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Green Synthesis of Silver Nanoparticles: Antifungal Efficacy Against Aspergillus Niger and Agricultural Benefits

Anshu Tomar[1,]*

Abstract

Silver nanoparticles (AgNPs) are gaining significant attention in agriculture due to their potent antifungal properties. This study focuses on evaluating the antifungal effects of green synthesized AgNPs derived from Aloe vera leaf extract against the pathogenic fungus Aspergillus niger. The results indicate that the synthesized nanoparticles exhibited a strong absorption maximum at 550 nm, indicative of surface plasmon resonance. UV-Vis spectroscopy was used to analyze the nanoparticles, and the solution exhibited faint red color characteristics. The synthesized AgNPs demonstrated significant antifungal activity against Aspergillus niger. To assess this, silver nanoparticle solution was mixed with PDA media and poured into petri plates, onto which fungal discs were placed. After incubating for 24-48 hours, it was observed that the fungus did not grow on the media containing the silver nanoparticle solution. These findings suggest that Aloe vera leaf extract-based silver nanoparticles have a promising potential for controlling pathogenic fungi. Additionally, the application of AgNPs was found to enhance morpho-physiological attributes in wheat and reduce nanoenzymatic compounds and antioxidant enzyme levels. This study underscores the potential of green synthesized AgNPs not only as a biological control agent for various fungal species but also as a means to improve agricultural productivity. Further research is needed to explore the size-dependent efficacy of AgNPs on different fungal species and to fully understand their impact on crop health and yield.

Keywords: Nanoenzymatic, fungal species, spectroscopy, AgNPs, Aspergillus niger

INTRODUCTION

About 40% of the world's population consumes wheat, making it one of the most important and abundant cereal crops [1]. It is considered as the second staple after rice. Due to its excellent nutritional value, wheat provides carbohydrates and protein for more than 21% of the world's population. Wheat is the most important crop in Pakistan; It adds 10% value to agriculture and 2.2% to the country's GDP. Even so, the country dwarfs global wheat production [2].

***Author for Correspondence**
Anshu Tomar
E-mail: anshuonline123@gmail.com

[1]Student, Department of Biotechnology, Chaudhary Charan Singh University, Meerut, Uttar Pradesh, India

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Fungal pathogens are the main culprit behind the 12.5% of annual losses caused by wheat disease worldwide. Major fungal diseases like rust, smut and blight caused significant losses in wheat production in India and many other countries. *Aspergillus niger*, the fungus responsible for black rust, is the main natural stress and pathogen affecting wheat.

It is a major cause of yield reduction, which can range from 20% to 50% depending on the time of year, region and season of wheat growth. The disease caused significant economic losses in many parts of the Americas, Europe and Australia. On wheat the Black rust appears as large, elongated and brown pustules on stem, leaf, and sheath. These brown stems will then develop into large black flowers [3].

The development of resistant maize varieties and fertilizers are the best-known methods of controlling fungal infection. While antifungals have been shown to be effective against serious fungal diseases, they also cause unintended consequences and threaten human health. *Aspergillus niger* is a rapidly spreading plant pathogen, causing epidemics in species that were thought to be immune to other diseases and pathogens. The use of modern agricultural technologies reduces the use of hazardous chemicals in agriculture and can be new ways of increasing productivity [4].

Fungal Diseases

Fusarium graminearum commonly infects barley if there is rain late in the season. *Fusarium* contamination in barley can result in head blight, and in extreme contaminations, the barley can appear pink. It can also cause root rot and seedling blight [5].

Figure 1 illustrates barley crops infected by Fusarium graminearum. Priest and Campbell estimated that the total losses of barley and wheat crops in the US from 1991 to 1996 amounted to $3 billion.

Fusarium xyrophilum was shown to be able to infect other plants by producing fake flowers, tricking bees and other pollinating insects into visiting them, and hijackinga South American variety of yellow-eyed Xyris grass in 2021 [5].

Puccinia Striiformis Westend. F. Sp. Tritici (Pst), a pathogen that is particularly abundant in temperate locations with chilly and rainy weather conditions, is the disease that causes wheat stripe (yellow) rust. In Figure 2 you can see that wheat plant is affected by *Puccinia striformis* due to which yellow rest is developed on the plant. With production losses of up to 100% in vulnerable cultivars, stripe rust is now the most commercially significant wheat rust disease.

Puccinia graminis f. Sp. *Tritici* is one of the most harmful diseases to durum and common or bread wheat in the globe. In Figure 3 wheat plant is affected by *Puccinia graminis* due to which black rust is developed. *Puccinia graminis* can significantly reduce yields in cultivars that are sensitive by infecting stems, leaves, and occasionally heads and awns. This condition is dark reddish-brown pustules that can develop on both sides of leaves, stems, and spikes and contain masses of urediospores. The disease can spread more easily in conditions of mild temperature and poor humidity (rain or dew). The first generation of urediospores will develop in 10 to 15 days at about 20°C. The impact of an infection during the early stages of crop growth can be significant, lowering tillering and grain production [6].

Triticale’s chromosomes 2R and 3R are the important carriers of stem rust resistance genes in hexaploid triticale.

		
Figure 1. Barely crop contaminated by *Fusarium graminearum*	**Figure 2.** Yellow rust is developed by *Puccinia striformis* on wheat plant	**Figure 3.** Wheat plant is affected by*Puccinia graminis*

Fungal Wheat Diseases

In almost all of the world's wheat-growing regions, *Puccinia striiformis* f. Sp. *Tritici*-caused leaf rust poses a production risk. Figure 4 Brown rust caused by Puccinia striiformis When susceptible cultivars are used, yield losses of 10% to 70% have been experienced in most wheat-producing countries. Leaf rust reduces yield, grain quality, and forage value. This condition is indicated by cylindrical or spherical cysts smaller than wood rust, generally not fused, and containing clusters of orange-orange-brown chromosomes. Most transition zones are located in leaves and leaf apices; Sometimes affects neck and ons.

Powdery Mildew

An obligate, biotrophic ascomycetous fungus called *Blumeria graminis* sp. *Tritici* causes wheat powdery mildew in the late winter and early spring. Any section of the plant that is above ground might develop this disease, but the upper surfaces of the lower leaves tend to be the most affected. Symptoms take the form of rub-off able tufts of white cottony mycelium on leaves and leaf sheaths. Under the mycelium, the leaves are light yellow. Figure 5 Powdery mildew caused by *Blumeria gramini.*

Loose Smut

Loose smut (*Ustilago* tritici) is a disease that affects wheat all over world. In Figure 6 you can see that Loose smut caused by *Ustilago tritici***.** This seed borne fungus survives from crop to crop in the embryo and is disseminated with the grain, making it spread easily but difficult to control. The fungus is protected within the seed and grows with the growing point of the wheat plant. The disease appears as a mass of loose brown spores replacing the tissues of the spike.

Black Rust

Puccinia graminis f. Sp. *Tritici* has historically been a prominent cause of wheat stem rust in Figure7. It is often referred to as wheat's black rust. It ranks among the top 10 fungal infections that can cause catastrophic crop losses due to historical yield reductions of wheat. For long years, stem rust was a terrible disease that affected wheat and other cereals [7]. It was eliminated after making numerous management adjustments, but stem rust returned. Because the stem rust pathogen is an obligatory parasite that feeds biotrophically, it needs more living hosts to complete its life cycle. The pathogen is a member of the phylum Basidiomycota and differs from other fungi in that, like the previously discussed leaf rust, it generates five distinct spores to complete its life cycle. Uredinia begins to create infection urediniospores 1-2 weeks after the onset of the illness.It is the phase of the life cycle that repeats itself. On a separate stalk within the fruiting body, urediniospores are formed in a dikaryotic manner. Host plants infected with this parasite may also develop visible symptoms Because of the darkening of its redrusty spores, it is often referred to as black rust. Crops produce teliospores in their oilseeds until the end of their growing season [8].

Teliospores are likewise dikaryotic and may survive the winter without a host. Teliospores can undergo meiosis under the right circumstances, which results in the production of haploid basidiospores, which are colourless spores that can infect non-cereal hosts but not cereal ones. After germination, it generates sticky honeydew known as pycnidiospore, which attracts insects and serves as a means of perpetuation. In aecia, pycnidiospores mat and develop dikaryotic aeciospores. The cereal host, not the alternative host, is where these aeciospores germinate and create urediniospores. Winter wheat can transmit urediniospores to spring wheat. Without contaminating the substitute host. The ideal temperature is 30°C, and two hours of dampness on the leaf can result in infection [6,9]. UG-99, JRCQC, MCC, QCC, QCCJ, QCCJB, QCCS.

The species identified include QFCS and TPMK, all of which have been found in different parts of the world at different times. Figure 7 Black rust is caused by *Puccinia graminis*.

Figure 4. Brown rust caused by Puccinia striiformis

Figure 5. Powdery mildew caused by *Blumeria gramini*

Figure 6. Loose smut caused by *Ustilago tritici*

Figure 7. Black rust is caused by *Puccinia graminis*

CONCLUSION

In conclusion, the study demonstrates that green synthesized silver nanoparticles (AgNPs) derived from Aloe vera leaf extract exhibit potent antifungal properties against Aspergillus niger, with significant inhibition of fungal growth observed. These nanoparticles, characterized by UV-Vis spectroscopy, showed a strong absorption maximum at 550 nm, confirming their effective synthesis. AgNPs have been used to reduce the levels of anti-inflammatory enzymes and nanoenzymatic compounds, enhance wheat morpho-physiological properties, and effectively control fungal pathogens [10]. These findings highlight the potential of Aloe vera-based AgNPs as a sustainable and effective biological control agent in agriculture. However, further research is necessary to evaluate the efficacy of AgNPs against a broader range of fungal species and to optimize their use for improved crop protection and productivity.

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