been increasingly applied to the development of novel antimicrobials for the management of pathogenic bacteria affecting agricultural crops, humans and animals. In particular, significant development in nanomaterials synthesis, such as polymeric, carbon-based and metallic, has attracted researchers' attention towards applications in managing plant diseases caused by bacteria.

2.4. Zinc nanoparticles

Zinc oxides appeared to be very important antimicrobials and the synthesis of zinc nanomaterials in large quantities is very easy. Several studies have revealed the antibacterial activity of zinc nanoparticles against *P. aeruginosa* [43] and *Staphylococcus aureus* [44]. NPs in precise have revealed broad-spectrum antibacterial properties against both Gram-positive and Gram-negative bacteria.

3. MECHANISM OF ANTIMICROBIAL ACTIVITY BY NANOPARTICLES

The antimicrobial activities of NPs are often thought to be operated by multiple mechanisms such as metal ion release, non-oxidative processesand oxidative stress and cell destruction [45]. All these mechanisms are interconnected and interdependent and operate in simultaneous manner.

Many recent studies found that the major processes of antibacterial effects of NPs comprise the disruption of the bacterial cell membrane, generation of ROS, piercing into the bacterial cell membrane. Initiation of antibacterial effects inside the cell includes interfering with important molecular pathways such as DNA replication and inhibition of protein synthesis [46, 47]. Experimental results reveal that silver nanoparticles damage the bacterial cell by causing over production of ROS [48]. The over production of ROS is the most important mechanisms by which nanotechnology applied to plant disease management. Silver nanos showed bactericidal activity against bacterial plant pathogens *Xanthomonas axonopodis* pv. *punicae* and *Ralstonia solanacearum* by the way of generation of ROS in pathogen [49].

The most possible mechanisms operated by nanoparticles to kill pathogenic bacteria comprise alteration of membrane properties. Nanoparticles cause the release of ROS which interact with the membrane lipids and ultimately disturb the membrane integrity. This could lead to the perforated membrane and disturbance in permeability of the membrane finally lead to cell death [50].

AuNPs cause pathogenic DNA damage by interfering with the transcription process [51]. Similarly, Studies demonstrated the antibacterial mechanism of AuNPs operate at various levels of transcription and protein synthesis [52, 53].

The main bactericidal activity by nanoparticles is achieved by deactivation of various enzymes. Galctosidase is a common enzyme, found to be inhibited by zinc oxide nanoparticles (ZnO) [54]. Silver nanoparticles are highly effective for antimicrobial activity by forming stable bonds with thiol groups of bacterial enzymes. They actively combine with the enzymes of the plasma membrane causing alteration in cell membrane permeability and hinder synthesis of ATP [55].

Studies reveal that silver nanos inhibit the NADH dehydrogenase II enzyme and succinate dehydrogenase enzymes [56]. The results [57] suggested that the Ag NPs show antibacterial activity against *E. coli* by changing the expression of several proteins.

Owing to various mechanisms of antibacterial action exhibited by Silver NPs (Ag NPs), they have been widely using in plant disease management [58]. One such mechanism established that when AgNPs come into contact with moisture, the AgNPs elute Ag^{+} ions. These silver ions disable the microbial growth processes [59].

4. LIMITATIONS

The nanoparticles are found to show several adverse effects on plant, animals and environment. When airborne, nano pesticides deposit on plant leaves and floral components. They may close stomata, occasionally stop pollen germination and even prevent pollen tubes from penetrating stigma. The NPs are believed to infiltrate the vascular tissues and obstruct mineral and water transport.

The detrimental effects of nano-silver on plants and microorganisms were found that nano silver treatment affected several plant species and changed the biomass, extracellular enzyme activity and makeup of the microbial community [60]. More studies are needed on the entry and bioaccumulation of NPs in the food chain and their interactions with other environmental contaminants.

Nanoparticles might enter the human beings and cause damage to vital organs. It is believed that the use of chemically produced nanomaterials are generally regarded as being harmful to the environment, it is now possible to create nanoparticles from plant systems, which is known as green nanotechnology [61]. Green nanotechnology is a safe method that uses less energy, produces less wasteand emits fewer greenhouse gases. These processes have less impact on the environment because renewable materials are used in their manufacturing [61, 62].

5. CONCLUSION

Largely, plant disease management makes use of chemical-based pesticides. Non judicious use of conventional pesticides has led to the rapid development of resistance to pesticide and adverse effects on human health and environment. Use of chemical pesticides and insecticides cause environmental problem as they are used in improper doses and they reach the soil and water bodies, in turn they reach food chain. To overcome this problem people started finding ways to manage diseases. Researchers are prompted to identify nanotechnology an alternative antimicrobial agent for crop protection which is eco-friendly. There is no any doubt that nanotechnology is useful for the sustainable management of agriculture.

Although there is a vast knowledge about specific nanomaterials is available, the toxicity level of many NPs is still unknowable. As a result, the application of these materials is constrained due to the lack of understanding of risk assessments and effects on human health, without decontamination of soils and waters. Although there may be certain restrictions, crop protection with nanoparticles has a wide range of potent applications.

Conflict of interest

None declared

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