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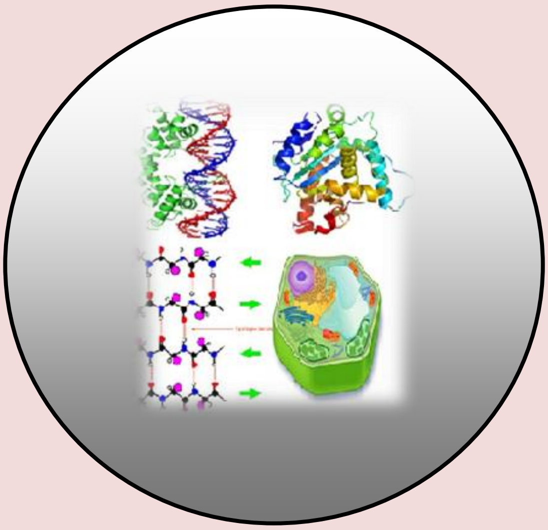

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RESEARCH PAPER

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Biogenic Silver Nanoparticles as Potential Fungicide against *Fusarium* Wilt Disease

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ABSTRACT

Fusarium wilt is causes 10-50 % crop loss every year. A wide range of chemical fungicides are used to control wilt and it has become a serious problem for the human health. Biofungicides may be a potential alternative but these have been observed to have slow and least effects on field. In order to find more alternatives, use of nanoparticles as fungicide is increasing and has been shown as an alternative solution to control plant pathogens. This review is contributed towards exploring the possible aspects of silver nanoparticles as a potential fungicide against Fusarium wilt.

Keywords: Fusarium, silver nanoparticles, biogenic synthesis, nanopesticides, wilt disease.

INTRODUCTION

In India more than 60% of the population relies on crops for their livelihood. However, crop pathogens are one of the major limiting factors for crop production. Control of plant diseases is the most challenging aspect of crop production. Among all microorganisms causing diseases in plants, fungi cause a significantly higher percentage of diseases in agricultural field (Gilligan, 2007).

Wilt caused by *Fusarium oxysporum* is a deadly vascular wilting syndrome in many plants from different family (Table 1). It is a common fungal disease on many crops and it is spotted on tomato, potato, dragon fruit, watermelon plants and other cucurbits, and so forth (Gordon, 2017). On a rough estimate, *Fusarium* wilt causes 10-50% crop loss every year (Mace, 2012). Most *F. oxysporum* strains lives as saprophyte on organic substrates. However, some strains cause root rots and wilt diseases. Other *F. oxysporum* strains are effectively used as biocontrol agents. *F. oxysporum* is a very complex group, divided into *Formae* species and physiological races depending on their pathogenicity towards particular plant species or cultivars (Fravel et al., 2003). *F. oxysporum* produces chlamydospores, macroconidia and microconidia (Ohara et al., 2010).

Table 1. List of *Fusarium oxysporum* causing wilt disease in different plants.

Fusarium oxysporum formae-species	Affected crop	Reference
Fusarium oxysporum batatas	Sweet potato	Smith and Snyder, 1975
Fusarium oxysporum cubense	Banana	Ploetz, 1990
Fusarium oxysporum lycopersici	Tomato	Jacobs et al., 2013
Fusarium oxysporum melonis	Muskmelon and cantaloupe	Schmidt et al., 2016
Fusarium oxysporum pisi	Pea	Hepple, 1963

Now days, the use of commercially available fungicides for phytopathogenic fungi has been increased and it has become a serious problem for the human health (Carmona-Hernandez et al., 2019). Biofungicides may be a potential alternative but these have been observed to have slow and least effects on field. In order to find more alternatives, use of nanoparticles as fungicide is increasing and has been shown as an alternative solution to control plant pathogens (Sharma et al., 2017). Currently, the treatment of crops using chemical fungicides before planting is the common used method to protect tomato and other plants from *F. oxysporum* infection. The application of chemical fungicides shows adverse effects on other living organisms including the useful soil microorganisms (Akbar et al., 2009). The antifungal effects of silver nanoparticles were measured against eighteen plant pathogenic fungi including genera of *Alternaria, Botrytis, Cladosporium*, *Corynespora*, *Cylindrocarpon*, *Fusarium*, *Pythium*, *Stemphylium* (Kim et al., 2012).

NANOTECHNOLOGY

Novel applications of nanoparticles are growing rapidly on various fields due to their completely new or effective properties, based on their size, distribution and morphology. It is showing renovation in a large number of fields such as health care, beauty products, food and fooder, drug-gene delivery, environment, health, mechanics, optics, chemical industries, electronics, space industries, energy science, catalysis, light emitters, single electron transistors, nonlinear optical devices and photo-electrochemical applications (Salata, 2004). Among the all noble nanoparticles, silver nanoparticles has gained boundless interests because of their unique properties such as chemical stability, good conductivity, catalytic and most important antibacterial, anti-viral, antifungal in addition to anti-inflammatory activities which can be incorporated into composite fibres, cryogenic superconducting materials, cosmetic products, food industry and electronic components (Ahmed et al., 2016). Biomedical applications such as wound dressings, topical creams, antiseptic sprays and fabrics, silver functions' as an antiseptic and display a broad biocides effect against microorganisms through the disruption of their unicellular membrane thus disturbing their enzymatic activities. These silver nanoparticles are being successfully used in the cancer diagnosis and treatment as well (Zhang et al., 2016). Synthesis of silver nanoparticles is the most valuable for scientific community because of their wide range of applications. The silver has been known for its natural antibacterial and antifungal properties over 100 years (Prabhu and Poulose, 2012). According to Dakal et al. (2016) silver nanoparticles are very reactive and inhibit microbe's respiration and their metabolism; suppresses electron transfer systems and transport of substrates in the microbial cell membrane as they cause physical damage. However attention is currently focused on plant mediated nanoparticles due to harmful effects of nanoparticles in plant protection.

SYNTHESIS AND CHARACTERIZATION OF BIOGENIC SILVER NANOPARTICLES

Leela and Vivekanandan (2008) reported, tapping the unexploited plant resources for the synthesis of silver nanoparticles. The bioreduction behaviour of various plant leaf extracts such as *Helianthus annus*, *Basella alba*, *Oryza sativa*, *Saccharum officinarum*, *Sorghum bicolour* and *Zea mays* in the synthesis of silver nanoparticles was investigated employing UV/Visible Spectrum (UV-Vis), X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). Shankar et al., (2008) reported geranium leaf assisted biosynthesis of silver nanoparticles. The aqueous solution silver nitrate mixed with geranium leaf extract; give the rapid reduction of the silver ions. That's leading to the formation of highly stable, crystalline silver nanoparticles in solution.

Mude et al., (2008) reported the first report of synthesis of silver nanoparticles by using callus extract of *Carica papaya*. Bar et al., (2009) reported green synthesis of silver nanoparticles using seed extract of *Jatropha curcas*. Raut et al., (2010) reported extracellular synthesis of Silver Nanoparticles using dried leaves of *Pongamia pinnata* (L) Pierre. Stable and crystalline silver nanoparticles were formed by the treatment of aqueous solution of AgNO3 (mM) with leaf extract of *Pongamia pinnata* (L) Pierre. Singhal et al., (2010) reported biosynthesis of silver nanoparticles using *Ocimum sanctum* (Tulsi) leaf extract and screening its antimicrobial activity. Ankanna et al., (2010) reported production of biogenic silver nanoparticles using *Boswellia ovalifoliolata* stem bark. Rajani et al., (2010) reported fabrication of biogenic Silver Nanoparticles using agricultural crop plant leaf extracts of *Vigna radiata, Arachis hypogaea, Cyamopsis tetragonolobus, Zea mays, Pennisetum glaucum, Sorghum vulgare*. Dubey et al., (2010) reported green synthesis and characterizations of silver and gold nanoparticles using leaf extract of *Rosa rugosa.* Rajasekharreddy et al., (2010) reported qualitative assessment of silver and gold nanoparticle synthesis by leave extract of the plants, *Tridax procumbens* L., *Jatropa curcas* L., *Calotropis gigantean* L., *Solanum melongena* L., *Datura metel* L., *Carica papaya* L. and *Citrus aurantium* L. by the sunlight exposure method. Among these *T. procumbens*, *J. curcas* and *C. gigantean plants* synthesized <20 nm sized and spherical-shaped Ag particles. Geethalakshmi and Sarada (2010) reported synthesis of plant-mediated silver nanoparticles using Trianthema decandra extract and evaluation of their anti microbial activities. Zhang et al., (2010) reported synergetic antibacterial effects of silver nanoparticles synthesized by *Aloe vera* exract. Vaseeharan et al., (2010) reported antibacterial activity of silver nanoparticles (AgNPs) synthesized by tea leaf extracts. Konwarh et al., (2011) reported biomimetic preparation of polymer- supported free radical scavenging, cytocompatible and antimicrobial green silver nanoparticles using aqueous extract of *Citrus sinensis* peel. Bankar et al., (2010) reported banana peel extract mediated novel route for the synthesis of silver nanoparticles. Bio- inspired silver nanoparticles were synthesized with the aid of a novel, non-toxic, eco-friendly biological material namely, banana peel extract (BPE). Zahir et al (2012) synthesis of Silver nanoparticles (Ag NPs) by using aqueous leaves extracts of *Euphorbia prostrata.*

ANTIFUNGAL EFFECT OF SILVER NANOPARTICLES AGAINST FUSARIUM:

Kim et al., (2012) examined the potential antifungal activity of silver nanoparticles (3, 5, 8 and 10 nm) on *Fusarium oxysporum* f. sp. *lycopersici* (FOL) isolates. Results also showed that the most significant inhibition of plant pathogenic fungi was observed on PDA and 50 ppm of silver nanoparticles. Alananbeh et al., (2017) studied antifungal effect of silver nanoparticles on selected fungi isolated from raw and waste water and concluded that it is possible to use silver nanoparticles as antifungal substances. Ruiz-Romero et al., (2018) studied application of biogenic silver nanoparticles from *Yucca shilerifera* leaf extract against *Fusarium solani* and *Macrophomina phaseolina* and concluded that AgNPs from leaf extracts of *Y. shilerifera* may be used as an agent of biocontrol of microorganism of importance. Abkhoo and Panjehkeh (2017) established that different concentrations of AgNPs inhibit colony formation of *F. oxysporum* at different levels. Al Abboud (2018) concluded that AgNPS at concentrations of 20, 40 and 80 ppm inhibited the *F. oxysporum* growth by 12.5, 12.5 and 61.11%, respectively. Villamizar-Gallardo et al., (2016) showed that AgNPs have a positive inhibitory effect in plant tissues, especially in the cortex, when infected with *F. solani*. Elamawi et al., (2018) prepared biological silver nanoparticle synthesized extracellularly by using the fungus, *Trichoderma longibrachiatum*, where the cell filtrate of the fungus was used as a reducing and stabilizing agent in the process of nanoparticle synthesis. The use of AgNPs as antifungal led to significant reductions in the number of forming colonies for many plant pathogenic fungi, with efficiencies reaching up to 90% against *Fusarium verticillioides* and *Fusarium moniliforme*. Xue et al., (2016) applied biosynthesized AgNPs that showed considerable activity against the tested fungal strains, including *Candida* spp., *Aspergillus* sp, and *Fusarium* sp, especially *Candida* sp.

CONCLUSION

Various reported researches have proven that biogenic silver nanoparticles have been found to be an ecofriendly and potential fungicide against *Fusarium* wilt. However, a greater deal with research, development and policy making is still required to use them as an alternative to harmful chemical fungicides at agricultural field level.

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