

Available online on 15.02.2026 at <http://jddtonline.info>

Journal of Drug Delivery and Therapeutics

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Research Article

Green Synthesis of Silver Nanoparticles using *Bryophyllum pinnatum* (Lam.) and monitoring their antibacterial activities

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Article Info:



Article History:

Received 23 Nov 2025
Reviewed 10 Jan 2026
Accepted 28 Jan 2026
Published 15 Feb 2026

Cite this article as:

Sahu P, Yadav M, Shukla A, Green Synthesis of Silver Nanoparticles using *Bryophyllum pinnatum* (Lam.) and monitoring their antibacterial activities, Journal of Drug Delivery and Therapeutics. 2026; 16(2):192-197
DOI: <http://dx.doi.org/10.22270/jddt.v16i2.7553>

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Abstract

The increasing demand for sustainable biomedical solutions has driven ongoing research toward green nanomaterial synthesis. The present study reported an eco-friendly, cost-effective protocol for synthesizing silver nanoparticles (AgNPs) using the aqueous leaf extract of the ethnomedicinal plant *Bryophyllum pinnatum* (Lam.). The reduction of Ag⁺ ions to metallic silver was confirmed by a distinct color transition from pale yellow to brown. Fourier Transform Infrared Spectroscopy (FTIR) analysis has been performed, validating the dual role of plant phytoconstituents. Significant absorption bands at ~3400 cm⁻¹ (O-H stretching) and ~1635 cm⁻¹ (C=O stretching) indicated that phenolic compounds, flavonoids and proteins were present within the extract. These functioned as effective bio-reductants and stabilizing capping agents for the nanoparticles. Further, antibacterial potential of the synthesized AgNPs was assessed against Gram-negative (*Pseudomonas aeruginosa* MTCC 2295 and *Escherichia coli* MTCC 5704) and Gram-positive (*Staphylococcus aureus* MTCC 3160, and *Bacillus subtilis* MTCC 121) bacteria by using agar-well diffusion method. The AgNPs was exhibited significantly greater antibacterial activity than the crude leaf extract. *B. subtilis* MTCC 121 has shown highest susceptibility with an inhibition zone of 21 ± 1.9 mm while *E. coli* showed a zone of 20 ± 1.7 mm. The AgNPs was exhibited slightly lower inhibition zones than standard antibiotic Ciprofloxacin (25–28 mm). However, their broad-spectrum efficacy was attributed to the synergistic interplay between the nanoparticles specific surface area and bioactive capping agents. The two-way ANOVA showed a highly significant effect of treatment type (p < 0.001) was represent that the synthesised *B. pinnatum* (Lam.) extract-derived AgNPs have superior antibacterial activity compared with the *B. pinnatum* (Lam.) extract alone. There was also a significant difference among bacterial strains (p < 0.05) indicates wide-ranging susceptibility. The prospects of the present findings endorsed *B. pinnatum* (Lam.) extract-derived AgNPs as promising candidates for developing natural and effective antimicrobial agents.

Keywords: Silver Nanoparticles (AgNPs), *Bryophyllum pinnatum* (Lam.), Green Synthesis, Antibacterial Activity, Eco-friendly

Introduction

Nanotechnology has emerged as a transformative discipline that integrates principles of physics, chemistry, biology and engineering to manipulate materials at nanoscale (<100 nm) ¹. The materials exhibit extraordinary properties e.g., mechanical strength, catalytic efficiency, thermal conductivity, optical behavior and surface reactivity, that significantly differ from their bulk counterparts at this scale ². Among various forms of nanomaterials, metallic nanoparticles have attracted special attention for their versatility across industrial, biomedical, environmental, and consumer applications. The synthesis method plays a pivotal role in determining their shape, size, stability, and overall bioactivity. Although conventional chemical and physical synthesis techniques are well-established and capable of producing nanoparticles with precise characteristics, they typically involve costly instrumentation, substantial energy consumption, and hazardous reagents. These requirements not only elevate production costs but also pose significant environmental and safety concerns,

particularly regarding toxic by-products and occupational exposure risks. In contrast, green synthesis of nanoparticles using plant extracts offers a sustainable, cost-effective, scalable, and environmentally benign approach ³. Green-synthesized nanoparticles are suitable for biomedical applications ⁴. Plant-based synthesis of nanoparticles offers a simplified, environmentally benign alternative, primarily by avoiding the complex maintenance of microbial cultures. This approach utilizes naturally occurring phytochemicals, such as flavonoids, alkaloids, phenols and terpenoids, which act as both reducing and stabilizing agents during nanoparticle formation ⁵. The use of whole-plant extracts or specific plant-derived compounds simplifies the synthesis process, thereby improving overall feasibility, scalability and environmental sustainability. Among the noble metals used for nanoparticle synthesis, the AgNPs have shown most promise due to their exceptional physicochemical and biological properties ⁶.

AgNPs exhibit strong antibacterial, antifungal, antiviral and anti-inflammatory effects and have been

incorporated into a wide range of products, including textiles and cosmetics, wound dressings, surgical instruments, water purification systems and drug delivery platforms⁷. Their small size and large surface area enhance cellular interactions, which enable them to damage microbial membranes, interfere with deoxyribonucleic acid (DNA) replication and inhibit vital enzymes. Despite these advantages, traditional methods for producing AgNPs are often relied on hazardous chemicals, such as sodium borohydride or hydrazine, which are unsafe for medical use⁸.

Recent research emphasized significant antimicrobial potential of AgNPs synthesized via eco-friendly plant-mediated routes. *Ocimum kilimandscharicum*-derived AgNPs effectively inhibited pathogens, including *S. choleraesuis*⁹. Similarly, *Ocimum sanctum* and *Euphorbia hirta* extracts based AgNPs have been observed for their broad-spectrum activity against both bacteria and fungi^{10,11}. The potent efficacy of *Onosma bracteatum* and *Azadirachta indica*-synthesized AgNPs against *E. coli* MTCC 5704 and *S. aureus* MTCC 3160 has been reported^{12,13}. Further expanding this therapeutic scope, the significant antibacterial properties of *Tinospora cordifolia*-mediated nanoparticles have been validated^{14,15}. Notably, the effectiveness of *Teucrium stocksianum* AgNPs against multi-drug-resistant strains has been established¹⁶. This trend has led to increased interest in biogenic synthesis of AgNPs using medicinal plants for pharmaceutical applications.

The *Bryophyllum pinnatum* (Lam.) (miracle leaf) has attracted significant interest due to its recognized traditional application as a medicinal for anti-inflammatory, antimicrobial, antifungal and wound-healing properties¹⁷. The leaves of *B. pinnatum* (Lam.) are rich in bioactive compounds viz., bufadienolides, flavonoids, alkaloids and polyphenols¹⁷. These compounds have been reported to reduce silver ions (Ag⁺) into nanoparticles but also act as natural stabilizers, preventing aggregation and improving biological activity of the resulting particles¹⁸. AgNPs synthesis from *B. pinnatum* (Lam.) leaf extract exemplifies principles of green chemistry by eliminating the use of synthetic capping agents. This also contributes to reducing chemical waste and emerges as a single-step rapid synthesis pathway under ambient conditions. The AgNPs synthesized through this method are typically spherical, well-dispersed and stable over a broad range of pH and temperature⁸. The antimicrobial potential of these *B. pinnatum* (Lam.) nanoparticles have been confirmed by several studies. It has been reported for high efficacy against both Gram-positive and Gram-negative bacteria as well as found to be effective against multidrug-resistant strains such as MRSA (Methicillin-resistant *Staphylococcus aureus*; ATCC 6538) and *Enterobacter aerogenes* (ATCC 13048)¹⁸. Further, Ultraviolet-Visible spectroscopy (UV-Vis), Fourier Transform Infrared Spectroscopy (FTIR), Transmission Electron Microscopy (TEM), and zeta potential (ZP) have been widely used for the effective characterization of AgNPs¹⁹.

Antimicrobial activity of AgNPs involves several mechanisms viz., generation of reactive oxygen species (ROS), protein denaturation, cell membrane disruption and inhibition of DNA replication²⁰. This diverse range of actions against microbes makes them a strong alternative to conventional antibiotics. Global challenges such as antimicrobial resistance and the demand for safer materials continue to grow and require scientific attention. The *B. pinnatum* (Lam.) plant-derived AgNPs represent a promising frontier for future research and applications in nanomedicine and pharmacology due to their previously reported antimicrobial potential^{9, 10, 18}. Therefore, the present research work was focused on the Green Synthesis of AgNPs using *B. pinnatum* (Lam.) and monitoring their antibacterial activities.

MATERIALS AND METHODS

Fresh and healthy leaves of *B. pinnatum* (Lam.) were collected and washed thoroughly with distilled water to remove surface contaminants. It was shade-dried at room temperature for 7 days, and the dried leaves were then finely powdered in a sterile electric blender. In the present study, *B. pinnatum* (Lam.) was used for the synthesis of nanoparticles to analyze antimicrobial activity. Human pathogenic microorganisms, viz., gram-negative bacteria (*P. aeruginosa* MTCC 2295 and *E. coli* MTCC 5704) and gram-positive bacteria (*S. aureus* MTCC 3160 and *B. subtilis* MTCC 121) were used to evaluate antimicrobial activity. Muller-Hinton broth was used to evaluate antimicrobial activity.

Preparation of *B. pinnatum* (Lam.) extract

B. pinnatum (Lam.) extract was prepared using the protocol mentioned by Jagdish and Nehra²¹. Fresh 30 g green leaves of *B. pinnatum* (Lam.) plant were gathered and washed multiple times under running tap water, followed by repeated washing with deionized water to remove dirt particles. The fresh green leaves were chopped into fine fragments and soaked in an Erlenmeyer beaker containing 250 ml of double-distilled water. The mixture was heated to 60–80 °C and stirred for 15–20 minutes on a hot magnetic stirrer plate. After boiling, a pale-yellow solution was obtained, which was allowed to cool to room temperature and subsequently filtered using Whatman filter paper No. 1. The resultant filtrate was preserved at 4 °C for further studies.

Synthesis of AgNPs from *B. pinnatum* (Lam.) extract

AgNPs from *B. pinnatum* (Lam.) extract were synthesised according to the protocol described by Jagdish and Nehra²¹. A 0.01 M solution of silver acetate dihydrate was prepared in a glass bottle containing 50 ml of double-distilled water, and 25 ml of *B. pinnatum* (Lam.) leaf extract was added to the prepared solution. This was followed by the dropwise addition of 2 M NaOH to the mixture of silver acetate and the plant extract to maintain a pH of 12. The mixture was then stirred continuously for 90 minutes on a magnetic stirrer, which led to formation of white precipitate that settled to the bottom. The resultant residue was isolated from the reaction mixture by centrifugation with double-distilled water twice at 7,000 rpm for 7 minutes each. A final washing with ethanol was performed at 7,000 rpm for 7 minutes to

remove any impurities or excess plant extract. The precipitate was then dried at 60 °C for 8–10 hours in a hot air oven to convert silver acetate to AgNPs. The resultant pale white-coloured powder was collected and stored in tightly sealed vials for further examination.

Antimicrobial activity of AgNPs derived from *B. pinnatum* (Lam.)

The antimicrobial activities of the plant extracts were evaluated by standard agar well diffusion assay as mentioned by Manandhar with slight modification²². The microbial inocula were aseptically spread uniformly on the surface of pre-solidified Mueller-Hinton Agar (MHA) plates using sterile cotton swabs. A well of about 6.0 mm diameter was aseptically punctured using a cork borer (sterile). The cut agar was removed with sterile forceps. Plant extract was used as a control in one of the wells. The Petri plates were kept in the laminar for 30 minutes for pre-diffusion to occur, and afterwards, the Petri plates were incubated at 37°C for 24 hours. The antimicrobial spectrum of the extract was determined by measuring the size of the inhibition zone around each well. Zones were measured by using the Zone Scale.

FTIR characterization of AgNPs derived from *B. pinnatum* (Lam.)

FTIR spectroscopic analysis was executed on AgNPs synthesised from *B. pinnatum* (Lam.) to identify the functional groups of active phytochemicals in the plant samples. The AgNPs were placed on a plate and analyzed using a FTIR spectroscope (Burker) across the

wavenumber range of 500 to 4,000 cm⁻¹ as mentioned by Thummajitsakul *et al.* with slight modification²³. This helped to enhance phytochemical profiling and investigate the antimicrobial mechanism.

All the experiments were conducted in triplicates. The standard deviation and ANOVA-based p-value were calculated using MS Excel 2021.

RESULTS AND DISCUSSION

This study presents an environmentally friendly and cost-efficient method, mainly focusing on synthesizing AgNPs through silver nitrate solution and *B. pinnatum* (Lam.) plant powder.

AgNPs Synthesis of *B. pinnatum* (Lam.)

AgNPs were successfully synthesized using the aqueous leaf extract of *B. pinnatum* (Lam.) through a green, eco-friendly method. The AgNPs were successfully synthesised with a distinct colour change from pale yellow to brown, where Ag⁺ ions were reduced to metallic silver and the subsequent formation of AgNPs.

Antimicrobial potential of *B. pinnatum* (Lam.) derived AgNPs

The antibacterial potential of synthesized AgNPs was evaluated against gram-negative bacteria (*P. aeruginosa* MTCC 2295 and *E. coli* MTCC 5704) and gram-positive bacteria (*S. aureus* MTCC 3160 and *B. subtilis* MTCC 121) using the agar well diffusion method. Comparative Antibacterial Activity of *B. pinnatum* (Lam.) extract and AgNPs, of *B. pinnatum* (Lam.) extract shown in Table 1

Table 1: Comparative Antibacterial Activity of *B. pinnatum*(Lam.) extract and AgNPs, of *B. pinnatum* (Lam.) extract

Microorganism	Type of Bacteria	Zone of Inhibition (mm ±SD)		
		<i>B. pinnatum</i> (Lam.) extract	AgNPs of <i>B. pinnatum</i> (Lam.) extract	Positive control (Ciprofloxacin 5 µg per ml)
<i>P. aeruginosa</i> (MTCC 2295)	Gram-negative	10 ±0.9	18 ±1.5	25 ±2.0
<i>E. coli</i> (MTCC 5704)		12 ±1.3	20 ±1.7	27 ±2.1
<i>S. aureus</i> (MTCC 3160)	Gram-positive	11 ±1.1	19 ±1.8	26 ±1.9
<i>B. subtilis</i> (MTCC 121)		13 ±1.4	21 ±1.9	28 ±1.7

The zones of inhibition indicated that the *B. pinnatum* (Lam.) derived AgNPs extract exhibited significantly greater antibacterial activity than the crude *B. pinnatum* (Lam.) extract. Among the Gram-negative strains, *E. coli* MTCC 5704 showed a larger inhibition zone (20 ±1.7 mm) when treated with *B. pinnatum* (Lam.) derived AgNPs extract than with the crude extract (12 ± 1.3 mm), whereas *P. aeruginosa* MTCC 2295 showed a similar trend with 18 ±1.5 mm for AgNPs versus 10 ±0.9 mm for the extract. In Gram-positive bacteria, *B. subtilis* MTCC 121 exhibited the highest susceptibility with 21 ±1.9 mm zone of inhibition for the *B. pinnatum* (Lam.) derived AgNPs extract compared to 13 ±1.4 mm for the extract without AgNPs. *S. aureus* MTCC 3160 also displayed a notable increase with 19 ±1.8 mm for AgNPs compared to 11 ± 1.1 mm for the extract. These findings underlined that green synthesis of AgNPs using *B. pinnatum* (Lam.)

significantly enhanced the antibacterial efficacy of the plant extract. The Two-Way ANOVA revealed a highly significant main effect of the treatment type (p < 0.001). This confirmed that the synthesized *B. pinnatum* (Lam.) extract-based AgNPs exhibited statistically superior antibacterial activity compared to the standard *B. pinnatum* (Lam.) extract. A significant difference was also observed among the bacterial strains (p < 0.05) which indicated that antimicrobial susceptibility varied by strain.

A significant rise in activity could be due to nanoscale particles, as they offer a larger surface area for interacting with bacterial cell membranes, thereby boosting antimicrobial effectiveness²⁴. The increased activity against Gram-negative bacteria, particularly *E. coli* MTCC 5704, could be due to their thin peptidoglycan

layer and outer membrane structure, which make them more vulnerable to nanoparticle damage²⁵. Moreover, the enhanced activity of AgNPs over the plant extract alone aligns with earlier research indicating that plant-mediated AgNPs have better antibacterial properties due to the synergistic effect of silver ions and phytochemicals from the plant matrix. Specifically, flavonoids, terpenoids, and phenolic compounds in *B. pinnatum* (Lam.) might be function as reducing agents during nanoparticle synthesis and as capping agents that stabilize the particles and potentially boosting their antimicrobial effects²⁶. The notable antimicrobial effect against *B. subtilis* MTCC 121 and *S. aureus* MTCC 3160 indicates that AgNPs have broad-spectrum activity, making them promising for targeting both Gram-positive and Gram-negative bacteria²⁷. However, when compared to Ciprofloxacin, a standard antibiotic, the AgNPs showed slightly smaller zones of inhibition. This suggests that although plant-based nanoparticles are effective, further optimization and concentration tuning are needed to match the bactericidal strength required for clinical use. Literature has been mentioned effective green synthesis of AgNPs using *B. pinnatum* (Lam.)²⁷. They synthesized AgNPs and characterized. UV-Vis spectroscopy confirmed the formation of AgNPs, while XRD analysis revealed their crystalline nature. Dynamic Light Scattering (DLS) analysis determined the average nanoparticle size to be approximately 65 nm. The antibacterial activity of the AgNPs was evaluated, and the minimum inhibitory concentration (MIC) indicated effective eradication of *S. aureus* MTCC 3160 and *B. subtilis* MTCC 121 (both Gram-positive bacteria), with inhibition zones of 12 mm for each. Additionally, biosynthesized AgNPs demonstrated efficient photocatalytic degradation of the methylene blue (MB) dye under natural sunlight, as tested over various time intervals. The *B. pinnatum* (Lam.) derived AgNPs was more effective against Gram-negative bacterial strains than Gram-positive¹⁸. Whereas, the present study observed the most potent antibacterial action of *B. pinnatum* (Lam.) derived AgNPs against Gram-positive *B. subtilis* with an inhibition zone of 21 ± 1.9 . But, Kumarmath and Sharada found significant antibacterial action of *B. pinnatum* (Lam.) derived AgNPs against *B. subtilis* MTCC 121²⁸, which closely supported present

findings. The most recent study by Sinha and Priya also reported inhibition zones of 8.0 mm and 7.0 mm against *B. subtilis* and *S. aureus*²⁹, which supported the present findings.

The FTIR analysis provided additional insight into the antimicrobial mechanism. The spectrum exhibited crucial absorption bands characteristic of specific functional groups (Fig 1). Most notably, a broad band at approximately 3400 cm^{-1} corresponding to O-H stretching vibrations was observed which indicated presence of hydroxyl groups associated with phenolic compounds. Additionally, a sharp peak near 1635 cm^{-1} was attributed to C=O stretching vibrations that suggested existence of carbonyl groups which possibly originating from proteins or flavonoids. These findings were closely related to the findings of Padmavathi *et al.*²⁷, who mentioned the presence of flavonoids or polyphenolic compounds at O-H stretching with AgNPs derived from *B. pinnatum* (Lam.) leaf extract. Beyond these major features, the spectrum displayed other minor peaks that implied the involvement of additional biomolecules e.g., C=C of benzene ($1,604.71\text{ cm}^{-1}$) and aliphatic amines ($1,095.75\text{ cm}^{-1}$) functional groups observed by Baishya *et al.*³⁰ which were close to 1637.3 cm^{-1} and 1016.39 cm^{-1} , respectively observed in present study. FTIR spectra have been reported to show the presence of organic acids, hydroxyl and phenolic compounds, amino groups, and aliphatic structures.³¹

These phytochemicals not only acted as bio-reductants to reduce silver ions to nanoparticles but also served as capping agents, stabilizing the nanoparticles⁸. Importantly, these compounds themselves possess antimicrobial properties. Thus, a synergistic effect between the AgNPs and the bioactive phytochemicals further enhanced the antimicrobial efficacy. Further optimization of nanoparticle size, concentration, or surface functionalization may be required to enhance clinical applicability. The antimicrobial evaluation strongly indicated that the biosynthesized AgNPs of *B. pinnatum* (Lam.) possess broad-spectrum and potent antibacterial activity. The effects observed were due to both the nanoparticles and the plant-derived capping biomolecules, as confirmed by FTIR characterization.

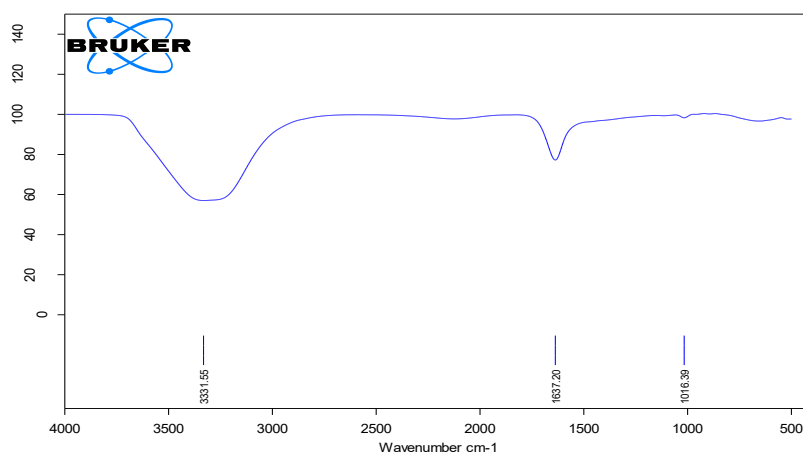


Figure 1: FTIR spectrum of *B. pinnatum* (Lam.) extract derived AgNPs

Hence, present findings substantiate earlier reports that *B. pinnatum* (Lam.) extract is an efficient bio-reductant and stabiliser for nanoparticle synthesis with promising applications of green-synthesised AgNPs in antimicrobial and environmental contexts.

CONCLUSION

AgNPs synthesized from *B. pinnatum* (Lam.) extract exhibited significantly enhanced antibacterial activity compared to the crude plant extract. This increased efficacy is attributed to the synergistic interaction between silver ions and phytochemicals such as flavonoids, terpenoids, and phenolic compounds, which act as both reducing and stabilizing agents. The AgNPs demonstrated strong antimicrobial effects against both *B. subtilis* MTCC 121 and *S. aureus* MTCC 3160 were indicated broad-spectrum potential. Although their antibacterial activity was slightly lower than that of the standard antibiotic Ciprofloxacin, the findings highlight the promise of *B. pinnatum* (Lam.) derived AgNPs as eco-friendly and effective antibacterial agents. Additionally, The biosynthesized AgNPs from *B. pinnatum* (Lam.) exhibited strong, broad-spectrum antibacterial activity, attributed to the combined effects of the nanoparticles and plant-derived capping biomolecules, as confirmed by FTIR analysis. These results highlight their potential as eco-friendly and cost-effective antibacterial agents for environmental and biomedical use. These results align with previous studies emphasizing the potential of green-synthesized nanoparticles for biomedical applications. However, further optimization regarding nanoparticle concentration and formulation may be necessary to achieve clinical-level bactericidal efficacy. Overall, *B. pinnatum* (Lam.) mediated AgNPs offer a sustainable approach for developing novel antimicrobial materials suitable for environmental and medical applications. The study revealed the importance of *B. pinnatum* (Lam.) as an exceptional plant material and a boon to nano researchers to act as a better reducing and capping agent, as reported by most of the researchers to date.

Conflict of Interest: The authors declare no potential conflict of interest concerning the contents, authorship, and/or publication of this article.

Author Contributions: All authors have equal contributions in revising and editing the manuscript.

Source of Support: Nil

Informed Consent Statement: Not applicable.

Ethical approval: Not applicable

REFERENCES

- Elzein, B. "Nano Revolution: 'Tiny tech, big impact: How nanotechnology is driving SDGs progress'." *Heliyon* 2024;10:e31393. <https://doi.org/10.1016/j.heliyon.2024.e31393>
- Yadav, V. K., P. Malik, A. H. Khan, P. R. Pandit, M. A. Hasan, M. M. S. Cabral-Pinto, S. Islam, R. Suriyaprabha, K. K. Yadav, P. A. Dinis, S. H. Khan, and L. Diniz. "Recent Advances on Properties and Utility of Nanomaterials Generated from Industrial and Biological Activities." *Crystals* 2021;11:634. <https://doi.org/10.3390/cryst11060634>
- Ying, S., Z. Guan, P. C. Ofoegbu, P. Clubb, C. Rico, F. He, and J. Hong. "Green synthesis of nanoparticles: Current developments and limitations." *Environmental Technology & Innovation* 2022;26:102336. <https://doi.org/10.1016/j.eti.2022.102336>
- Singh, H., M. F. Desimone, S. Pandya, S. Jasani, N. George, M. Adnan, A. Aldarhami, A. S. Bazaid, and S. A. Alderhami. "Revisiting the Green synthesis of nanoparticles: Uncovering influences of plant extracts as reducing agents for enhanced synthesis efficiency and its biomedical applications." *International Journal of Nanomedicine* 2023;18:4727-4750. <https://doi.org/10.2147/IJN.S419369>
- Kazemi, S., A. Hosseingholian, S. D. Gohari, F. Feirahi, F. Moammeri, G. Mesbahian, Z. S. Moghaddam, and Q. Ren. "Recent advances in green synthesized nanoparticles: from production to application." *Materials Today Sustainability* 2023;24:100500. <https://doi.org/10.1016/j.mtsust.2023.100500>
- Meher, A., A. Tandi, S. Moharana, S. Chakroborty, S. S. Mohapatra, A. Mondal, S. Dey, and P. Chandra. "Silver nanoparticle for biomedical applications: A review." *Hybrid Advances* 2024;6:100184. <https://doi.org/10.1016/j.hybadv.2024.100184>
- Xu, L., Y. Y. Wang, J. Huang, C. Y. Chen, Z. X. Wang, and H. Xie. "Silver nanoparticles: Synthesis, medical applications and biosafety." *Theranostics* 2020;10:8996-9031. <https://doi.org/10.7150/thno.45413>
- Fahim, M., A. Shahzaib, N. Nishat, A. Jahan, T. A. Bhat, and A. Inam. "Green synthesis of silver nanoparticles: A comprehensive review of methods, influencing factors, and applications." *JCIS Open* 2024;16:100125. <https://doi.org/10.1016/j.jciso.2024.100125>
- Ouandaogo, H. S., S. Diallo, E. Odari, and J. Kinyu. "Silver nanoparticle biosynthesis utilizing *Ocimum kilimandscharicum* leaf extract and assessment of its antibacterial activity against certain chosen bacteria." *PloS one* 2024;19:e0295463. <https://doi.org/10.1371/journal.pone.0295463>
- Patil, M. P., G. D. Kim, and J. H. Dong. "Green synthesis of silver nanoparticles using *Ocimum sanctum* extract and their antimicrobial potential." *Saudi Journal of Biological Sciences* 2021;28:309-316.
- Egbunu, I. E., and P. F. Uzor. "Green Synthesis of Silver Nanoparticles Using *Euphorbia hirta* Leaf Extract and the Determination of Their Antimicrobial Activity." *Advances in Bioscience and Bioengineering* 2021;9:124-129. <https://www.sciencepublishinggroup.com/article/10.11648/j.ab.b.20210904.14>
- Kumar, P., S. Senthamil Selvi, and A. Lakshmi Prabha. "Green synthesis of silver nanoparticles using *Azadirachta indica* leaf extract and their antimicrobial activity." *Materials Today: Proceedings* 2020;22:904-908.
- Benakashani, F., A. Allafchian, and S. A. H. Jalali. "Green synthesis, characterization and antibacterial potential of silver nanoparticles from *Onosma bracteatum* extract." *Tropical Journal of Natural Product Research* 2022;6:202-206.
- Phanse, N. V., K. Venkataraman, P. A. Kekre, S. Shah, and S. Parikh. "Phyto-assisted synthesis of Silver nanoparticles using *Tinospora cordifolia* leaf extract and their antibacterial activity: An ecofriendly approach." *Brazilian Journal of Science* 2023;3. <https://doi.org/10.14295/bjs.v3i2.501>
- Kumar, P., S. S. Selvi, and M. Govindaraju. "Green synthesis and characterization of silver nanoparticles from *Tinospora cordifolia* leaf extract: Evaluation of their antioxidant, anti-inflammatory, antibacterial, and antibiofilm efficacies." *Nanomaterials* 2023;15:381.
- Ullah, S., A. Ahmad, A. Wang, M. Raza, T. Jan, and X. Wang. "Green synthesis: The antibacterial and photocatalytic potential of silver nanoparticles using extract of *Teucrium stocksianum*." *Nanomaterials* 2023;13:134.
- Sheikh, S., N. Bhandakkar, P. Khairkar, and R. Mahajan. "Pharmacological and Phytochemical Profile of *Bryophyllum Pinnatum*." *International Journal of Pharmaceutical Sciences* 2025. <https://doi.org/10.5281/ZENODO.14859610>

18. Noor, H., A. Ayub, E. Dilshad, T. Afsar, S. Razak, F. M. Husain, and J. H. Trembley. "Assessment of Bryophyllum pinnatum mediated Ag and ZnO nanoparticles as efficient antimicrobial and cytotoxic agent." *Scientific reports* 2024;14:22200. <https://doi.org/10.1038/s41598-024-73092-6>
19. Fafal, T., P. Taştan, B. S. Tüzün, M. Ozyazici, and B. Kivcak. "Synthesis, characterization and studies on antioxidant activity of silver nanoparticles using *Asphodelus aestivus* Brot. aerial part extract." *Suid-Afrikaanse Tydskrif Vir Plantkunde [South African Journal of Botany]* 2017;112:346–353. <https://doi.org/10.1016/j.sajb.2017.06.019>
20. Allahverdy, J., and S. M. Jafari. "Silver nanoparticles for inactivation and destruction of foodborne pathogens and spoilage microorganisms; mechanisms, efficiency and recent advances." *Future Foods: A Dedicated Journal for Sustainability in Food Science* 2026;13:100889. <https://doi.org/10.1016/j.fufo.2025.100889>
21. Jagdish, R., and K. Nehra. "Bryophyllum pinnatum mediated synthesis of zinc oxide nanoparticles: characterization and application as biocontrol agents for multi-drug-resistant uropathogens." *Heliyon* 2022;8:e11080. <https://doi.org/10.1016/j.heliyon.2022.e11080>
22. Manandhar, S., S. Luitel, and R. K. Dahal. "In Vitro Antimicrobial Activity of Some Medicinal Plants against Human Pathogenic Bacteria." *Journal of tropical medicine* 2019;2019:1895340. <https://doi.org/10.1155/2019/1895340>
23. Thummajitsakul, S., P. Paensanit, T. Saeieo, J. Sirirat, and K. Silprasit. "FTIR and multivariate analysis of total phenolic content, antioxidant and anti-amylase activities of extracts and milk of *Glycine max* L. and *Phaseolus vulgaris* L." *Electronic Journal of Biotechnology* 2023;64:69–75. <https://doi.org/10.1016/j.ejbt.2023.04.001>
24. Ozdal, M., and S. Gurkok. "Recent advances in nanoparticles as antibacterial agent." *ADMET & DMPK* 2022;10:115–129. <https://doi.org/10.5599/admet.1172>
25. More, P. R., S. Pandit, A. Filippis, G. Franci, I. Mijakovic, and M. Galdiero. "Silver Nanoparticles: Bactericidal and Mechanistic Approach against Drug Resistant Pathogens." *Microorganisms* 2023;11:369. <https://doi.org/10.3390/microorganisms11020369>
26. Khan, S., M. Zahoor, R. Sher Khan, M. Ikram, and N. U. Islam. "The impact of silver nanoparticles on the growth of plants: The agriculture applications." *Heliyon* 2023;9:e16928. <https://doi.org/10.1016/j.heliyon.2023.e16928>
27. Padmavathi, J., A. Anantharaj, S. Velmurugan, G. Mariappan, and B. Gokulakumar. "Synthesis of Silver nanoparticles employing *Bryophyllum pinnatum* leaf extract and it's efficiency towards photocatalytic and antibacterial properties." *Chemical Data Collections* 2023;101085. <https://doi.org/10.1016/j.cdc.2023.101085>
28. Kumarmath, P. S., and P. Sharada. "Green approach for the synthesis of silver nanoparticles using *Bryophyllum pinnatum*." *International Journal of Green Pharmacy* 2021;15:307.
29. Sinha, N., and S. S. Priya. "Studies on anti-bacterial activity of silver nanoparticles synthesised using *Bryophyllum pinnatum* leaves." *International Journal of Pharmacy and Pharmaceutical Research* 2025;31.
30. Baishya, D., N. Sharma, and R. Bora. "Green synthesis of silver nanoparticle using *Bryophyllum pinnatum* (Lam.) and monitoring their antibacterial activities." *Archives of Applied Science Research* 2012;4:2098–2104. <https://www.scholarsresearchlibrary.com/articles/green-synthesis-of-silver-nanoparticle-using-bryophyllum-pinnatum-lam-and-monitoring-their-antibacterial-activities.pdf>
31. Shaheen, G., A. Ashfaq, T. Shamim, H. M. Asif, A. Ali, S. U. Rehman, and L. Sumreen. "Antioxidant, Antimicrobial, Phytochemical and FTIR Analysis of *Peganum harmala* (Fruit) Ethanolic Extract From Cholistan Desert, Pakistan." *Dose-response: a publication of International Hormesis Society* 2022;20:15593258221126832. <https://doi.org/10.1177/15593258221126832>