



Plant-mediated silver nanoparticles from leaf extract of *Dolichandra unguis-cati*: Synthesis, antibacterial activity and cytotoxicity

Swetha Ravindran¹, Archana E R¹, Anagha P¹, Veena V¹ & Sinitha K^{2*}

¹Department of Botany, Providence Women's College (Autonomous), Kozhikode 673 009, Kerala, India

²Department of Botany, Govt. Arts and Science College, Kozhikode 673 018, Kerala, India

*Correspondence: Sinitha K, drsinitthak@gmail.com

Abstract

The use of plant-mediated synthesis of nanoparticles has gained attention as a simple and economical approach for the development of antimicrobial and cytotoxic nanomaterials. The biological activities of silver nanoparticles (AgNPs) synthesised using *Dolichandra unguis-cati* (Cat's claw) remain insufficiently explored. This study aimed to synthesise and characterise AgNPs using an aqueous leaf extract of *D. unguis-cati* and to evaluate their antibacterial and preliminary cytotoxic activities. The formation of AgNPs was initially confirmed by a visible colour change of the reaction mixture from pale green to dark brown. Characterisation using UV-visible spectroscopy revealed a surface plasmon resonance peak at 415 nm after 24 hr of incubation. Transmission electron microscopy (TEM) showed the presence of spherical nanoparticles with sizes ranging from 5–20 nm. scanning electron microscopy (SEM) showed polygonal surface morphology and particle aggregation, while the TEM supported the polycrystalline nature of the AgNPs. Energy dispersive X-ray spectroscopy (EDX) confirmed the presence of silver (Ag) through a sharp Ag peak. Antibacterial activity evaluated by agar well diffusion assay showed an inhibition zone of 13 ± 0.58 mm at 1 mg/mL against *Staphylococcus aureus* and 11 ± 0.29 mm at 1 mg/mL for *Escherichia coli*. Furthermore, the *Allium cepa* mitotic index and human erythrocyte abnormality assays revealed cytotoxic and genotoxic effects, indicating apoptosis-like cell death. The present study provides a basis for further investigation of their potential biomedical applications.

Keywords: *Allium cepa*; antibacterial activity; *Dolichandra unguis-cati*; erythrocyte cytotoxicity; green synthesis; silver nanoparticles

Received: 01 June 2026. **Accepted:** 01 September 2026. **Available online:** Version 1.0: 03 October 2026; Version 2.0: 13 October 2026.

Cite this article: Swetha R, Archana ER, Anagha P, Veena V, Sinitha K. Plant-mediated silver nanoparticles from leaf extract of *Dolichandra unguis-cati*: Synthesis, antibacterial activity and cytotoxicity. Plant Science Today. 2026; 13(4): 1-10. <https://doi.org/10.14719/pst.15783>

1. Introduction

Nanomedicine is a rapidly developing branch of therapeutics in the field of biomedicine and the finest nanoparticles (AgNPs) can be formulated from metals like silver (Ag), gold (Au) and platinum (Pt) (1). Among these, AgNPs exhibit a characteristic surface plasmon resonance band that enables preliminary monitoring of nanoparticle formation (2). Surface plasmon resonance (SPR) refers to the collective, resonant oscillation of conduction-band electrons at the nanoparticle surface when excited by light of a matching wavelength (3). The resonance condition is highly sensitive to particle size, shape and aggregation state, the position, width and intensity of the SPR band and are widely used as an indirect, solution-based indicator of nanoparticle formation and quality, complementing direct imaging techniques such as transmission electron microscopy (TEM) and scanning electron microscopy (SEM) (3).

The AgNPs have been widely investigated for antibacterial applications because their nanoscale dimensions and surface properties facilitate interactions with microbial cells. (4). Synthesis of AgNPs through chemical processes is expensive and uses toxic chemicals, which adversely affects medical applications (5). The size, morphology, composition and surface chemistry of AgNPs strongly influence their physicochemical properties, biological activity and toxicity. Hence, synthesis methods capable of producing AgNPs with controlled and application-specific characteristics are inevitable. Conventional methods may involve high energy requirements and potentially hazardous chemical reagents, which necessitate environmentally compatible approaches such as plant-mediated synthesis (6). Plant-mediated synthesis can reduce reliance on hazardous reducing and capping agents by using phytochemicals as natural electron donors and stabilising molecules (7).

Dolichandra unguis-cati L., the "cat's claw creeper," is a climbing plant belonging to the family Bignoniaceae distributed in South America, Egypt and Western India (8). It is an ornamental plant and is employed in traditional medicine practices of Latin America for the treatment of several ailments (9–10). Phytochemical investigations of *D. unguis-cati* have reported the presence of flavonoids and related phenolic constituents (9), which are known to act as reducing and capping agents during the biogenic synthesis of metal nanoparticles and may also contribute to the antibacterial and cytotoxic activities evaluated in this study. The use of this plant in wound healing and in the treatment of uterine cysts and infections was also reported (10–12). Reports are available on plant-mediated synthesis of AgNPs from plants like *Tecoma stans*, *Tecomella undulata*, *Mansoa alliacea* of family Bignoniaceae (13–15). However, in most of these reports the synthesis is limited to physicochemical characterisation, with comparatively few studies extending to a systematic evaluation of biological activity across both antimicrobial and cytotoxic/genotoxic endpoints. Even though this plant has been widely discussed for its potential medicinal uses, to date, the biosynthesis of AgNPs using *D. unguis-cati* extracts has not been reported. Thus, the main objective of our present study was to biosynthesise AgNPs using an aqueous leaf extract of *D. unguis-cati*, to characterise the synthesised AgNPs and to evaluate the antibacterial and cytotoxic activities.

2. Materials and Methods

The plant leaf was collected from the Botanical Garden of Providence Women's College, Kozhikode, Kerala. The plant was authenticated by a qualified taxonomist and a voucher specimen was deposited in the Providence Women's College Herbarium under accession number PWC0112. The leaves were washed twice, first with running tap water and subsequently with distilled water. 1 g of fresh leaves was cut into small pieces and homogenised using 10 mL distilled water using mortar and pestle for 5 min at room temperature. The homogenate was filtered through Whatman No. 1 filter paper (11 µm pore size) and was stored in an airtight container under refrigeration (4 °C) and used within a week for further analyses.

Synthesis of silver nanoparticles (AgNPs)

0.01 M aqueous solution of silver nitrate (AgNO_3) (Spectrochem, India) was prepared and used for the synthesis of AgNPs using 1 g/ 10 mL plant extract (16). Combinations of temperatures (60, 70 and 80 °C) and duration (30 min, 1 hr, 6 hr, 24 hr) were carried out to standardise the conditions required for maximum yield of AgNPs. The optimum condition for the maximum production of nanoparticles was obtained by combining 1 mL of plant extract (1 g/10 mL) with 9 mL of 0.01 M AgNO_3 , followed by incubation at 80 °C in a water bath (Rotek, India) for 30 min. The obtained particles were centrifuged at 4000 rpm for 15 min (REMI R- 8C, India),

washed thrice with distilled water and dried in laminar air flow for 8 hr and stored in airtight vials.

Characterisation of nanoparticles

For UV-visible spectroscopy, 1 mg of the nanoparticles was resuspended in 3 mL of deionised water, transferred into the vial and analysed using UV-visible spectroscopy (ELICO Ltd, India). Absorbance spectra were recorded and the presence of characteristic peaks was used to confirm nanoparticle formation. Transmission electron microscopy (HR transmission electron microscope (HRTEM) with selected area electron diffraction (SAED) (JEM 2100, Jeol Ltd., Japan) analysis was conducted to examine the morphology, size and crystallinity of AgNPs synthesised. The particles were suspended in distilled water, mounted on the carbon-coated copper grid and were examined at different resolutions ranging from 2–10 nm.

The nanoparticles were resuspended in a drop of deionised water, mounted on the stub with the help of a carbon tape and subjected to scanning electron microscopic imaging (JEOL JSM-6390). Images of the nanoparticles were recorded in various resolutions. In order to confirm the presence of elemental silver, energy dispersive X-ray analysis was done. The particles were mounted on the carbon tape on the stub through which X-rays were passed and examined for EDX spectrum.

Antibacterial studies

Antibacterial activity of *D. unguis-cati* derived AgNPs were assessed. The bacterial strains were procured from microbial type culture collection and gene bank (MTCC), Chandigarh, India. Antibacterial efficacy was evaluated against *Staphylococcus aureus* (MTCC 96), *Escherichia coli* (MTCC 443) and *Citrobacter koseri* (MTCC 1657). Sterile nutrient agar (pH 7.2) was prepared and poured into petri dishes. Bacterial cultures were evenly spread using sterile swabs. Wells (7 mm) were bored into the agar and 50 µL of 0.5 and 1 mg/mL of nanoparticle solution were loaded into the wells. Distilled water served as control and a standard antibiotic disc (tetracycline-30 µg/disc) as positive control. Plates were incubated at 37 °C for 24 hr. Zones of inhibition were measured in millimetres to assess the antibacterial activity.

Cytotoxicity assay using plant system

The cytotoxicity assay on *Allium cepa* root meristem was carried out using a modified protocol (17). The healthy bulbs of *A. cepa* were planted in sterilised sandy soil and the germinated bulbs were collected on day 2. Bulbs were incubated in different concentrations (0.1, 0.5 and 1 % v/v) of biogenically synthesised AgNPs in triplicates for 24 hr at room temperature. On day 3, 5 root tips from each bulb were collected during the peak mitotic hours (9–10 am). The root tips were fixed using ethanol-glacial acetic acid in 3 : 1 ratio (modified Carnoy's fluid) for about 1 hr. It was washed thoroughly and kept for hydrolysis in 1 N HCl for 2–4 min. Mitotic squash preparations were made using acetocarmine as stain. The root tips incubated in distilled water and H_2O_2



were taken as negative and positive control respectively. The prepared slides were observed under light microscope and the photographs were taken (Magnus, India) to study the effect of the extracts on the dividing cells. Mitotic index was calculated by the formula:

$$\text{Mitotic index} = \frac{\text{Number of cells in mitotic division}}{\text{Total number of cells}} \times 100$$

Cytotoxicity assay using mammalian system

The cytotoxic assay in erythrocytes was carried out by standard protocol (18). The blood samples were collected from the blood bank. About 1 mL of blood sample was subjected to centrifugation to remove the plasma. The supernatant was removed and the settled cells were washed twice with 0.9 % NaCl. The obtained RBC was treated with 1 μ M of biosynthesised nanoparticles. The saline solution served as the control. After incubation for 2–4 min, May - Grunwald-Giemsa stain was applied for staining and smears were prepared. The prepared slides were observed under light microscope (100 x) and the photographs were taken (Magnus, India). Abnormality index was calculated using the following formula:

$$\text{Abnormality index} = \frac{\text{Number of abnormal cells}}{\text{Total number of cells}} \times 100$$

Statistical analysis

All assays were performed in triplicate and the results are expressed as mean $\pm$ standard error (SE). Statistical significance was done for cytotoxic studies. It was determined using one-way analysis of variance (ANOVA), followed by DMRT (Duncan's multiple range test) with $p < 0.05$ considered statistically significant.

3. Results

The change in the colour of the mixture containing AgNO_3 and plant extract, from pale green to deep brown denoted the biogenic reduction of metallic silver into elemental nanoparticles (Fig. 1).

Characterisation of synthesised silver nanoparticles (AgNPs)

UV-visible spectroscopy

Silver nanoparticles synthesised by using the aqueous extract of *D. unguis-cati* were dispersed in deionised water to undergo UV-visible spectroscopy. A broad surface plasmon resonance band was observed over approximately 400–440 nm, with a λ_{max} at 415 nm (Fig. 2). A strong and broad absorption band centred at 415 nm was observed confirming the formation of stable AgNPs. This peak corresponds to SPR, a phenomenon characteristic of metallic nanoparticles.

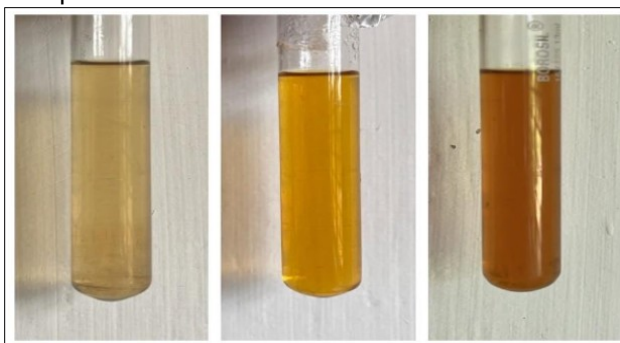


Fig. 1. Change of colour of solution from pale green, pale brown to brown indicates the synthesis of silver nanoparticles by the aqueous leaf extract of *Dolichandra unguis-cati*.

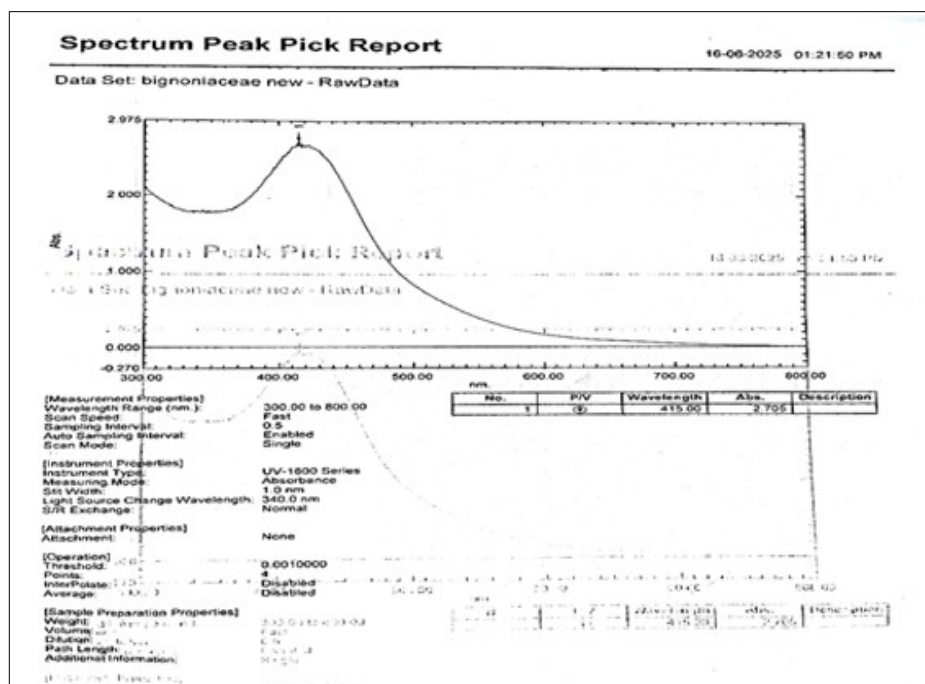


Fig. 2. UV-Vis absorption spectrum of the biogenically synthesised silver nanoparticles using the aqueous extract of *Dolichandra unguis-cati*.

Transmission electron microscopy (TEM)

Transmission electron microscopy imaging provided high-resolution visualisation of the synthesised AgNPs, confirming their nanoscale dimensions and morphological characteristics. The majority of the particles appeared spherical to slightly elliptical in shape, with sizes ranging between 5–20 nm. A few smaller nanoparticles were observed to aggregate into loosely bound clusters, although mono dispersity was generally maintained, with minimal signs of agglomeration.

At higher magnification, the particles were well-defined, with uniform contrast and shape, supporting the formation of stable and discrete nanoparticles. The SAED pattern exhibited multiple distinct diffraction spots around the central transmitted beam which confirms the ordered crystalline nature of the nanoparticles. This suggests a polycrystalline structure of the nanoparticles with differently oriented crystalline domains. Lower magnification images revealed the presence of a bio-organic matrix, which is indicative of the involvement of plant-derived phytochemicals in the synthesis and capping process (Fig. 3).

SEM analysis

Scanning electron microscopy analysis of the biogenically synthesised AgNPs showed well-defined, crystalline particles with smooth surfaces and polygonal shapes. The size of the particles ranged from 32–600 nm (Fig. 4). At higher magnification, individual

particles are distinct, while the lower magnification image displays a uniform distribution with limited agglomeration. The minimal clustering is a desirable property that indicates the stability of the biogenic method. It is noted that the SEM-derived size range (32–600 nm) is substantially larger than the primary particle size observed by TEM (5–20 nm); this most likely reflects SEM imaging of agglomerated particle clusters and the surrounding phyto-organic capping layer rather than individual nanoparticle cores, so TEM is taken here as the more reliable measure of the true primary particle size.

EDX analysis

Energy dispersive X-ray spectroscopy is used to determine the elemental position of a sample. The elemental composition analysis conducted by EDX showed the strongest signal for the silver region, along with weaker signals from the C, N, O and Cl atoms (Fig. 5).

Antibacterial activity

The antibacterial potential of *D. unguis-cati* AgNPs were evaluated against *S. aureus*, *E. coli* and *C. koseri* using the well diffusion method (Table 1). Increasing the AgNP concentration from 0.5 to 1 mg/mL increased the inhibition zone against *S. aureus* from 10.6 ± 0.77 to 13.0 ± 0.58 mm and against *E. coli* from 10.0 ± 1.26 to 11.0 ± 0.29 mm. No inhibition zone was observed against *C. koseri* at either concentration.

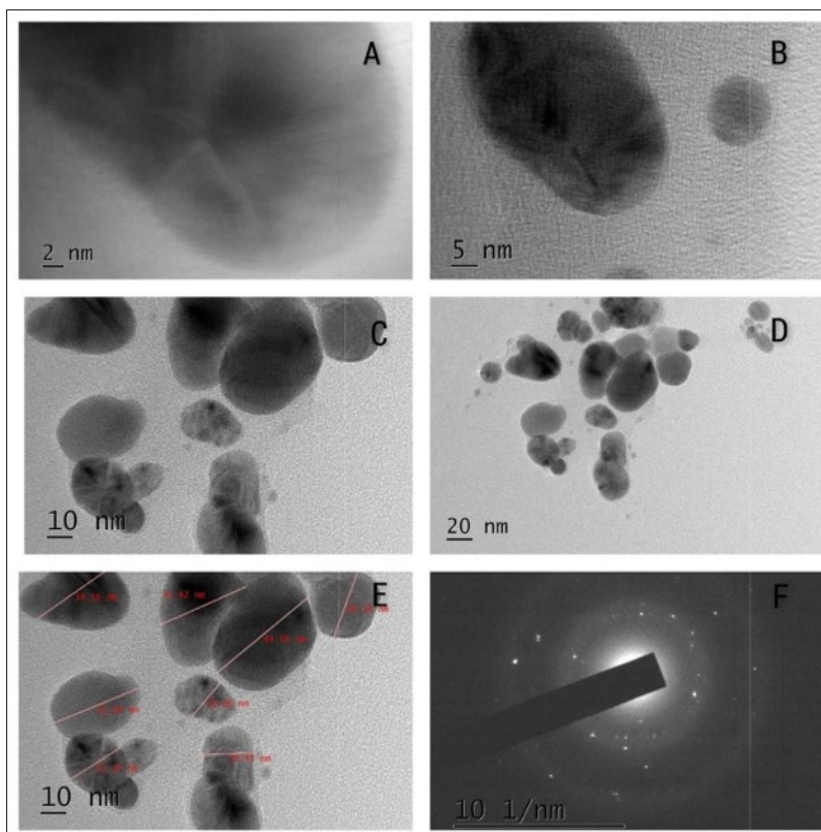


Fig. 3. The TEM analysis of AgNPs synthesised using *Dolichandra unguis-cati* leaf extract (A) High-resolution TEM image showing lattice fringes at scale bar of 2 nm; (B) Individual AgNPs at scale bar 5 nm; (C, D) Morphology and dispersion at different magnifications at scale bars of 10, 20 nm respectively; (E) Size distribution of AgNPs; (F) Selected area electron diffraction (SAED) pattern confirming polycrystallinity at scale of 101 nm.

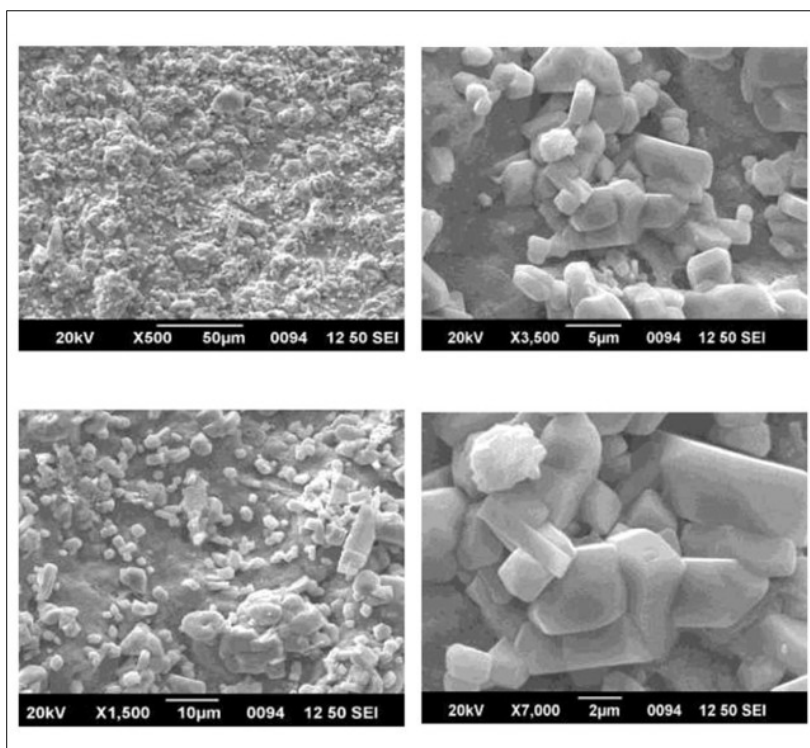


Fig. 4. Scanning electron microscopic images, under different magnifications, of the biogenically synthesised silver nanoparticles using the aqueous extract of *Dolichandra unguis-cati*.

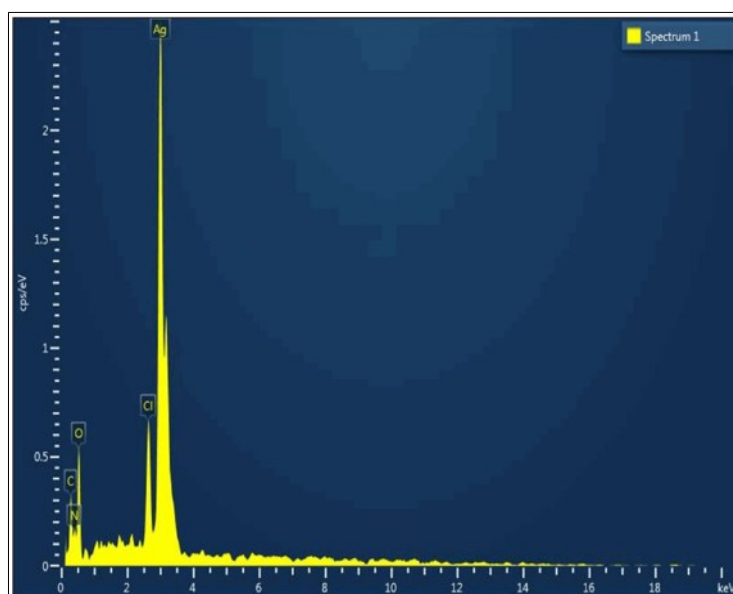


Fig. 5. Energy dispersive X-ray spectroscopy (EDX) spectrum of the biogenically synthesised silver nanoparticles using the aqueous extract of *Dolichandra unguis-cati* showing the most prominent peak for Ag denoting the presence of elemental silver particles.

Table 1. Zone of inhibition (mm) of synthesised silver nanoparticles (AgNPs) against bacterial strains

Test compounds		<i>Staphylococcus aureus</i>	<i>Escherichia coli</i>	<i>Citrobacter koseri</i>
Distilled water (C)		0	0	0
Tetracyclin		19 ± 0.29	22.5 ± 0.5	18.6 ± 0.59
AgNPs	0.5 mg/mL	10.6 ± 0.77	10 ± 1.26	0
AgNPs	1 mg/mL	13 ± 0.58	11 ± 0.29	0

Data represented as mean ± SE (n = 3).

Cytotoxic effects on *Allium cepa* root meristematic cells

Cells were treated in different concentrations of synthesised AgNPs. Various concentrations such as 0.1, 0.5 and 1 % for a time period of 24 hr were tested. The bulb treated in hydrogen peroxide was taken as positive control whereas those kept in distilled water was considered as negative control. The effect of the extract on the *Allium* root meristem was studied by direct microscopic observation and by determining mitotic index. The aberrations of cells which were different from that of normal cells were noted. Some of the important clastogenic aberrations include nuclear disintegration, chromosome erosion, pulverised chromosome, chromosome fragments, sticky chromosomes etc. whereas the non-clastogenic ones include displaced chromosomes, chromosomal vagrants, hyperploidy and polyploidy (Fig. 6). All concentrations tested were found to induce aberrations, but the highest toxicity was observed at 1 % concentration. The percentage of damaged cells increased with an increase in the concentration of AgNPs. The cells treated with highest concentration of AgNP showed the highest toxicity with the least mitotic index. Mitotic index decreased progressively with increasing AgNP concentration, showing an inverse dose-response relationship Table 2.

Apoptotic assay on human erythrocytes

The samples treated with various concentrations of AgNPs showed varying degrees of cell distortion and lysis (Fig. 7). The samples treated with 0.1 % AgNPs showed loss of membrane integrity and membrane blebs and at highest concentration of 1 % it showed cell lysis. Loss of membrane integrity, cell shrinkage, membrane blebs, nuclear fragmentation and appearance of

apoptotic bodies were observed in all the treated samples. These morphological features are commonly associated with apoptosis in eukaryotic cells; however, in the absence of confirmatory assays, they are suggestive of, rather than conclusive evidence for apoptosis-like cell death. With increase in the concentration of solution, the abnormality index showed an increased rate. The maximum abnormality index was shown by biogenically synthesised AgNPs at 1 % (Table 3).

Table 2. Mitotic index in *Allium cepa* assay carried out using biogenically synthesised silver nanoparticles using *Dolichandra unguis-cati*

Sample	Mitotic index
Negative control (Distilled water)	$6.28 \pm 0.731^{a,b}$
Positive control H_2O_2	$0.11 \pm 0.023^{a,b}$
AgNP 0.1 % (v/v)	$0.711 \pm 0.291^{b,c}$
AgNP 0.5 % (v/v)	$0.592 \pm 0.167^{a,c}$
AgNP 1 % (v/v)	$0.473 \pm 0.167^{b,c}$

Data represented as mean $\pm$ SE (n = 3). Values with different letters are significantly different according to DMRT at $p < 0.05$.

Table 3. Abnormality index in human erythrocytes treated with the aqueous extract, biogenically synthesised silver nanoparticles and mixture of both from *Dolichandra unguis-cati*

Sample	Abnormality index
Control	$0.04 \pm 0.003^{a,c}$
AgNP 0.1 % (v/v)	$5.04 \pm 0.82^{a,b}$
AgNP 0.5 % (v/v)	$5.202 \pm 0.60^{a,b}$
AgNP 1 % (v/v)	$5.365 \pm 0.39^{b,c}$

Data represented as mean $\pm$ SE (n = 3). Values with different letters are significantly different according to DMRT at $p < 0.05$.

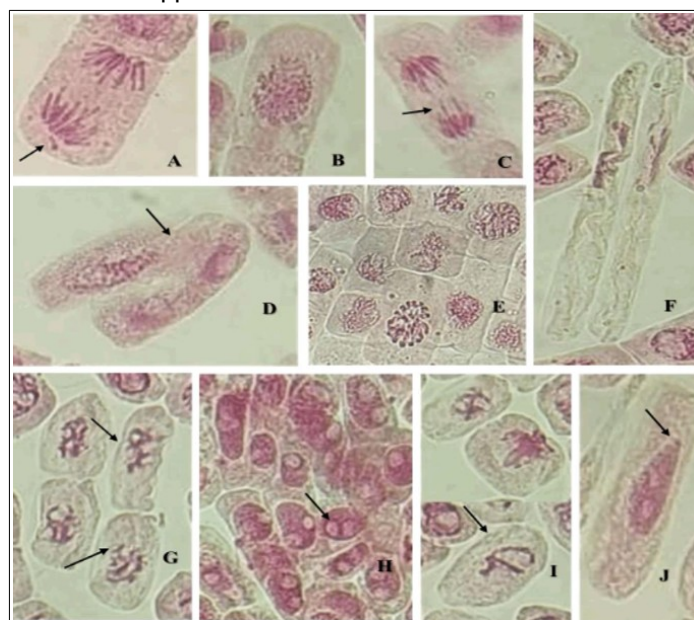


Fig. 6. Cytological aberrations seen in the root meristem of *Allium cepa* as a result of treatment with AgNP. (A) Chromosomal breakage during anaphase; (B) Pulverised chromatin during prophase; (C) Chromosomal laggards during anaphase; (D) Cytomixis (E) Chromosome rosette formation during early metaphase; (F) Strap cells with pulverised strap nuclei; (G) Chromatin disintegration (H) Multiple nuclear lesions; (I) Nuclear erosion and ghost cell formation; (J) Nuclear beak.

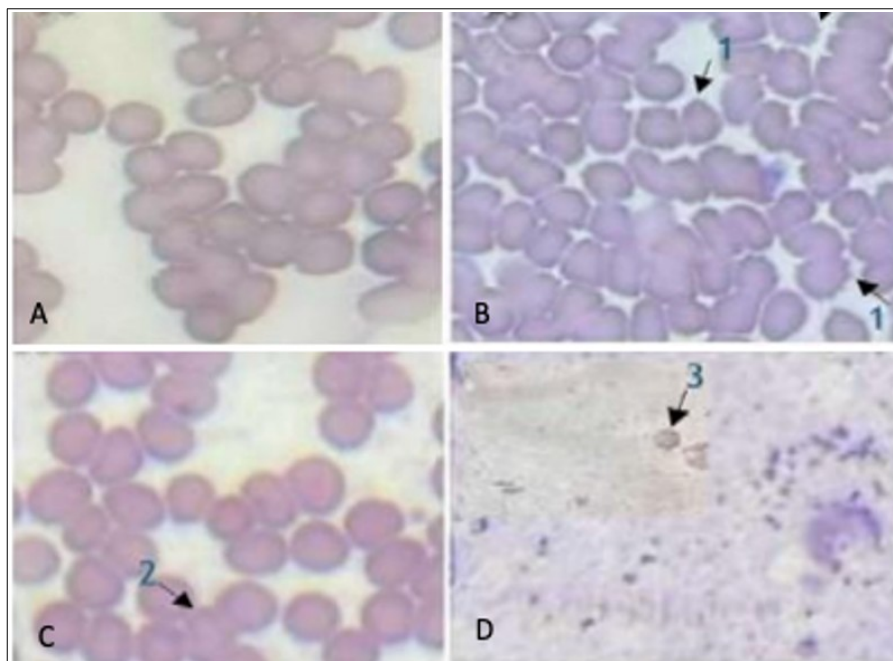


Fig. 7. Human erythrocytes treated with various concentrations of biogenically synthesised AgNP of *Dolichandra. Unguis-cati* (A. Control B. 0.1 %, B. 0.5 %, C. 1 %) (1. Membrane blebs; 2. Cell shrinkage; 3. Apoptotic body formation).

4. Discussion

The present study shows an eco-friendly approach for the synthesis of AgNPs using the leaf extract of *D. unguis-cati*. The visible colour change from pale green to dark brown observed during the reaction is an indication of AgNP formation. The development of the brown colour might be associated with the surface plasmon resonance of newly formed AgNPs following the reduction of Ag^+ to Ag^0 . The leaf-extract and AgNO_3 controls are necessary to confirm that the observed colour change resulted from the interaction between the two components. However, similar colour transitions have been widely reported in plant-mediated AgNP synthesis, confirming the suitability of phytochemical-rich extracts as reducing agents (1, 5, 19).

The UV-visible absorption peak at 415 nm observed after 24 hr of incubation, confirms the formation of AgNPs and falls within the characteristic surface plasmon resonance range of spherical AgNPs. The excitation of SPR is responsible for the formation of colour and absorbance in a colloidal solution of AgNPs. The SPR peaks in the general range of 400–450 nm are typically reported in the literature as confirming the reduction of AgNO_3 into AgNPs, consistent with the 415 nm peak observed in the present study (20). The absence of additional peaks in the 335–560 nm range further suggests that the synthesised nanoparticles were non-aggregated and predominantly spherical in the colloidal (solution) state; this is noted as distinct from the larger, more heterogeneous sizes seen by SEM, which reflects the dried, deposited sample rather than the dispersed nanoparticles. Similar SPR bands have been reported in several plant-mediated AgNP synthesis studies. For instance, AgNPs synthesised from leaves of *Tecoma stans* of the same family showed peaks

around 390–450 nm (13). The AgNPs from *Couroupita guianensis* showed SPR peaks around 415–420 nm, indicating the formation of stable spherical nanoparticles (21). Likewise, AgNPs synthesised from *Peltophorum pterocarpum* pods exhibited an SPR peak at 407 nm corresponding to nanosilver formation (22). These findings are also consistent with earlier reports indicating that SPR is a reliable indicator of AgNP formation (23, 24). Phytochemicals such as phenolics, flavonoids and alkaloids reported from this plant likely acted as capping agents (9). These characteristics indicate that the synthesised AgNPs are suitable for applications that benefit from controlled particle size and shape (25). The EDX analysis confirms the purity of green-synthesised AgNPs through the presence of a sharp Ag peak. The additional signals might have originated from the organic phytochemicals associated with the plant extract. The SEM images further showed crystalline nanoparticles with smooth and polygonal morphology which support the formation of well-defined nanostructures (26, 27).

The small particle size contributes to the enhanced surface area-to-volume ratio, which in turn augments their biological reactivity, particularly against microorganisms (28). Reports by earlier investigators demonstrated similar enhanced antibacterial activity for small sized spherical AgNPs synthesised through green routes (29–31). The antibacterial activity of the biosynthesised AgNPs showed moderate inhibition against both *S. aureus* and *E. coli*. No activity was seen against *C. koseri* with both the concentrations. The lack of inhibitory activity against *C. koseri*, in contrast to the moderate susceptibility observed for *S. aureus* and *E. coli*, may reflect species-specific differences in outer-membrane permeability, porin expression, or efflux-pump activity among Enterobacteriaceae, all of which are known to modulate nanoparticle and metal-ion uptake in

gram-negative bacteria (32, 33). Capsule or biofilm formation, that can limit nanoparticle penetration, may also have contributed to the reduced susceptibility of this strain. Comparative MIC/MBC determination and strain-specific permeability studies would help clarify the basis for this resistance and are suggested as follow-up work. Although not directly investigated in the present study, the antibacterial action of AgNPs has been proposed in the literature to be multifactorial, potentially involving cell membrane disruption, generation of reactive oxygen species (ROS), interaction with cellular proteins and DNA and modulation of microbial signal transduction pathways (34); these remain hypothesised mechanisms for the present system rather than experimentally confirmed ones. Furthermore, Gram-positive bacteria like *S. aureus* often show greater sensitivity to AgNPs due to their simpler peptidoglycan layers, whereas gram-negative bacteria possess lipopolysaccharide barriers, which may affect nanoparticle uptake (34). Although the inhibition zones were less pronounced than conventional antibiotics, the green-synthesised AgNPs demonstrate promising potential as alternative antimicrobial agents, especially in an era of increasing antibiotic resistance. It should be noted that the present assay did not include a silver-ion (e.g., AgNO_3) or bulk-silver control at an equivalent silver concentration; since the antimicrobial activity of silver in ionic form is already well established, such controls are needed in future work to establish whether the nanoparticle form confers activity beyond that of dissolved silver and the present results should be interpreted as evidence of antibacterial activity of the biosynthesised preparation rather than proof of a nanoparticle-specific effect. These findings indicate potential for enhanced antibacterial efficacy through dose optimisation or synergistic use with conventional antibiotics.

Cytotoxicity and apoptosis studies conducted in both *A. cepa* and mammalian cell systems revealed cytotoxic and genotoxic effects, with morphological changes suggestive of apoptosis-like cell death. The *A. cepa* assay serves as a well-established preliminary model for assessing cytotoxic and genotoxic effects and the consistency of apoptotic responses across plant and mammalian systems strengthens the biological relevance of the findings. Although these mechanisms were not directly investigated here, apoptosis-like cell death induced by AgNPs has been attributed in other studies to oxidative stress, mitochondrial dysfunction and DNA fragmentation and these remain plausible, literature-supported explanations for the morphological changes observed in the present study (35).

The studies on other members of Bignoniaceae have revealed the antibacterial effect of varying range. *Tecoma stans* flower extract-mediated AgNP-talc nanostructures, with AgNPs of approximately 50–60 nm, exhibited inhibition zones of 24 mm against *S. aureus* and 16 mm against *E. coli* (36). The AgNPs synthesised using *Tecomella undulata* leaf extract were reported to have particle sizes ranging from 0.2–50 nm which exhibited antibacterial activity against *E. coli*,

Pseudomonas aeruginosa, *Vibrio cholerae* and *S. aureus* (37). Another plant of the same family, *Mansoa alliacea*-mediated AgNPs showed significant antibacterial activity against susceptible and multidrug-resistant bacterial strains; the lowest activity was reported against *S. enterica*, *E. coli* and *S. aureus*, a moderate activity was observed against *Enterococcus faecalis* (15). Compared with these reports, the present AgNPs demonstrate appreciable antibacterial activity. Variations in nanoparticle characteristics and differences in phytochemicals acting as reducing and capping agents, may account for variations in antibacterial efficacy among these systems.

Abnormality in the membrane characteristics were observed in the treated RBCs. Similar responses have been reported using May-Grünwald-Giemsa staining and scanning electron microscopy by earlier workers (18). Together, these morphological aberrations are consistent with a loss of cell viability and are suggestive of apoptosis-like cell death, although, as noted above, this cannot be confirmed without dedicated apoptosis assays. Features such as membrane blebbing, cell shrinkage and apoptotic body formation are generally regarded as more consistent with a regulated, apoptosis-like process than with outright necrotic lysis, but this interpretation remains provisional pending confirmatory testing. Biocompatibility assessments such as protein- and DNA- AgNP interaction studies (e.g., SDS-PAGE, agarose gel electrophoresis) were beyond the scope of the present study, which focused on synthesis, physicochemical characterisation and preliminary bioactivity screening; such studies, together with apoptosis-confirmatory assays and cancer-cell-line testing, are recommended as future work before the biomedical potential of these AgNPs is evaluated further.

5. Conclusion

The present study demonstrates that silver nanoparticles (AgNPs) can be synthesised using *Dolichandra unguis-cati* leaf extract using an eco-friendly phytosynthetic approach. The synthesised AgNPs exhibited the characteristic optical, morphological and elemental features of silver nanoparticles which showed moderate antibacterial activity against *Staphylococcus aureus* and *Escherichia coli*, whereas no appreciable activity was observed against *Citrobacter koseri*. The nanoparticles also induced a dose-dependent reduction in the mitotic index of *Allium cepa* root meristem cells thereby, indicating cytotoxic and genotoxic effects. The morphological changes observed in human erythrocytes indicate that the nanoparticles can induce eryptosis. Thus, the present findings provide preliminary evidence of the biological activity of *D. unguis-cati*-mediated AgNPs, while their biomedical applicability and safety remain to be established. Further studies involving cancer cell lines, apoptosis-specific assays and *in vivo* studies using *D. unguis-cati*-mediated AgNPs may serve as promising candidate for green nanotherapeutic development.



Acknowledgements

The authors gratefully acknowledge the financial support provided by the Providence Research Scheme (PRS) of Providence Women's College (Autonomous), which facilitated the completion of this research.

Authors' contributions

SR conducted the study, performed data analysis and visualisation and prepared the original draft of the manuscript. AER contributed to laboratory analyses and manuscript preparation. AP contributed to laboratory analyses and data visualisation. VV supervised the study and critically reviewed the manuscript. SK contributed to data analysis and critically reviewed the manuscript. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

References

- Yarrappagaari S, Gutha R, Narayanaswamy L, Thopireddy L, Benne L, Mohiyuddin SS, et al. Eco-friendly synthesis of silver nanoparticles from the whole plant of *Cleome viscosa* and evaluation of their characterization, antibacterial, antioxidant and antidiabetic properties. *Saudi J Biol Sci.* 2020;27:3601–14. <https://doi.org/10.1016/j.sjbs.2020.07.034>
- Chaudhari K, Ahuja T, Murugesan V, Subramanian V, Ganayee MA, Thundat T, et al. Appearance of SERS activity in single silver nanoparticles by laser-induced reshaping. *Nanoscale.* 2019;11:321–30. <https://doi.org/10.1039/C8NR06497K>
- Zhou J, Wang Y, Zhang GJ. State-of-the-art strategies of surface plasmon resonance biosensors in clinical analysis: a comprehensive review. *Coord Chem Rev.* 2024;520:216149. <https://doi.org/10.1016/j.ccr.2024.216149>
- Jain D, Daima HK, Kachhwaha S, Kothari SL. Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their antimicrobial activities. *Dig J Nanomater Biostruct.* 2009;4:557–63.
- Baskaran X, Geo Vigila AV, Parimelazhagan T, Muralidhara-Rao D, Zhang S. Biosynthesis, characterization and evaluation of bioactivities of leaf extract-mediated biocompatible silver nanoparticles from *Pteris tripartita*. *Int J Nanomedicine.* 2016;11:5789–806. <https://doi.org/10.2147/IJN.S108208>
- Madani M, Hosny S, Alshangiti D, Nady N, Alkhursani SA, Alkhalidi H, et al. Green synthesis of nanoparticles for varied applications: green renewable resources and energy-efficient synthetic routes. *Nanotechnol Rev.* 2022;11:731–59. <https://doi.org/10.1515/ntrev-2022-0034>
- Phanjom P, Sultana A, Sarma H, Ramchiary J, Goswami K, Baishya P. Plant-mediated synthesis of silver nanoparticles using *Elaeagnus latifolia* leaf extract. *Dig J Nanomater Biostruct.* 2012;7:1117–23.
- Brondani JC, Reginato FZ, da Silva Brum E, de Souza Vencato M, Lhamas CL, Viana C, et al. Evaluation of acute and subacute toxicity of hydroethanolic extract of *Dolichandra unguis-cati* leaves in rats. *J Ethnopharmacol.* 2017;202:147–53. <https://doi.org/10.1016/j.jep.2017.03.011>
- Aboutabl EA, Hashem FA, Sleem AA, Maamoon AA. Flavonoids, anti-inflammatory activity and cytotoxicity of *Macfadyena unguis-cati*. *Afr J Tradit Complement Altern Med.* 2008;5:18–26. <https://doi.org/10.4314/ajtcam.v5i1.31251>
- Duke JA. Duke's handbook of medicinal plants of Latin America. Boca Raton: CRC Press; 2008. <https://doi.org/10.1201/9781420043174>
- Flor ASSDO, Barbosa WLR. Sabedoria popular no uso de plantas medicinais pelos moradores do bairro do sossego no distrito de Marudá-PA. *Rev Bras Plantas Med.* 2015;17:757–68. https://doi.org/10.1590/1983-084X/14_064
- Mors WB, do Nascimento MC, Pereira BMR, Pereira NA. Plant natural products active against snake bite-the molecular approach. *Phytochemistry.* 2000;55:627–42. [https://doi.org/10.1016/S0031-9422\(00\)00229-6](https://doi.org/10.1016/S0031-9422(00)00229-6)
- Arunkumar C, Nima P, Astalakshmi A, Ganesan V. Green synthesis and characterization of silver nanoparticles using leaves of *Tecoma stans* (L.) Kunth. *Int J Nanotechnol Appl.* 2013;3:1–10.
- Chaudhuri SK, Chandela S, Malodia L. Plant mediated green synthesis of silver nanoparticles using *Tecomella undulata* leaf extract and their characterization. *Nano Biomed Eng.* 2016;8:1–8. <https://doi.org/10.5101/nbe.v8i1.p1-8>
- Zuñiga-Miranda J, Carrera-Pacheco SE, Gonzalez-Pastor R, Mayorga-Ramos A, Rodríguez-Pólit C, Heredia-Moya J, et al. Phytosynthesis of silver nanoparticles using *Mansoa alliacea* (Lam.) A.H. Gentry (Bignoniaceae) leaf extract: characterization and their biological activities. *Pharmaceutics.* 2024;16:1247. <https://doi.org/10.3390/pharmaceutics16101247>
- Dada AO, Adekola FA, Dada FE, Adelani-Akande AT, Bello MO, Okonkwo CR, et al. Silver nanoparticle synthesis by *Acalypha wilkesiana* extract: phytochemical screening, characterization, influence of operational parameters and preliminary antibacterial testing. *Heliyon.* 2019;5:e02517. <https://doi.org/10.1016/j.heliyon.2019.e02517>
- Prajitha V, Thoppil JE. Cytotoxic and apoptotic activities of extract of *Amaranthus spinosus* in *Allium cepa* and human erythrocytes. *Cytotechnology.* 2017;69:123–33. <https://doi.org/10.1007/s10616-016-0044-5>
- Bhagyanathan NK, Thoppil JE. Pre-apoptotic activity of aqueous extracts of *Cynanchum sarcomedium* on cells of *Allium cepa* and human erythrocytes. *Protoplasma.* 2016;253:1433–8. <https://doi.org/10.1007/s00709-015-0898-y>
- Gaddam SA, Kotakadi VS, Subramanyam GK, Penchalaneni J, Challagundla VN, Dvr SG, et al. Multifaceted phytogetic silver nanoparticles by an



- insectivorous plant *Drosera spatulata* var. *bakoensis* and its potential therapeutic applications. *Sci Rep.* 2021;11:21969. <https://doi.org/10.1038/s41598-021-01281-8>
20. Jiang T, Huang J, Peng J, Wang Y, Du L. Characterization of silver nanoparticles synthesized by the aqueous extract of *Zanthoxylum nitidum* and its herbicidal activity against *Bidens pilosa* L. *Nanomaterials.* 2023;13:1637. <https://doi.org/10.3390/nano13101637>
 21. Rajesh Kumar TV, Murthy JSR, Narayana Rao M, Bhargava Y. Evaluation of silver nanoparticles synthetic potential of *Couroupita guianensis* Aubl. flower buds extract and their synergistic antibacterial activity. *3 Biotech.* 2016;6:92. <https://doi.org/10.1007/s13205-016-0407-9>
 22. Raja S, Ramesh V, Thivaharan V. Antibacterial and anticoagulant activity of silver nanoparticles synthesised from a novel source-pods of *Peltophorum pterocarpum*. *J Ind Eng Chem.* 2015;29:257–64. <https://doi.org/10.1016/j.jiec.2015.03.033>
 23. Vanlalveni C, Lallianrawna S, Biswas A, Selvaraj M, Changmai B, Rokhum SL. Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activities: a review of recent literature. *RSC Adv.* 2021;11:2804–37. <https://doi.org/10.1039/D0RA09941D>
 24. Mohammed AE, Al-Qahtani A, Al-Mutairi A, Al-Shamri B, Aabed K. Antibacterial and cytotoxic potential of biosynthesized silver nanoparticles by some plant extracts. *Nanomaterials.* 2018;8:382. <https://doi.org/10.3390/nano8060382>
 25. Gowramma B, Keerthi U, Rafi M, Muralidhara Rao D. Biogenic silver nanoparticles production and characterization from native strain of *Corynebacterium* species and its antimicrobial activity. *3 Biotech.* 2015;5:195–201. <https://doi.org/10.1007/s13205-014-0210-4>
 26. Kumari A, Guliani A, Singla R, Yadav R, Yadav SK. Silver nanoparticles synthesised using plant extracts show strong antibacterial activity. *IET Nanobiotechnol.* 2015;9:142–52. <https://doi.org/10.1049/iet-nbt.2014.0021>
 27. Ali SSM, Dharmadhikari K, Saiyed KI, Vasava H, Jowhari MA, Robin P. Ecofriendly synthesis of silver nanoparticles using *Barleria gibsonii* and evaluation of antibacterial, antioxidant, cytotoxic and catalytic activities. *Sci Rep.* 2026;16:8281. <https://doi.org/10.1038/s41598-026-37330-3>
 28. Rai M, Ingle AP, Trzcińska-Wencel J, Wypij M, Bonde S, Yadav A, et al. Biogenic silver nanoparticles: what we know and what do we need to know? *Nanomaterials.* 2021;11:2901. <https://doi.org/10.3390/nano11112901>
 29. Chinnasamy G, Chandrasekharan S, Bhatnagar S. Biosynthesis of silver nanoparticles from *Melia azedarach*: enhancement of antibacterial, wound healing, antidiabetic and antioxidant activities. *Int J Nanomedicine.* 2019;14:9823–36. <https://doi.org/10.2147/IJN.S231340>
 30. Tang S, Zheng J. Antibacterial activity of silver nanoparticles: structural effects. *Adv Healthc Mater.* 2018;7:1701503. <https://doi.org/10.1002/adhm.201701503>
 31. Salayová A, Bedlovičová Z, Daneu N, Baláž M, Lukáčová Bujňáková Z, Balážová L, et al. Green synthesis of silver nanoparticles with antibacterial activity using various medicinal plant extracts: morphology and antibacterial efficacy. *Nanomaterials.* 2021;11:1005. <https://doi.org/10.3390/nano11041005>
 32. Franci G, Falanga A, Galdiero S, Palomba L, Rai M, Morelli G, et al. Silver nanoparticles as potential antibacterial agents. *Molecules.* 2015;20:8856–74. <https://doi.org/10.3390/molecules20058856>
 33. Dakal TC, Kumar A, Majumdar RS, Yadav V. Mechanistic basis of antimicrobial actions of silver nanoparticles. *Front Microbiol.* 2016;7:1831. <https://doi.org/10.3389/fmicb.2016.01831>
 34. Lara HH, Ayala-Núñez NV, Ixtapan Turrent LDC, Rodríguez Padilla C. Bactericidal effect of silver nanoparticles against multidrug-resistant bacteria. *World J Microbiol Biotechnol.* 2010;26:615–21. <https://doi.org/10.1007/s11274-009-0211-3>
 35. Jiang X, Khan S, Dykes A, Stulz E, Zhang X. Biogenic synthesis of silver nanoparticles and their diverse biomedical applications. *Molecules.* 2025;30:3104. <https://doi.org/10.3390/molecules30153104>
 36. Hariram M, Vivekanandhan S, Ganesan V, Muthuramkumar S, Rodriguez-Urbe A, Mohanty AK, et al. *Tecoma stans* flower extract assisted biogenic synthesis of functional Ag-Talc nanostructures for antimicrobial applications. *Bioresour Technol Rep.* 2019;7:100298. <https://doi.org/10.1016/j.biteb.2019.100298>
 37. Vaishnav R, Agrawal RD. Synthesis and characterization of silver nanoparticles by using aqueous leaf extract of *Tecomella undulata* (Sm.) Seem. and their antibacterial properties. *Res Rev J Pharmacogn.* 2020;7:5–13.

Additional information

Peer review: Publisher thanks the Sectional Editor and anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information: Available at https://horizonpublishing.com/journals/index.php/PST/open_access_policy.

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: See https://horizonpublishing.com/journals/index.php/PST/indexing_abstracting.

Copyright: © The Author(s). This is an open-access article distributed under the Creative Commons Attribution License CC BY 4.0.

Publisher information: Plant Science Today is published by Horizon e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.