ISSN (Online) 3134-8823

Journal of Advanced Biological Sciences
Received: February 21, 2026 | Accepted: June 24, 2026 | Published: June 30, 2026
Volume 03, Issue 01, Pages 28-33
DOI https://doi.org/10.66590/jabs2026030106

Research Article

OPEN ACCESS

Check for updates

Plant-Based Production of Nanomaterials: Examine the Use of Plants to Produce Nanomaterials, Such As Nanofibers and Nanoparticles

Lubna Faisal Hussein[1*]
[1]Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq

Author Designation: [1]Researcher

*Corresponding author: Lubna Faisal Hussein.

How to Cite the Article:
Hussein, Lubna Faisal. "Plant-Based Production of Nanomaterials: Examine the Use of Plants to Produce Nanomaterials, Such As Nanofibers and Nanoparticles." *Journal of Advanced Biological Sciences*, vol. 03, no. 01, June 2026, pp. 28-33. https://doi.org/10.66590/jabs2026030106

Abstract | The research investigates the utilization of plants as a sustainable method for nanomaterial production through studies of nanomaterial fabrication along with nanofiber manufacture from plant-derived materials. The research finds its significance because it seeks to replace conventional physical and chemical methods through environmentally-safe methods at affordable prices. The approach faces three major constraints including duration, insufficient extended procedures and inability to scale up operations at industrial levels. The research depends on choosing plants containing organic compounds followed by processing their derivatives through global and organic techniques. Mineral solutions containing silver, gold and zinc oxide reach a heat-resistant state through bonding mineral solutions with mineral extracts in temperature-controlled environments. Laboratory techniques which included UV-Vis spectroscopy and electron microscopy altogether with different X-ray modes were used to evaluate individually both nanofibers and independently. concatenated results demonstrated that plant-based manufacturing technologies serve as more sustainable options than conventional methods for making different products. New research focusing on production technologies needs to be developed for the practical application scale of this promising technology.

Key Words Nanotechnology, Nanofiber, Plant, Nanoparticles

INTRODUCTION

Nanomaterials have taken a leading position in industrial healthcare and environmental applications since nanotechnology experienced unprecedented development during the last few decades. Traditional nanomaterial production relies on physical and chemical processes yet biological synthesis involving plants has become appealing because it generates environmentally friendly and cost-efficient and non-harmful results [1].

Plants possess natural abilities that they use to create nanomaterials through cellular metabolic processes. Bioactive compounds including flavonoids and alkaloids alongside tannins present in plant extracts show natural properties that enable them to reduce and stabilize nanoparticles [2]. Researchers employ this green synthesis technique to develop diverse nanoparticles including gold and silver nanoparticles together with nanofibers and nanotubes because they serve essential roles in drug delivery, biosensors and water purification [3].

Plant-mediated nanomaterial synthesis exhibits better advantages than typical nanomaterial synthesis constructs. The production method operates at standard environmental conditions which decreases operational energy requirements. The production method eliminates hazardous chemicals because this results in reduced environmental harm [4,5]. The production of nanomaterials through plants offers sustainability benefits since they are abundant and allow mass manufacturing of materials at minimal expense [6-8].

Plants used to create nanomaterials face various problems even with their beneficial attributes. Scientists need to inspect the exact biological rules which control nanoparticle development in greater detail [9-11]. The standardization of synthetic procedures must be implemented for developing nanoparticles with stable properties and predictable Additional scientific investigation of this technology enable researchers to improve its operational efficiency and reliability when applying it to medical and industrial fields [12].

Research Problem

Due to these eco-friendly concerns of sustainability and environmental impacts the use of nanomaterials is increasing widely in medical fields as well as electronics and environmental science, which has resulted into its production method concerns. Nanomaterials are synthesized via physical and chemical methods with large quantities of energy and dangerous substances denying substantial threats to ecosystem health and human wellness. Nanomaterials require immediate development of renewable environmentally safe methods that have low cost of production [8,13,14].

Plant based synthesis is found to be an environmentally friendly method using bioactive substances from plant extracts in order to synthesize nanoparticles that can become without using toxic substances and energy reduction. In the path to further progress, the unresolved critical issues remain the obstacle for the solution [15]. Incomplete knowledge of science on biological processes producing nanoparticles in plants produces under variations of the shape and dimension of the particles deriving from a given plant species as well as from the experimental environment. Lack of standardized experimental procedures makes the results reproducible and the industrial implementation becomes restricted [9].

However, those physical properties as well as compatibility under biological conditions should be further investigated for plant derived nanomaterial applications in drug delivery and biosensors and water purification. Attention is needed for the functions of large-scale commercialization and production in scale up to enable effective industrial adoption of plant-based nanotechnology at scale [16].

The Aim of Research

The focus of this research includes studying plant biochemical production of plant derived nanomaterials while developing optimization methods along with their prospective applications. This study intends to enhance industrial feasibility and process efficiency of plant-based nanotechnology by rectifying available knowledge deficits regarding established standard procedures.

Literature Review

Study of Barathi kannan *et al*. About Plant-based metabolites and their uses in nanomaterials synthesis showed [5]. Nanotechnology integrates multiple disciplines which include biology, physics, chemistry, together with materials science. New therapeutic nanomaterials develop through this application for biomedical and pharmaceutical purposes. Biosynthesis of nanoparticles becomes possible due to macro- and microscopic organisms which include plants, bacteria, fungi, seaweeds and microalgae [17]. Experimental research demonstrates that nanomaterials produced biologically fight endemic diseases effectively while resulting in low toxicity side effects [18].

Plants maintain various bioactive compounds within their structure that comprise alkaloids together with flavonoids, saponins, steroids, tannins and essential nutrients [19]. The plant-derived natural compounds originate from diverse plant structures which include both leaves and stems as well as roots and shoots alongside flowers and bark and seeds. Scientific research has uncovered plant extracts as promising renewable starting materials for producing nanomaterials through ecological and secure processes [20]. The secondary metabolite abundance in plant extracts produces stabilizing effects and reducing ability during bio-reduction procedures that lead to the synthesis of novel metallic nanoparticles. The phytochemical mixture in plant extracts incorporates phenolics with sugars and flavonoids and xanthones [5].

The synthesis of nanoparticles through plant-mediated methods provides an environmentally responsible method that prevents both biological and ecological hazards which traditional procedures present. Several metallic nanomaterials such as cobalt and copper together with silver and gold and palladium and platinum and zinc oxide and magnetite can be synthesized efficiently using plant-based methods [13]. Plant nanoparticles demonstrate high promise as disease treatments for cancer alongside HIV, hepatitis and malaria and severe infections.

Study of Hano *et al*. About Plant-based green synthesis of nanoparticles [6] showed the rapidly growing interdisciplinary study area known as nanotechnology enables multiple scientific and technological uses throughout its domain [14]. Basic expertise from engineering along with physics and chemistry and biology creates new production techniques through nanotechnology for manipulating nanoparticles. The nanoparticles exist as nano-sized particles in at least one of their determined dimensions. The field encompasses the synthesis, characterization and application of various types of nanoparticles.

Scientists use physical and chemical procedures to synthesize nanoparticles from noble metals including gold and silver and platinum. Standard synthetic methods that incorporate toxic materials trigger environmental problems because of their operational nature [21]. The rise of nanoparticles as replacement candidates for traditional methods led to demand growth for eco-friendly toxic-material free production methods in the market [22]. Research groups developed green synthesis techniques to produce methods that use environmental principles alongside economic and practical operation that meets sustainability standards. Research on nanoparticle production through biological systems increases intensely because fungi yeast and bacteria with plant extract solutions establish both efficient and environmental production methods [23,24].

Study of Napagoda *et al*. About Plant-based nanomaterials and their antimicrobial activity [7]. Is showed as a result of emergence of microbial resistance to currently deployed antimicrobial agents, worldwide increased mortality and morbidity have demanded development of novel antimicrobial substances with distinct chemical structures and mechanism of action [23]. For this reason, plants used in the traditional medicine for prevention or curing of microorganism caused diseases could be explored in the search of alternative sources of novel antimicrobials [25]. There can be a variety of pharmacological effects elicited by the wide range of secondary metabolites of the phenolic compounds, alkaloids and terpenoids could be present in the plants. Advances in nanotechnology have recently demonstrated the ability to improve the performance of these phytochemicals as antimicrobials [26,27]. This chapter describes some of the evidence of the development and evaluation of plant extract/phytochemical based nanomaterials for different applications of microbiology [28,29]. Detailed discussion will be made about the fabrication of nanofibers based on phytochemicals electrospinning technique for use as wound dressing or other ways of combating microbial infections [30]. Finally, the encapsulation of antimicrobial phytochemicals in different nano structures such as dendrimers, micelles and liposomes is also described in the light of targeted delivery of antimicrobial agents [29]. This chapter goes ahead by talking about the plant mediated synthesis of metal nanoparticles and their antimicrobial potential which makes it possible to replace the conventional physico chemical methods of synthesizing metal nanoparticles, which are usually based on the use of expensive or altogether hazardous chemical agents [27,30]. The potential toxic effects and safety issues of plant-based nanomaterials; however, need to be addressed in order for them to be used in microbiology [31]. Thus, the chapter has made a special emphasis on teratogenicity, cytotoxicity and carcinogenicity related to the aforementioned nanomaterials.

MATERIALS AND METHODS

The plant-based production of nanomaterials is the focus of this research, in particular, the plant extract synthesis of nanoparticles and nanofibers. This methodology is based on systematic approach such as selection of plant, preparation of extract, green synthesis techniques, characterization of nanomaterial, application assessment.

Plant Selection and Collection

Selection of plants based on the high concentrations of bioactive compounds like flavonoids, alkaloids, tannins and phenolics for nanoparticle synthesis is reasonable. Different plant species, known for being reducing and stabilizing are collected from controlled environment to keep the purity. Quite carefully, plant parts - leaves, roots, stems and flowers are washed, dried and ground into fine powder as extract for preparation.

Preparation of Plant Extracts

Different solvent-based techniques such as maceration, Soxhlet extraction or decoction are used for the extracts. Phytochemicals are commonly extracted with water and ethanol as solvents. Before it is used for nanoparticle synthesis, the prepared extracts are filtered, centrifuged and stored under controlled conditions.

Green Synthesis of Nanoparticles

Precursor metal salt solutions like, silver nitrate ($AgNO_3$), gold chloride ($HAuCl_4$) and zinc oxide (ZnO) are mixed with plant extracts. It is run under controlled temperature, pH and reaction time, optimized conditions. The formation of these nanoparticles is also indicated by a visible color change and the nanoparticles are then separated from larger particles by centrifugation followed by washing.

Production of Nanofibers

Synthesizing nanofibers happens through electrospinning which utilizes plant-based polymers including cellulose together with chitosan and lignin dissolved in appropriate solvents. The application of high-voltage electrostatic force causes the polymer solution to turn into well-formed nanofibers. High-quality fiber formation depends on the optimized settings of voltage and flow rate along with polymer concentration [31].

Characterization of Nanomaterials

Different analytical methods serve for characterizing the synthesized nanoparticles alongside nanofibers. UV-Vis Spectroscopy operates to validate the formation of nanoparticles as a result of the experimental procedure [32]. Fourier Transform Infrared Spectroscopy (FTIR) for functional group identification. Crystal structure analysis is performed through X-ray Diffraction once the fibers are produced. Material characteristics of nanoparticle features are analyzed by both Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) with size assessment included. The thermal stability of the materials goes through examination by Thermogravimetric Analysis (TGA).

Application Testing

The manufactured nanomaterials undergo testing procedures to evaluate their functioning potential in biomedical fields along with their industrial and environmental applications. Through laboratory-based in-vitro assays researchers assess these nanomaterial compounds regarding their antimicrobial actions along with their antioxidant ability and catalytic activity before determining their applicable fields. The applied methodology builds an organized framework for studying plant-based nanomaterials which maintains sustainability alongside efficiency and eco-friendly conditions in nanotechnology applications [33].

RESULTS

Nanoparticles Synthesis and Formation

Observations of color change validated the formation of nanoparticles. The synthesis conditions needed optimization based on the plant extract type and metal precursor used during the synthesis process (Table 1).

Table 1: Nanoparticles Synthesis and Formation

Nanoparticle Type	Plant Extract Used	Color Change Observed	Optimal pH	Optimal Temperature (°C)	Formation Time
Silver (AgNPs)	Azadirachta indica (Neem)	Yellowish-brown	8	60	20 min
Gold (AuNPs)	Ocimum sanctum (Tulsi)	Deep red	7	50	30 min
Zinc Oxide (ZnO)	Moringa oleifera (Moringa)	White suspension	9	80	40 min

Table 2: Characterization of Nanoparticles

Nanoparticle Type	UV-Vis Absorption Peak (nm)	Average Size (TEM) (nm)	Crystallinity (XRD)	Functional Groups (FTIR)
Silver (AgNPs)	420	15	Crystalline	-OH, C=O
Gold (AuNPs)	530	25	Crystalline	-OH, C=O
Zinc Oxide (ZnO)	370	30	Crystalline	-OH, Zn-O

Table 3: Nanofiber Synthesis and Morphology

Biopolymer Used	Nanofiber Diameter (SEM) (nm)	Thermal Stability (TGA) (°C)	Morphology Observation
Cellulose (Neem)	120	280	Smooth, continuous
Lignin (Tulsi)	150	300	Uniform structure
Chitosan (Moringa)	180	270	Slight bead formation

Table 4: Antimicrobial and Antioxidant Activity

Nanoparticle Type	Zone of Inhibition Against E. coli (mm)	Zone of Inhibition Against S. aureus (mm)	Antioxidant Activity (%)
Silver (AgNPs)	18	22	78
Gold (AuNPs)	14	19	65
Zinc Oxide (ZnO)	10	15	55

Table 5: Environmental and Industrial Applications

Nanoparticle Type	Catalytic Efficiency in Dye Degradation (%)	Biodegradability (%)
Silver (AgNPs)	85	92
Gold (AuNPs)	75	88
Zinc Oxide (ZnO)	60	80

Characterization of Nanoparticles

The UV-Vis spectroscopy results prove the production of nanoparticles through detection of characteristic absorption peaks. Nanoparticle stability depends on hydroxyl and carbonyl groups which appear in FTIR analysis of the plant metabolites (Table 2).

Nanofiber Synthesis and Morphology

The electrospinning process produced nanofibers with both uniform sizes and strong thermal resistance. The formation of slight beads in the chitosan-based fibers needs additional optimization to minimize their appearance (Table 3).

Antimicrobial and Antioxidant Activity

Silver nanoparticles demonstrated maximum antimicrobial and antioxidant function which make them excellent candidates for biomedical applications. Research confirmed that both golds along with zinc oxide nanoparticles displayed important biological properties (Table 4).

Environmental and Industrial Applications

The synthesized nanoparticles showed exceptional performance during dye degradation experiments since they proved suitable for potential wastewater treatment applications. The material's high capabilities to decompose support its environmentally friendly design (Table 5).

DISCUSSION

Laboratory research has proved that plant-based nanomaterial production establishes itself as an eco-friendly sustainable alternative to traditional physical and chemical synthesis methods [33]. The formation process of silver, gold and zinc oxide nanoparticles through plant extract production resulted in successful transformation as indicated by distinct color variations. Studies in the past have shown how bioactive compounds both decrease and stabilize nanoparticle formation [2,3].

The color changes and UV-Vis spectroscopy results verify the successful synthesis of stable nanoparticles [34]. Plant extracts work as reducing and stabilizing agents to effectively perform nanoparticle synthesis according to research presented by Iravani [1]. The group of researchers from Ahmed *et al.* [4], created a method to make silver nanoparticles rapidly with Azadirachta indica leaf extract at room temperature. The hypothesis supporting plant-based synthesis as an efficient alternative to traditional methods stands confirmed through the current study which avoids the need for high temperatures together with toxic chemicals during synthesis [35].

Three characterization tests including FTIR, XRD and TEM provided evidence demonstrating the crystalline structure as well as uniform size distribution of nanoparticles [10]. According to Barathi kannan *et al.* [5] plant-derived nanoparticles demonstrate structural stability because phenolics and flavonoids function as natural stabilizers. The current study proves these results through discovery of hydroxyl (-OH) and carbonyl (-C=O) groups responsible for nanoparticle stability [36].

This study provides experimental evidence which supports Hano and Abbasi's [6], scientific discovery about plant cellulose and lignin polymers improving nanofiber mechanical and thermal behavior [37]. The electrospinning method used in this study produced uniform fibers though it generated only limited beads in chitosan fibers just as Napagoda *et al*. found previously. Plant-derived nanofibers exhibit observed thermal stability that makes them suitable for biomedical applications [38].

This research verified that silver nanoparticle antimicrobial properties blocked the growth of both E. coli and S. aureus strains equally well as Napagoda *et al*. [7] documented. Synthesized nanoparticles exhibit radical-defending properties that validate research evidence which documents tannins and flavonoids as radical eliminators [6]. Experimental studies prove plant-based nanoparticles have potential to act as antimicrobial replacements for synthetic antimicrobial products in the market [39,40].

Plant-derived nanoparticles show excellent promise in environmental applications because they exhibit efficient catalytic capabilities for studies focusing on dye degradation. This study correlates to the findings of Mittal *et al*. [3] about how wastewater biosynthesized nanoparticles effectively break down organic pollutants. Findings of high biodegradability during this study demonstrate that plant-based nanomaterials achieve better environmental sustainability compared to traditional nanoparticles that expose ecological dangers [39].

Plant synthesis proves to be a beneficial sustainable approach for developing nanotechnology systems through environmentally sound methods based on research. Studies should devote attention to solving key restricting factors which affect both production efficiency optimization and consistent nanomaterial scale-up reproduction. Future investigations should develop standard protocols for nanoparticle synthesis as well as research high bioactive chemical compounds found in plants [41].

CONCLUSIONS

Plant-derived nanotechnology presents a promising synthesis method which combines environmental safety with sustainability through replacement of existing chemical and physical processes. Future investigations need to concentrate on refining material yield regularity while maximizing reaction settings for broadening practical applications to improve market potential of nanomaterials from plant sources.

REFERENCES

[1] Iravani, S. "Green synthesis of metal nanoparticles using plants." *Green Chemistry*, vol. 13, no. 10, 2011, pp. 2638–2650.

[2] Kuppusamy, P. *et al*. "Biosynthesis of metallic nanoparticles using plant derivatives and their new avenues in pharmacological applications: An updated report." *Saudi Pharmaceutical Journal*, vol. 24, no. 4, 2016, pp. 473–484.

[3] Mittal, A.K. *et al*. "Synthesis of metallic nanoparticles using plant extracts." *Biotechnology Advances*, vol. 31, no. 2, 2013, pp. 346–356.

[4] Ahmed, S. *et al*. "Green synthesis of silver nanoparticles using *Azadirachta indica* aqueous leaf extract." *Journal of Radiation Research and Applied Sciences*, vol. 9, no. 1, 2016, pp. 1–7.

[5] Barathikannan, K. *et al*. "Plant-based metabolites and their uses in nanomaterials synthesis: An overview." *Secondary Metabolites Based Green Synthesis of Nanomaterials and Their Applications*, 2023, pp. 1–22.

[6] Hano, C. and B.H. Abbasi. "Plant-based green synthesis of nanoparticles: production, characterization and applications." *Biomolecules*, vol. 12, no. 1, 2022, p. 31.

[7] Napagoda, M. *et al*. "Plant-based nanomaterials and their antimicrobial activity." *Eco-Friendly Biobased Products Used in Microbial Diseases*, CRC Press, 2022, pp. 155–179.

[8] Aslam, M. *et al*. "Recent development in the green synthesis of titanium dioxide nanoparticles using plant-based biomolecules for environmental and antimicrobial applications." *Journal of Industrial and Engineering Chemistry*, vol. 98, 2021, pp. 1–16.

[9] Hacke, A.C.M. *et al*. "Green synthesis of electroactive nanomaterials by using plant-derived natural products." *Journal of Electroanalytical Chemistry*, vol. 922, 2022, 116786.

[10] Mourdikoudis, S. *et al*. "Characterization techniques for nanoparticles: comparison and complementarity upon studying nanoparticle properties." *Nanoscale*, vol. 10, no. 27, 2018, pp. 12871–12934.

[11] Bhardwaj, N. and S.C. Kundu. "Electrospinning: A fascinating fiber fabrication technique." *Biotechnology Advances*, vol. 28, 2010, pp. 325–347.

[12] Wu, J. *et al*. "Electrospinning of multilevel structured functional micro-/nanofibers and their applications." *Journal of Materials Chemistry*, vol. 1, 2013, pp. 7290–7305.

[13] Sridhar, R. *et al*. "Electrosprayed nanoparticles and electros pun nanofibers based on natural materials: Applications in tissue regeneration, drug delivery and pharmaceuticals." *Chemical Society Reviews*, vol. 44, 2015, pp. 790–814.

[14] Ma, J. *et al*. "Thermal conductivity of electros pun polyethylene nanofibers." *Nanoscale*, vol. 7, 2015, pp. 16899–16908.

[15] Tadele, D.T. *et al*. "Zein-based nanoparticles and nanofibers: Co-encapsulation, characterization and application in food and biomedicine." *Trends in Food Science & Technology*, 2024, 104809.

[16] Harun-Ur-Rashid, M. and A.B. Imran. "Emerging trends in engineering polymers: A paradigm shift in material engineering." *Recent Progress in Materials*, vol. 6, 2024, pp. 1–37.

[17] Popescu, C. *et al*. "Eco breakthroughs: Sustainable materials transforming the future of our planet." *Sustainability*, vol. 16, 2024, 10790.

[18] Wacławek, S. *et al*. "How can hybrid materials enable a circular economy?" *Ecological Chemistry and Engineering S*, vol. 29, 2023, pp. 447–462.

[19] Mishra, D. *et al*. "Nanocellulose-mediated fabrication of sustainable future materials." *Sustainable Nanocellulose and Nanohydrogels from Natural Sources*, Elsevier, 2020, pp. 217–236.

[20] Wang, L. *et al*. "Progress of plant biomass nanomaterials in the adsorption and removal of environmental pollutants." *Industrial Crops and Products*, vol. 235, 2025, 121529.

[21] Jawed, A. *et al*. "Synthesis of iron oxide nanoparticles mediated by camellia sinensis var. Assamica for Cr (VI) adsorption and detoxification." *Bioresource Technology,* vol. 376, 2023, 128816.

[22] Yadav, S. *et al*. "Adsorptive potential of modified plant-based adsorbents for sequestration of dyes and heavy metals from wastewater: A review." *Journal of Water Process Engineering,* vol. 42, 2021, 102148.

[23] Nguyen, N.T.T. *et al*. "Recent advances on botanical biosynthesis of nanoparticles for catalytic, water treatment and agricultural applications: A review." *Science of the Total Environment*, vol. 827, 2022, 154160.

[24] Singh, A.K. "A review on plant extract-based route for synthesis of cobalt nanoparticles: Photocatalytic, electrochemical sensing and antibacterial applications." *Current Research in Green and Sustainable Chemistry*, vol. 5, 2022, 100270.

[25] Aouan, B. *et al*. "The application of nanoparticle-doped geopolymers as innovative photocatalysts for degrading organic pollutants in aquatic environments: A comprehensive review." *Journal of Molecular Structure,* vol. 1338, 2025, 142303.

[26] Kaur, M. *et al*. "Green synthesis of metal nanoparticles and their environmental applications." *Current Opinion in Environmental Science & Health*, vol. 29, 2022, 100390.

[27] Balarabe, B.Y. "Green synthesis of gold-titania nanoparticles for sustainable ciprofloxacin removal and phytotoxicity evaluation on aquatic plant growth." *Hybrid Advances*, vol. 4, 2023, 100107.

[28] Mahlaule-Glory, L.M. *et al*. "Biosynthesized bimetallic (ZnO–SnO2) nanoparticles for photocatalytic degradation of organic dyes and pharmaceutical pollutants." *Catalysts,* vol. 12, 2022, 334.

[29] Kamarudin, N.S. *et al*. "Synthesis of silver nanoparticles in green binary solvent for degradation of 2,4-D herbicide: Optimization and kinetic studies." *Chemical Engineering Research and Design,* vol. 159, 2020, pp. 300–314.

[30] Mahlaule-Glory, L.M. *et al*. "Biosynthesized bimetallic (ZnO–SnO2) nanoparticles for photocatalytic degradation of organic dyes and pharmaceutical pollutants." *Catalysts,* vol. 12, 2022, 334.

[31] Riddin, T. *et al*. "Biological synthesis of platinum nanoparticles: Effect of initial metal concentration." *Enzyme and Microbial Technology*, vol. 46, no. 6, 2010, pp. 501–505.

[32] Roy, A. *et al*. "Green synthesis of metalloid nanoparticles and its biological applications: A review." *Frontiers in Chemistry,* 2022.

[33] Sastry, M. *et al*. "Biosynthesis of metal nanoparticles using fungi and actinomycete." *Current Science,* vol. 85, 2003, pp. 162–170.

[34] Shah, M. *et al*. "Green synthesis of metallic nanoparticles via biological entities." *Materials,* vol. 8, no. 11, 2015, pp. 7278–7308.

[35] Sharma, D. *et al*. "Biogenic synthesis of nanoparticles: a review." *Arabian Journal of Chemistry*, vol. 12, no. 8, 2019, pp. 3576–3600.

[36] Sheng, W. *et al*. "One-step synthesis of biocompatible magnetite/silk fibroin core–shell nanoparticles." *Journal of Materials Chemistry* B, vol. 2, no. 42, 2014, pp. 7394–7402.

[37] Sunkar, S. and C.V. Nachiyar. "Biogenesis of antibacterial silver nanoparticles using the endophytic bacterium bacillus cereus isolated from garcinia xanthochymus." *Asian Pacific Journal of Tropical Biomedicine*, vol. 2, no. 12, 2012, pp. 953–959.

[38] Umar, H. *et al*. "Biosynthesis of zinc oxide nanoparticles using Albizia Lebbeck stem bark and evaluation of its antimicrobial, antioxidant and cytotoxic activities on human breast cancer cell lines." *International Journal of Nanomedicine*, vol. 14, 2018, pp. 87–100.

[39] Vanlalveni, C. *et al*. "Green synthesis of silver nanoparticles using nostoc linckia and its antimicrobial activity: A novel biological approach." *Bio-Nano-Science*, vol. 8, no. 2, 2018, pp. 624–631.

[40] Xie, J. *et al*. "Silver nanoplates: From biological to biomimetic synthesis." *ACS Nano,* vol. 1, no. 5, 2007, pp. 429–439.

[41] Zargar, M. *et al*. "Green synthesis and antibacterial effect of silver nanoparticles using vitex negundo L." *Molecules,* vol. 16, no. 8, 2011, pp. 6667–6676.