

Fungal-Mediated Myco-Nanoparticle Synthesis Using *Fusarium* Species

Archana Mahakalkar¹, Hariprasad M. Paikrao^{2*}, Tisha Ramteke³, Sakshi Fulke³

Abstract

*Green synthesis of nanoparticles is a developing technology known for its safe and environmentally friendly approach. Fungi possess essential features in fabricating biogenic nanoparticles of different metals due to their enzymatic capabilities. Myconanoparticles derived from *Fusarium* species are synthesized in multiple stages. The most utilized species for nanoparticle creation are *Fusarium oxysporum* and *Fusarium solani*. This study aims to investigate the growth and conduct microscopic inspection of *Fusarium* sp. The extraction was achieved endogenously and exogenously, and later the extract was utilized for the synthesis of silver nanoparticles. The enzymatic activities of *Fusarium* extracts, such as reductase and oxidoreductase, play a significant role in fungal-mediated biogenic synthesis of silver nanoparticles. The synthesis was optimized and subsequently, the nanoparticle characterization was carried out using UV-visible spectroscopy and Fourier-transform infrared spectroscopy. The present paper discusses the significance of silver nanoparticles over other metal nanoparticles, such as zinc, titanium oxide, platinum, and magnetite, in terms of stability, shape, size, and biological activities. Biogenic nanoparticles can be employed for several applications such as in forensic science, agriculture, and pharmaceuticals. The synthesized nanoparticles are useful for the development of nano-biosensors to detect bodily fluids, such as semen, saliva, sweat, etc., from the crime scene in forensic investigations, along with onsite detection of drugs of abuse. Similarly, the applications of silver nanoparticles include fabricating diagnostic biosensors for non-invasive detection of marker analytes in various diseases such as cancer. The nanoparticle-mediated drug delivery can be utilized using fungal-mediated silver nanoparticles and will have the advantage of biological compatibility over chemically synthesized nanoparticles.*

Keywords: Nanotechnology, forensic, myco-nanoparticles, fungi, *Fusarium oxysporum*

INTRODUCTION

The significance of a billionth of a portion is indicated by the term “nano,” which represents 10⁻⁹ meters. The term “nanotechnology” (NT) was first used in public in 1974 by renowned Japanese scientist Norio Taniguchi, whose research focused on finding methods to control certain dimensions of

*Author for Correspondence

Hariprasad M. Paikrao

E-mail: harish.paikrao13@gmail.com

¹Assistant Professor, Department of Zoology, Institute of Science, Nagpur, Maharashtra, India

²Assistant Professor, Department of Biology, Government Institute of Forensic Science, Nagpur, Maharashtra, India

³UG Student, Government Institute of Forensic Science Nagpur, Maharashtra, India

Received Date: January 05, 2026

Accepted Date: February 09, 2026

Published Date: February 20, 2026

Citation: Archana Mahakalkar, Hariprasad M. Paikrao, Tisha Ramteke, Sakshi Fulke. Fungal-Mediated Myco-Nanoparticle Synthesis Using *Fusarium* Species. International Journal of Applied Nanotechnology. 2026; 12(1): 8–17p.

materials that fell within the nanoscale range. The precision manufacturing of materials at the nanoscale level was disclosed in a paper by Tokyo Science University professor Norio Taniguchi in the spring of 1974 [1]. A DNA strand has a width of only 2.5 nm, to put it in nanoscale terms. The breadth of a hair is 0.080 mm, a red blood cell is 7000 nm, and a molecule is 5 nm. Nanoparticles (NPs) are created by microorganisms in the field of green nanotechnology. It is well known that a vast range of microbes can produce NPs by combining inorganic components, either inside or outside their cells. The process of producing metal nanoparticles (NPs) is important, even if a wide variety of microorganisms can do so.

Microbial synthesis of nanoparticles (NPs) is an environmentally friendly chemical process that integrates nanotechnology and microbial biotechnology. Reports indicate that bacteria, actinomycetes, fungi, yeasts, and viruses have been shown to biosynthesize nanoparticles such as platinum, selenium, magnetite, titania, zirconia, uraninite, and tellurium nanoparticles [2]. According to a survey of 502 nanoproducts, silver nanoparticles (AgNPs) are now one of the most often employed nanomaterials in consumer goods (104 of them) [3]. The precise mechanism by which AgNPs prevent and suppress the growth of fungi that cause diseases is unknown.

Although several possible causes have been explored by researchers, the exact mechanism is still unknown. It is believed that bacteria need an enzyme to break down oxygen To survive. Silver ions damage the enzyme and halt oxygen metabolism. As a result, the bacteria and fungi are suffocated and eventually die [4]. Fungal enzymes can attach to metal ions in liquids and convert them into nanoparticles (NPs). UV-Vis spectroscopy is used to study the reaction's kinetics, and high-resolution transmission electron microscopy (TEM), energy-dispersive X-ray (EDX), and X-ray diffraction (XRD) are used to further characterize the reaction. In addition to interacting chemically and physically with nanomaterials, microbes can also occasionally produce materials including nanostructures. The aforementioned biosorption method is preferred because of its large-scale availability, low cost, naturally occurring nature, high biosorption capacity, regenerative ability, and verified 100% selective adsorption of metal ions.

Metal nanoparticle mycosynthesis, also known as myconanotechnology (MNT) [5, 6], is the process by which fungi are used in NT to synthesize NPs. There has been a lot of interest in using filamentous fungi as production microorganisms in biotechnology due to their capacity to thrive on widely accessible, low-cost substrates and their synthesis of a variety of metabolites with commercial interest [7, 8]. Nanodiagnosics encompasses a range of techniques, including gene transfer, specific targeting, gene expression analysis, gene sequencing, gene regulation studies, bioimaging, DNA targeting, DNA extraction, DNA hybridization, and cell sorting [9]. According to preliminary research, nanomaterials may be able to enhance disease identification, plant protection, pesticide/herbicide residue detection, and seed germination and growth [10]. The utilization of MNT to battle infections in crop production and the overview of fungal and genetic alterations in plants help to attain agricultural sustainability. With its plethora of rapidly expanding applications, nanotechnology is slowly becoming the most exciting field of scientifically grounded research. There is also the issue of having to come up with new techniques to produce nanoparticles with the least amount of energy, effort, and money. Researchers looking to create medicinal nanoparticles (NPs) may find fungi to be a suitable organism. Efforts being made worldwide to employ fungi for the staining of microorganisms and their potential applications in the medical field are thus examined.

Synthesis of Myconanoparticles

It has recently come to light that a novel method to produce metal nanoparticles is the utilization of microbial cells to produce nanoscale materials [11]. A growing number of researchers are employing several fungi that are known to encourage the growth of plant branches such as *Fusarium*, *Aspergillus*, *Verticillium*, and *Penicillium*. These fungi possess amazing qualities for the synthesis of nanoparticles, yet this might be a constraint. Numerous fungal species possess the ability to effectively penetrate the vestibules of plant development, which function as portals to the interior. This is the process by which living things produce NPs in their extracellular and internal surroundings.

The main challenge for this purpose is to synthesize metal NPs with controlled sizes, shapes, and compositions. Certain beneficial characteristics are present in fungi such as their preference over other external microbes or plants for the synthesis of nanoparticles. Mycelium enrichment with enzymes and its laboratory-friendly nature make it a sensible decision to consider the mycelium approach to nanoparticle manufacturing as potentially significant (Figure 1).

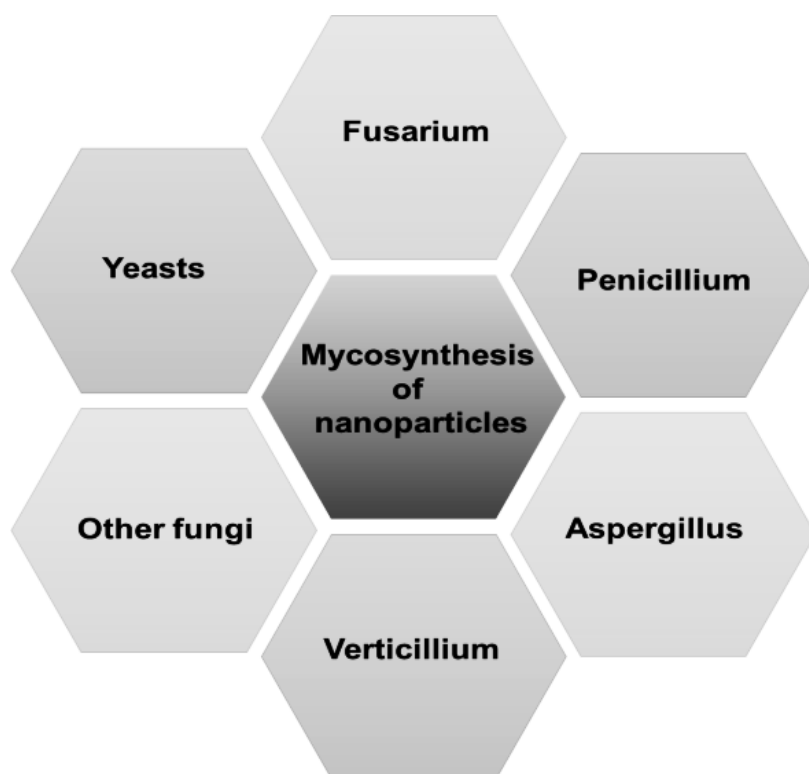


Figure 1. The primary fungal species that are employed as bionanofactories for the synthesis of AgNPs are *Verticillium*, *Fusarium*, *Penicillium*, and *Aspergillus*.

A comparative evaluation of fungal-mediated nanoparticles with other nanoparticle synthesis methods is given in Table 1.

Table 1. Summary of fungal-mediated synthesis of different metal nanoparticles.

Fungal mediated synthesis	Physical characteristics (size, shape, etc.)	Stability	Biological activity	Reference
Silver	Spherical to oval (3–27 nm)	Stable	Antimicrobial Antioxidant Anticancer	[12] [13] [14]
Zinc oxide	Hexagonal wurtzite (59.1 nm average size)	Stable	Antifungal	[15]
Platinum	Rectangular (70–180 nm)	Spherical and aggregates	–	[16]
Magnetite (Fe ₃ O ₄)	Irregular (20–50 nm)	Quasi spherical	–	[17]
Titanium dioxide (TiO ₂)	Spherical (32 nm)	Aggregate	Photocatalytic	[18]

Table 1. clearly exhibits the potential of fungal-mediated biogenic synthesis of silver nanoparticles regarding its physicochemical properties, stability, and bioactivity. Similarly, several other studies are also mentioned in the previous report [19]; thus, the silver salt was chosen for the present study.

MATERIALS AND METHODS

Selection of Fungal Cultures

Fusarium species are usually used by scientists because they significantly increase the efficiency of nanoparticle synthesis. The two most used fungi are *Fusarium oxysporum* and *Fusarium solani*. The selection factors may include the strain's ease of in-laboratory adaptability, faster growth rate, and productivity in the manufacture of nanoparticles. The present study chose *Fusarium oxysporum* for the study. The culture was procured from Microbial Type Culture Collection and Gene Bank (MTCC), Chandigarh, India. The culture number for *Fusarium* species is MTCC-3109 (*Fusarium oxysporum* var. *zingiberi*).

Preparation of the Culture Medium

The culture medium offers vital nutrients for fungal growth and nanoparticle synthesis. PDA, nutrient broth, and other carbon–nitrogen-rich media are common. Sample fungi were grown in flask-prepared culture media. 39.0 g of potato dextrose agar (PDA) was dissolved in 1000 ml of distilled water and sterilized in an autoclave at 121°C for 15 minutes. The nutrient broth is processed similarly. After sterilization, the medium broth and petri plates were held under laminar air flow, and the liquid medium was poured into 10–12 plates to solidify overnight. The next day, the fungal culture ampoule was broken using sterile forceps and placed in room-temperature liquid broth, then kept in an incubator to examine development (Figures 2 & 3).

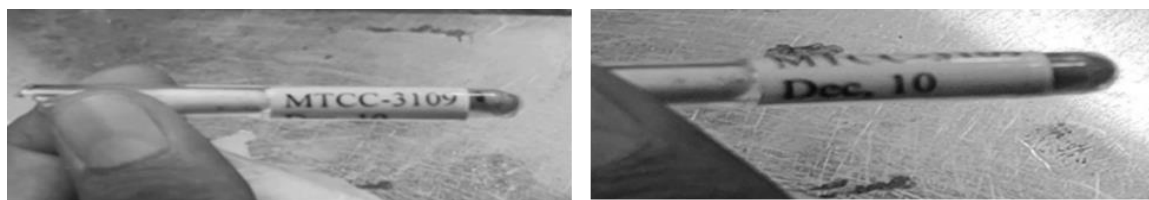


Figure 2. Fungal ampoule procured from MTCC: *Fusarium oxysporum* and *Fusarium solani*, respectively.

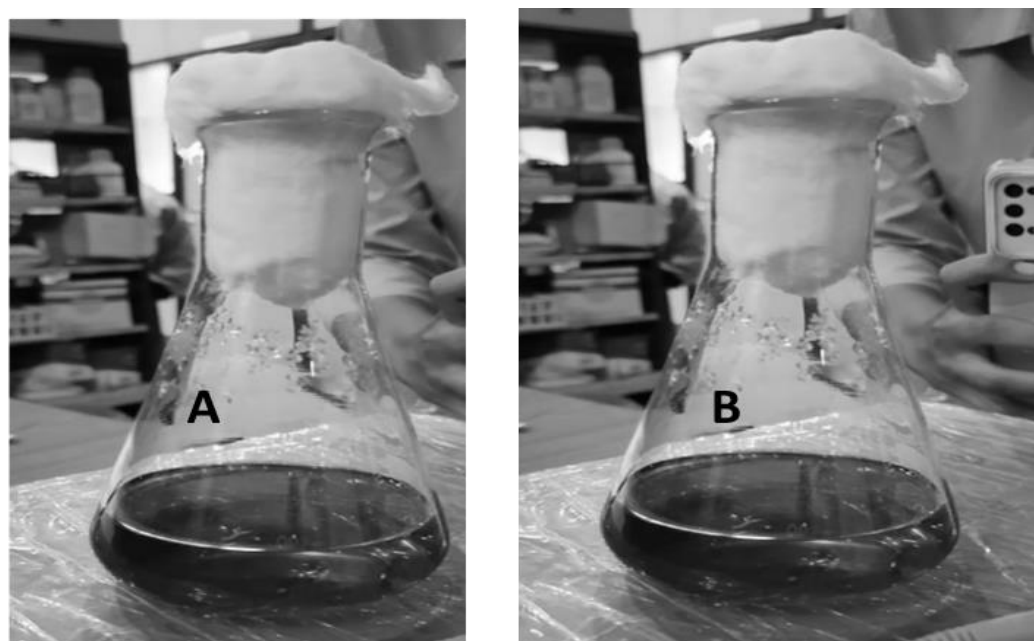


Figure 3. Medium for fungal culture. Flasks (A & B) contain potato dextrose agar medium with fungi.

No growth was found in the broth. The original fungal growths A and B are subcultured in the other four flasks. The fungal growth was collected on filter paper, and the filtrate was collected in the flask.

Myco-Synthesis of Silver Nanoparticles

Filtered and distilled water is poured into a flask. In this step, extracellular enzymes reduce the silver nitrate. Next, a solution of silver nitrate is prepared by mixing 50 ml of distilled water with 0.0087 g of AgNO_3 . After preparing the silver nitrate solution, the fungal extract is added drop by drop until the color changes from white to brown–orange. It takes a total of 8 ml of the fungal extract to achieve this color change. A micropipette with a volume of 1000 μL is used to add the solutions drop by drop.

UV-Visible Spectroscopy

The sample was evaluated by UV-Vis spectroscopy using a Lab India UV spectrophotometer for the presence of characteristic absorption of nanoparticles. The sample was scanned in the range of 300 to 700 nm. The distilled water was used as a blank.

Fourier-Transform Infrared Spectroscopy (FTIR)

In FTIR spectroscopy, the Shimadzu FTIR spectrophotometer was used at RTM Nagpur University, Nagpur, Maharashtra. The scanning was carried out in the range of 400–4000 cm^{-1} at a resolution of 4 cm^{-1} , and about 45 scans were performed.

RESULTS

Fungal Culture and Morphological Analysis

After subculturing, *Fusarium oxysporum* appeared as a yellow–green powdery mat on the surface of the broth medium (Figure 4). A microscopic examination was carried out under a compound microscope, which revealed the growth of *Fusarium oxysporum* (Figures 5 & 6).

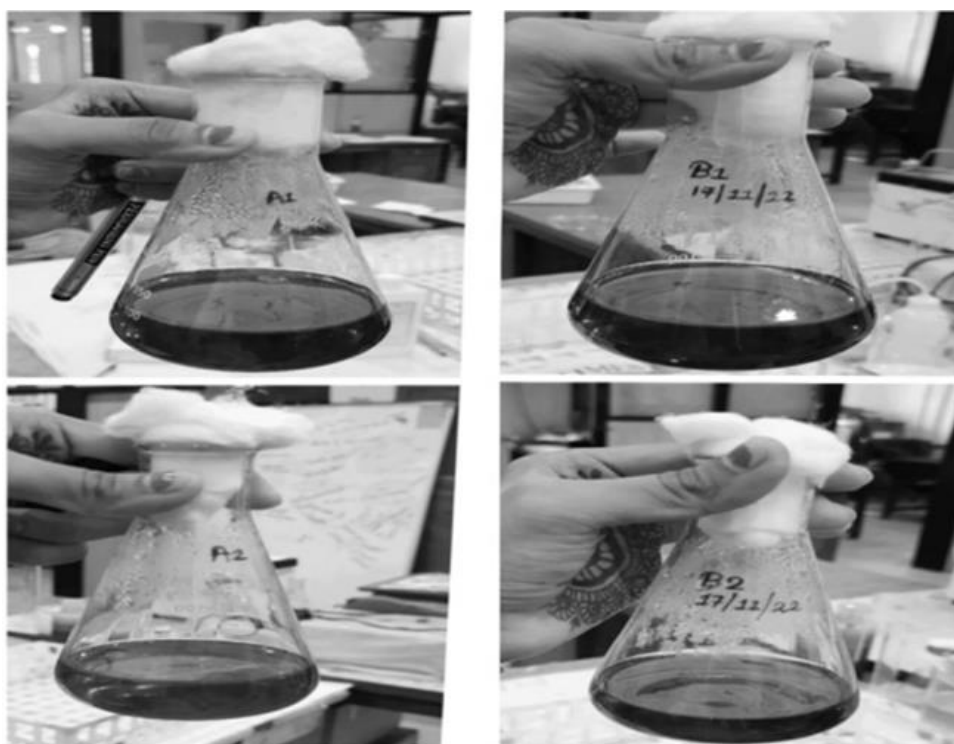


Figure 4. The four conical flasks (A1, A2, B1, B2) are subcultures of the original medium (A and B).

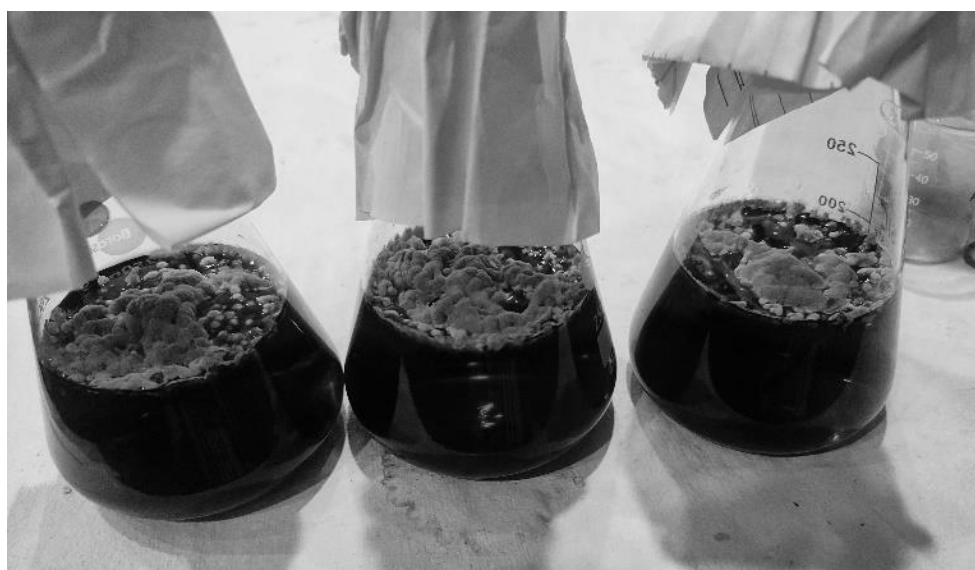


Figure 5. Powdery mat of *Fusarium* grown on the liquid growth medium.

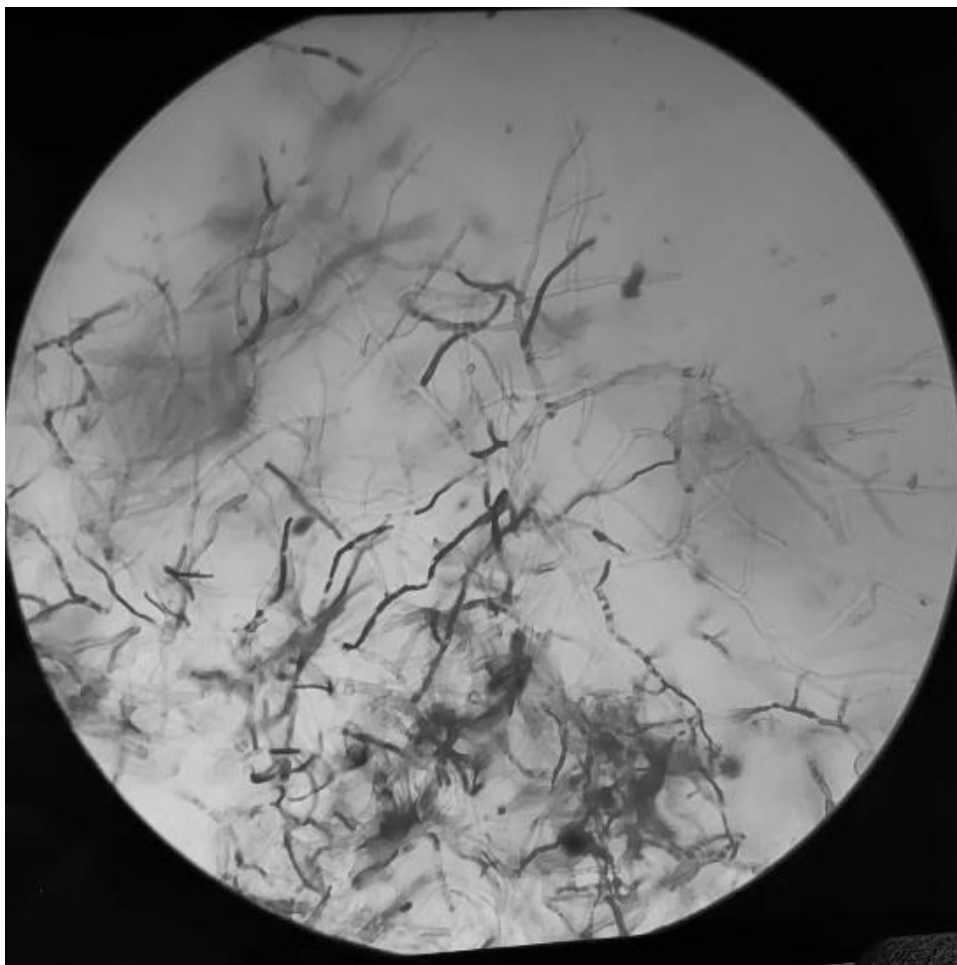


Figure 6. Microscopic examination of *Fusarium oxysporum*.

Nanoparticle Synthesis and Characterization

The nanoparticle synthesis was carried out using *Fusarium oxysporum* extract. The visible color change was observed during nanoparticle synthesis from colorless to light brown after 10 minutes, and it later turned to brown–orange after one hour (Figure 7).



Figure 7. Myco-synthesis of silver nanoparticles using silver nitrate and fungal filtrate.

UV Spectroscopic Analysis

The UV analysis confirmed the synthesis of silver nanoparticles using fungal extracts. The absorption maximum at 420 nm was observed (Figure 8), as earlier studies support the myco-synthesis and confirmation using UV spectra [20].

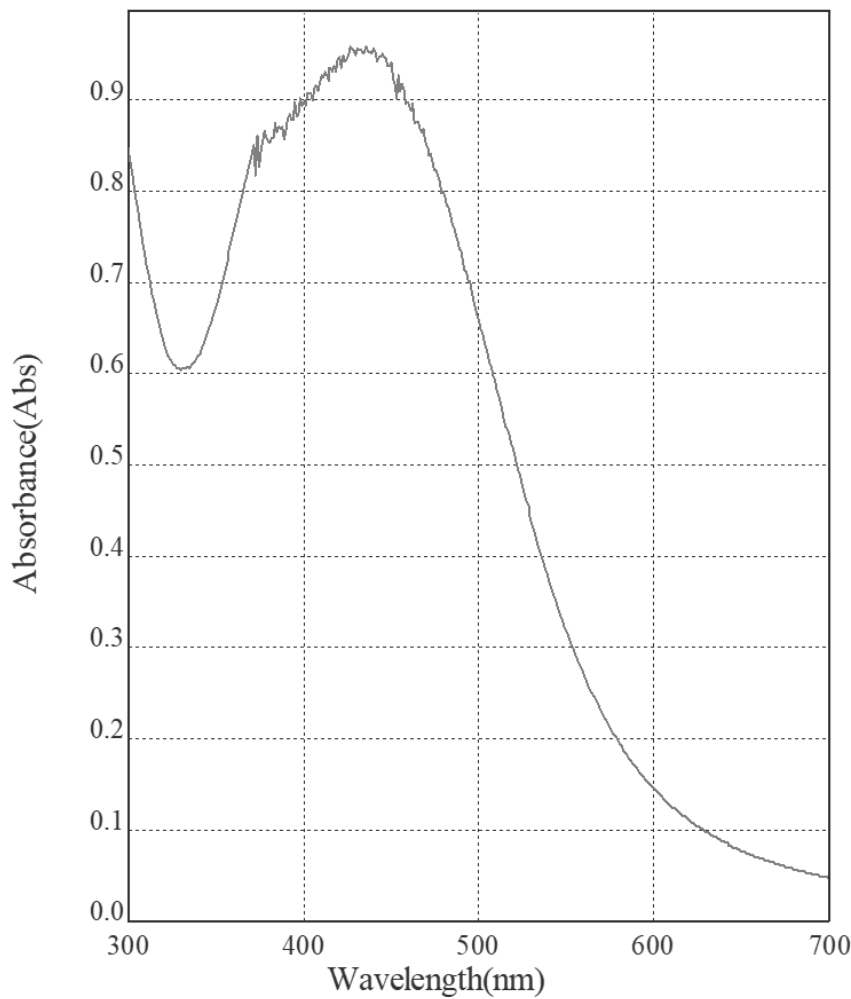


Figure 8. UV-absorption spectrum of myco-synthesized silver nanoparticles.

FTIR Analysis

The FT-IR analysis produced characteristic bands such as 1032.62, 1635.82, and 3320.47 cm^{-1} (Figure 9). The earlier reports on *F. oxysporum* myco-synthesis support the present research output [21].

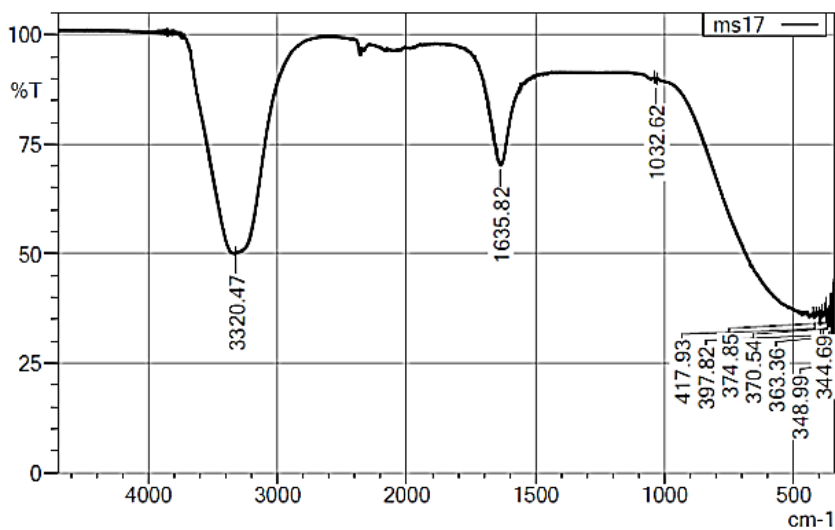


Figure 9. FT-IR spectrum of myco-synthesized silver nanoparticles.

DISCUSSION

The present study demonstrates the effectiveness of *Fusarium* species as a fungal agent for the green production of silver nanoparticles (AgNPs), aligning with the growing focus on eco-friendly nanotechnology alternatives to chemical methods. Fungal extracts from *Fusarium* species were acquired using both endogenous (intracellular) and exogenous (extracellular) techniques, facilitating rapid AgNP synthesis. Duran and Syed showed that the unique surface plasmon resonance (SPR) peak at about 420 nm in UV-Vis spectroscopy matches what has been seen with *Fusarium oxysporum* and *Fusarium solani* [22]. In these fungi, extracellular enzymes, like nitrate reductase and cell wall-bound reductases, reduce Ag^+ ions into metallic Ag^0 .

The two extraction methods show how flexible *Fusarium*'s enzymes are. Exogenous extracts yielded smaller, more monodisperse nanoparticles owing to enhanced enzyme accessibility, a phenomenon previously seen in mycosyntheses [23]. A recent study reveals the secretome of two *Fusarium oxysporum* strains to produce and stabilize the silver nanoparticles. Similarly, the generated nanoparticles exhibit antimicrobial activity due to these secretome enzymes such as glyceraldehyde reductase and FAD-oxidoreductase. The confirmation of proteome analysis was done by electrophoretic (PAGE), spectrometric (LC-MS/MS), and fluorescence microscopy [24].

The biological activities of mycosynthesized silver nanoparticles by *Fusarium nygamai* isolate AJTYC1 were reported. The biogenic silver nanoparticles were assessed for their antioxidant, anticancer, antimicrobial, and cytogenetic effects. Similarly, the characterization was done using UV and FTIR analysis, which reported the absorption maximum of 420 nm and vibration frequencies at 3433.4, 3194.9, 2926.2, 2295.5, 1634.2, 1516.04, 1384.5, 1134.3, and 824.7 cm^{-1} [14]. Similar reports were observed in the present study during the characterization of synthesized nanoparticles.

Earlier reports claim that the best conditions for synthesis were pH 7–8, 40–50°C, and 1 mM AgNO_3 . In these conditions, spectral broadening and FTIR data were utilized to estimate the sizes of nanoparticles, which ranged from 20 to 50 nm. These conditions resemble those of *F. oxysporum*, wherein alkaline pH enhances reductase activity and thermostable proteins stabilize colloids [25].

The use of two endophytic fungi, *Fusarium oxysporum* and *Fusarium proliferatum*, from the epiphytic plant, *Pyrrosia lanceolata*, was done for generating silver nanoparticles, and *in silico* studies were performed in tomato wilt. Effective cellular penetration against bacterial and fungal cells was found, thus showing enhanced antibacterial activity [26].

In 2014, Makarov used FTIR analysis to confirm that fungal biomolecules play a role in making nanoparticles. Peaks at 3400 cm^{-1} (O–H/N–H stretching), 1650 cm^{-1} (amide I), and 1380 cm^{-1} (carboxylates) show that proteins are acting as reducing and capping agents, which stops aggregation and makes the substance biocompatible [27].

Microscopic analysis of *Fusarium* sp. growth revealed significant mycelial proliferation under optimal culture conditions, aligning with the elevated biomass yields necessary for scalable extract extraction. This growth pattern shows that *Fusarium* is more suitable than bacteria and plants for making myconanoparticles because it can tolerate high concentrations of metals and secretes hydrolytic enzymes [28, 29].

The synthesized AgNPs have potential uses in agriculture, such as antifungal coatings against *Fusarium* wilt pathogens that use the fungus's own metabolites, and in medicine, such as antimicrobial agents against multidrug-resistant strains, since AgNPs have been shown to disrupt bacterial membranes [30].

CONCLUSION

Fungi have long been recognized for their potential applications in medicinal chemistry. Although fungi have been utilized in recent years to produce metal nanoparticles, the potential of bioactive components present in fungi is immense. This paper proposes a simple and feasible method for

producing silver nanoparticles using myco-mediated techniques. The article presents many outcomes, including the distinctive UV spectrum and the FT-IR analysis, which serve as evidence of the successful synthesis of nanoparticles. This study has the capacity to be valuable for pharmaceutical research, namely in the production of metal nanoparticles using *F. oxysporum* and for further experimental evaluation of the biological capabilities of nanoparticles. The myco-nanoparticles can also be a good avenue for forensic biology applications for biological fluid detection, drugs of abuse sensing, and fingerprint identification.

Acknowledgments

The authors express gratitude to the Director of the Government Institute of Forensic Science, Nagpur, for granting permission to conduct the research and for providing unwavering support and encouragement throughout the study. The authors are also thankful to the Head of the Department of Forensic Biology for providing support in conducting the research.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Funding

The authors declare that no funding was available to conduct the research.

Data Availability

Data are available from the corresponding author upon reasonable request.

REFERENCES

1. Taniguchi N. On the basic concept of nanotechnology. In: Proceedings of the Japan Society of Precision Engineering; 1974.
2. Narayanan KB, Sakthivel N. Biological synthesis of metal nanoparticles by microbes. *Adv Colloid Interface Sci.* 2010;156(1–2):1–13.
3. Maynard A, Michelson E. The nanotechnology consumer products inventory. Washington (DC): Woodrow Wilson International Center for Scholars; 2006.
4. Alvarez-Puebla RA, Aroca RF. Surface-enhanced Raman scattering for ultrasensitive chemical analysis of 1 and 2-naphthalenethiols. *Analyst.* 2004;129(12):1251–1256.
5. Rai M, Yadav A, Bridge P, Gade A. Myconanotechnology: A new and emerging science. *Appl Mycol.* 2009;258–267.
6. Meyer V. Genetic engineering of filamentous fungi—Progress, obstacles and future trends. *Biotechnol Adv.* 2008;26(2):177–185.
7. Dhillon GS, Brar SK, Kaur S, Verma M. Green approach for nanoparticle biosynthesis by fungi: Current trends and applications. *Crit Rev Biotechnol.* 2012;32(1):49–73.
8. Sastry RK, Rashmi H, Rao NH, Ilyas SM. Integrating nanotechnology into agri-food systems research in India: A conceptual framework. *Technol Forecast Soc Change.* 2010;77(4):639–648.
9. Khot LR, Sankaran S, Maja JM, Ehsani R, Schuster EW. Applications of nanomaterials in agricultural production and crop protection: A review. *Crop Prot.* 2012;35:64–70.
10. Bhainsa KC, D'Souza SF. Extracellular biosynthesis of silver nanoparticles using the fungus *Aspergillus fumigatus*. *Colloids Surf B Biointerfaces.* 2006;47(2):160–164.
11. Gericke M, Pinches A. Biological synthesis of metal nanoparticles. *Hydrometallurgy.* 2006;83(1–4):132–140.
12. Nikam S, Shelar KR, Munde MB, Bhosale TY, Bedake PS, Hagawane RM, et al. Fungal-mediated synthesis of silver nanoparticles using *Fusarium oxysporum* and their antimicrobial evaluation. *Int J.* 2024;10(2).
13. Rahli F, Chentouf H, Terbeche R, Chougrani S. Biosynthesis of silver nanoparticles using *Fusarium oxysporum* and their therapeutic applications. *J Appl Nat Sci.* 2022;14(4).
14. El-Ansary AE, Omran AAA, Mohamed HI, El-Mahdy OM. Green synthesized silver nanoparticles mediated by *Fusarium nygamai* isolate AJTYC1: Characterization, antioxidant, antimicrobial, anticancer and photocatalytic activities. *Environ Sci Pollut Res.* 2023;30(45):100477–100499.

15. Djearamane S, Xiu LJ, Wong LS, Rajamani R, Bharathi D, Kayarohanam S, et al. Antifungal properties of zinc oxide nanoparticles on *Candida albicans*. *Coatings*. 2022;12(12):1864.
16. Govender Y, Riddin T, Gericke M, Whiteley CG. Bioreduction of platinum salts into nanoparticles: A mechanistic perspective. *Biotechnol Lett*. 2009;31(1):95–100.
17. Bharde A, Rautaray D, Bansal V, Ahmad A, Sarkar I, Yusuf SM, et al. Extracellular biosynthesis of magnetite using fungi. *Small*. 2006;2(1):135–141.
18. Vinayagam Y, DR V. Mycosynthesis of TiO₂ nanoparticles using *Aspergillus penicillioides* for toxic metal removal and photocatalytic applications. *J Water Process Eng*. 2024;67:106279.
19. Rai M, Bonde S, Golinska P, Trzecińska-Wencel J, Gade A, Abd-Elsalam KA, et al. *Fusarium* as a novel fungus for the synthesis of nanoparticles: Mechanism and applications. *J Fungi*. 2021;7(2):139.
20. Fatima F, Wahid I. Eco-friendly synthesis of silver and copper nanoparticles by *Schizophyllum commune* fungus and its biomedical applications. *Int J Environ Sci Technol*. 2022;19(8):7915–7926.
21. Husseiny SM, Salah TA, Anter HA. Biosynthesis of size-controlled silver nanoparticles by *Fusarium oxysporum*, their antibacterial and antitumor activities. *Beni Suef Univ J Basic Appl Sci*. 2015;4(3):225–231.
22. Durán N, Marcato PD, Durán M, Yadav A, Gade A, Rai M. Mechanistic aspects in the biogenic synthesis of extracellular metal nanoparticles by peptides, bacteria, fungi and plants. *Appl Microbiol Biotechnol*. 2011;90(5):1609–1624.
23. Sidhu AK, Agrawal SB, Verma N, Kaushal P, Sharma M. Fungal-mediated synthesis of multimetallic nanoparticles: Mechanisms, unique properties and potential applications. *Front Nanotechnol*. 2025;7:1549713.
24. Santana da Costa T, Delgado GG, Braga CB, Tasic L. Insights into fungal secretomes and their roles in formation and stabilization of biogenic silver nanoparticles. *RSC Adv*. 2025;15(9):6938–6951.
25. Binupriya AR, Sathishkumar M, Vijayaraghavan K, Yun SI. Bioreduction of trivalent aurum to nano-crystalline gold particles by active and inactive cells and cell-free extract of *Aspergillus oryzae* var. *viridis*. *J Hazard Mater*. 2010;177(1–3):539–545.
26. Jana S, Das D, Bhattacharyya S, Raha S. Mycogenic synthesis of silver nanoparticles using endophytic fungi and their characterization and biological activities with special reference to *Fusarium wilt* of tomato. *Fungal Biol*. 2025;129(5):101610.
27. Makarov VV, Love AJ, Sinitsyna OV, Makarova SS, Yaminsky IV, Taliansky ME, et al. “Green” nanotechnologies: Synthesis of metal nanoparticles using plants. *Acta Naturae*. 2014;6(1):35–44.
28. Sarkar J, Saha S, Chattopadhyay D, Patra S, Acharya K. Mycosynthesis of silver nanoparticles and investigation of their antimicrobial activity. *J Nanosci Nanoeng Appl*. 2011;1:17–26.
29. Selvi KV, Sivakumar T. Isolation and characterization of silver nanoparticles from *Fusarium oxysporum*. *Int J Curr Microbiol Appl Sci*. 2012;1(1):56–62.
30. Prabhu S, Poulouse EK. Silver nanoparticles: Mechanism of antimicrobial action, synthesis, medical applications and toxicity effects. *Int Nano Lett*. 2012;2(1):32.