# Silver Nanoparticles (Medicinal Scenario): A Novel Platform to Combat Microbial Pathogens- A Review

***Kalitha Parveen.P Kandasamy Prabakar[1] M.Mohamed Meeran[2]**
[*2] PG Department of Zoology, Hajee Karutha Rowther Howdia College of arts and science, Uuthamapalayam.
[1]PG and Research Department of Zoology, Jamal Mohamed College, Trichurapalli.
620020 Tamil Nadu, India

***Abstract:*** ***India has a rich cultural heritage of traditional medicines which includes Ayurveda and Siddha system of medicines. Medicinal plants are important for pharmacological research and drug development, not only when plant constituents are used directly as therapeutic agents, but also as starting materials for the synthesis of drugs or as models for pharmacologically active compounds. The considerable test in the world is confronting today. It is the method of treatment of pathogenic microscopic organisms which have turned out to be impervious to the current anti-infection agents. Step by step, the protection from existing anti-infection agents or medications is expanding for one or different reasons. This expanding frequency of anti-infection protection among the microbial life forms requires a substitute treatment to check the safe irresistible microorganisms. Another way to deal with counteracts or battle microbial pathogen is by the utilization of silver nanoparticles particularly integrated with the assistance of characteristic therapeutic plants. Restorative plants are as of now known for some remedial qualities and have been utilized since ages for curing numerous illnesses and disarranges including irresistible infections. This is a result of the phytoconstituents display in them. The phytoconstituents or auxiliary metabolites exhibit in them can be utilized for blending silver nanoparticles. The blend of silver nanoparticles by methods for utilizing watery concentrates of restorative plants is basic, proficient, eco inviting, reasonable, and safe and it doesn't require any modern instrumentation. Any piece of the plant like leaf, root, stem, peel or organic product can be used for the union of silver nanoparticles. The integrated silver nanoparticles can be utilized independently or utilized as a part of blend treatment or synergistic treatment. The combined silver nanoparticles are for the most part described by UV-vis spectroscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), Zeta potential, X-beam diffraction (XRD), and so forth. The present review depicts the most encouraging plants by the assistance of which silver nanoparticles have been integrated which can be utilized as new novel wellspring of antimicrobes and to battle various medication microorganisms.***

***Keywords:*** ***AgNO3, silver nanoparticles, medicinal plants, green biosynthesis, nanotechnology, structural characterization.***

## INTRODUCTION

A significant number of modern pharmaceutical drugs are thus based on or derived from medicinal plants. This therapeutically important medicinal plant is not present in the Ayurvedic Pharmacopeia of India and it should be incorporated therein. The current appearance of multi drug resistant bacteria and the infections caused by them is on the grow very abruptly. This is distressing and a worldwide hazard. Prior they were the most effective weapons to battle against a microbial contamination and it was the fundamental treatment to treat a wide range of diseases. Be that as it may, the mistreatment of anti-infection agents has lessened their adequacy and correspondingly bacterial protection expanded. The lower viability of anti-microbials causes a large number of passings around the world. Antimicrobial protection has a huge negative effect on the result of treatment and increase the danger of diseases in healing facilities. Multi drug resistant pathogens cause many challenging and demanding infections for eg. Gram positive *Staphylococcus aureus* has evolved from penicillin resistant phenotypes into a methicillin resistant strain (MRSA), which has become a global epidemic. *Enterococcus faecium, Staphylococcus aureus, Clostridium difficile, Acinetobacter baumannii, Pseudomonas aeruginosa and Enterobacteriaceae (including Escherichia coli, Klebsiella pneumoniae, Enterobacter spp.).*

**Therapeutic plants:** An elective source as antimicrobes another expectation of treating such multi sedate safe contaminations originated from therapeutic plants since nature is the main source to give an assortment of mixture aggravates that can be utilized for new medication revelation. Various optional metabolites like phenols, flavonoids, glycosides, alkaloids, saponins, triterpenes, and so on produced by plants are pharmacologically dynamic. The additional favorable position of utilizing restorative plants are they are privileged, matter-of-fact and with lesser reactions. The plant concentrates can be utilized independently or in blend with anti-infection agents or other plant concentrates or a few chemicals i.e. blend treatment. This was the following way to deal with battle the multidrug safe microscopic organisms. This mix treatment or synergistic treatment demonstrated very fruitful. Be that as it may, the advancement of medication safe strains is rising alarmingly and the scan for new and novel methods for battling the medication protection component and win-win circumstance against the new or re-rising microorganisms goes on. Requirement for novel approach increasing protection against anti-infection agents is a consuming medical issue. So there is a vital and critical need to enhance the current medications or find new, novel methodologies to defeat this issue. Lessening the molecule measure is an effective and solid instrument to attempt. The restorative relevance of silver and therapeutic plants in treating bacterial diseases is as of now surely understood. As of late, unification of silver nano particles (SNPs) with the assistance of therapeutic plants is endeavored; the diminishment of silver to nano measure is expert by the optional metabolites exhibit in the restorative plants. Nano particles, for the most part considered as particles with a size of up to 100 nm, display totally new or enhanced properties when contrasted with the bigger particles of the mass material that they are comprised of. There are different strategies for blending silver nano particles, for example, bright illumination, vaporized advancements, lithography, laser removal, ultrasonic fields, warming and electrochemical decrease, photochemical lessening and utilization of diminishing chemicals like hydrazine hydrate and sodium citrate, sodium borohydride, formaldehyde, polyethylene glycol, glucose, and so on. Yet, these systems are costly and some of the time dangerous chemicals are engaged with their synthesis which is harmful to nature additionally. To circumvent this many biological systems like bacteria, fungi, yeast, cyanobacteria, actinomycetes and plants have been used. But the best one appears to be the use of plants. Any part of the plant

like leaf *Saraca indica , Lawsonia inermis, Piper betle L. , stem, Cissus quadrangularis, peel Punica granatum , Citrus sinensis , Annona squamosa , Tribulus terrestris , Terminalia chebula , Solanum torvum , Macrotyloma uniflorum , Medicago sativa , Euphorbia nivulia, Callicarpa maingayi , Boswellia valifoliolata, Shorea tumbuggaia , Morinda citrifolia, Blepharis maderaspatensis* can be utilized for the synthesis of silver nanoparticles. The use of various parts of plants for the synthesis of nanoparticles is considered as a green technology as it does not involve any harmful chemicals. The synthesis of silver nanoparticles by means of using aqueous extracts of medicinal plants is simple, efficient, eco friendly, inexpensive, safe and it does not require any sophisticated instrumentation.

**Combination of silver nanoparticles** – The initial step is to influence watery plant to extricate, which is normally done by heating up the plant material in refined water. The time by and large changes from 2 to 15 minutes. This plant separate is added to AgNO3 and the minute the two arrangements are blended the development of silver nano particles. When the plant extricate is added to AgNO3, the shade of AgNO3 changes from watery to yellow to darker to orange showing the presence of silver nano particles in the fluid.. Be that as it may, this time length changes from plant to plant. The start of development of silver nano particles fluctuates from couple of minutes to couple of hours after which, there is slight variety in its arrangement yet ordinarily the strategy is proceeded for 24 h. There are numerous elements which influence the development of silver nano particles. The grouping of the fluid plant extricate assumes a vital part in the development of silver nano particles. The higher grouping of the plant concentrate will prompt the development of more silver nano particles; the convergence of AgNO3 additionally impacts the arrangement of silver nano particles yet higher centralization of AgNO3 will create bigger silver particles and the other way around. Alternate factors that impact the shape and size of silver nano particles are pH and temperature. Huge particles are shaped at lower pH though at higher pH, exceptionally scattered and littler nano particles are framed by the instrument of antibacterial movement of silver nanoparticles. The antibacterial action displayed by silver nano particles relies upon AgNO3 fixation. It is conversely corresponding i.e. less metal fixation more is the movement and the other way around. This is on account of littler particles have bigger surface zone accessible for association and will give more bactericidal impact than the bigger particles. Nano particles display totally new or enhanced properties in light of particular attributes, for example, size, dispersion and morphology. The film of microorganisms is contrarily charged and silver nano particles are decidedly charged and when these emphatically charged silver nano particles aggregate on adversely charged cell layer, it realizes a considerable conformational change in the layer and it eventually loses penetrability control which prompts cell passing. Some articles expressed that once silver nano particles enter the bacterial cell; they would meddle with the bacterial development flagging pathway by tweaking tyrosine phosphorylation of putative peptides substrates basic for cell feasibility and cell division. The nanoparticles discharge silver particles in the bacterial cells, which upgrade their bactericidal action. Some authors expressed that silver nano particles idealy attack the respiratory chain, cell division at long last prompting cell demise. As indicated by *Amro et al.*, metal exhaustion may cause the arrangement of unpredictably molded pits in the external layer and change film porousness, which is caused by dynamic arrival of lipopolysaccharides and film proteins. Or on the other hand maybe DNA loses its replication capacity and articulation of ribosomal subunits proteins and also some other cell proteins and catalysts basic to ATP creation moves toward becoming inactivated. The other mechanism proposed by *Danilczuk et al.*, and *Kim et al.*, is the arrangement of free radicals which along these lines instigates silver screen harm prompting productive antimicrobial property of silver nano particles. The other component proposed is inclusion of collaboration of silver nano particles with organic macromolecules, for example, proteins and DNA through an electro-discharge implement. The nanoparticles get appended to the cell layer and infiltrate inside the microscopic organisms. The bacterial layer contains sulfur containing proteins and the silver nanoparticles interface with these proteins in the cell and in addition with the phosphorus containing substances like DNA. Ag+ ties to utilitarian gatherings of proteins, bringing about protein denaturation. The silver nano particles demonstrate productive antimicrobial property because of their to a great degree expansive surface territory, which furnishes better contact with microorganisms. It is sensible to express that the authoritative of the nano particles to the microorganisms relies upon the cooperation of the surface zone accessible. Particles having a bigger surface region accessible for communication will have a more grounded bactericidal impact than bigger particles.

**Utilization of silver nanoparticles:**

Antimicrobial capacity of SNPs enables them to be reasonably utilized in various family items, for example, materials, sustenance stock piling compartments, home machines and in restorative gadgets. The most essential utilization of silver and SNPs is in medicinal industry, for example, tropical salves to avoid disease against consume and open injuries. Silver nano particles are accounted for to have numerous restorative employments. There are accounted for to have hostile to viral, antibacterial, antifungal, against parasitic, larvicidal action and anticancer properties. Because of solid antibacterial property silver nano particles are utilized as a part of garments, sustenance industry, sunscreens, beautifying agents and numerous family unit apparatus. Hardly any examinations have demonstrated that silver nanoparticles execute contagious spores by destructing the layer respectability.

**Characterization of silver nanoparticles:**

The incorporated silver nanoparticles are for the most part described by UV-vis spectroscopy, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), Zeta potential, X-ray diffraction (XRD), and so on .

**(UV-VIS) spectroscopy:**

UV-vis spectroscopy is a significant device for auxiliary portrayal of SNPs. It is a crucial method to find out the development of stable metal nanoparticles in fluid medium. It is outstanding that the optical ingestion spectra of metal nanoparticles are overwhelmed by surface Plasmon resonances (SPRs) that move to longer wavelengths with expanding molecule estimate. Additionally, it is very much perceived that the absorbance of Ag NPs depends essentially upon size and shape. When all is said in done, the quantity of SPR crests diminishes as the symmetry of the nanoparticles increments. The position and state of the Plasmon assimilation relies upon the particles' size and shape, and the dielectric consistent of the encompassing medium. The presence of SPR tops at 446 nm gives an advantageous spectroscopic mark to the arrangement of silver nano particles.

**Scanning electron microscopy (SEM):**

The SEM examination is utilized to portray the size, shape, morphology and appropriation of integrated silver nano particles.

**Transmission electron microscopy (TEM):**

TEM estimations are led to gauge the molecule size and size conveyance of the orchestrated silver nano particles. The plant concentrate ought to be sufficiently adequate to be covered on the integrated silver nano particles, generally accumulation of particles is quickened and the particles are not adequately balanced out.

**Fourier transform infrared spectroscopy (FTIR):**

FTIR estimations are completed to recognize the conceivable biomolecules in charge of diminishment, topping and proficient adjustment of silver nano particles and the nearby sub-atomic condition of the topping operators on the nanoparticles.

**Zeta potential:**

Zeta potential is a fundamental parameter for the portrayal of soundness in watery nano suspension. At least + 30 mV zeta potential qualities is required for sign of stable nano suspension. Higher zeta potential demonstrates more prominent dependability of the integrated silver nano particles.

**X-ray diffraction (XRD):**

The XRD has ended up being an important research device to demonstrate the arrangement of silver nano particles and to decide the gem structure of the silver nano particles and to compute the crystalline molecule measure. Mounting confirmations recommend that silver nanoparticles go about as promising antimicrobial operators and may develop as another option to regular anti-infection agents. They could be of enormous use in the medicinal field for their productive antimicrobial capacity. The present survey portrays the absolute most encouraging plants by the assistance of which silver nanoparticles have been integrated which can be utilized as another novel wellspring of antimicrobics to battle numerous medication safe intense microorganisms and furthermore can be restoratively used to battle different infections and disarranges.

Table 1: List of silver nano particles synthesized medicinal plants and their activities.

| S.NO | NAME OF THE PLANT | PARTS USED TO SYNTHESIZE NPs AND ITS ACTIVITY |
|---|---|---|
| 1. | *Acalypha indica* | Leaf- Antifungal |
| 2. | *Allium sativum* | Clove-Antibacterial |
| 3. | *Artemisia nilagirica* | Leaf- Antibacterial |
| 4. | *Blepharis maderaspatensis* | Leaf- Anticancer A431 cell line |
| 5. | *Boswellia serrata* | Gum- Antibacterial |
| 6. | *Catharanthus roseus* | Leaf- Antiplasmodial |
| 7. | *Cissus quadrangularis* | Stem- Antiparasitic |
| 8. | *Euphorbia nivulia* | Stem latex – Antibacterial |
| 9. | *Ocimum sanctum* | Leaf- Antibacterial |
| 10. | *Solanum torvum* | Leaf- Antioxidant |
| 11. | *Punica granatum* | Peel- Antibacterial |
| 12. | *Morinda pubescens* | Leaf- Antioxidant and Anticancer |
| 13. | *Morinda citrifolia* | Root- Cytotoxicity HeLa cell lines |
| 14. | *Solanum trilobatum* | Leaf- Antidandruff activity |
| 15. | *Vitex negundo* | Leaf- Anticancer HCT15 |
| 16. | *Mayaca fluvatilis* | Marine plant- Antimicrobial |
| 17. | *Cocus nusifera* | Coir – Nosocomical infection |
| 18. | *Indigifera longeracemosa* | Leaf- cytotoxicity SK MEL-28 cell lines |
| 19. | *Olea europaea* | Leaf- Anticancer MCF-7 cells |
| 20. | *Elettaria cardamomum* | Seed – cytotoxic activity |
| 21. | *Adenium obesum* | Leaf extract- Apoptosis |

| | | |
|---|---|---|
| 22. | *Anisochillus carnosus* | Leaf- Antimicrobial |
| 23. | *Cochlospermum religiosum* | Stem bark- Antibacterial |
| 24. | *Mukia scabrella* | Leaf extract- nosocomial pathogens |
| 25. | *Phyllanthus amarus* | Leaf – Antifungal |
| 26. | *Tinospora cardifolia* | Leaf – Antibacterial |

**References**


1. Alam MB, Hossain S, Haque ME. International Journal of Pharmaceutical Science and Research 2011; 2: 303-310.

**[1]** Khan AV, Ahmad QU, Shukla I, Khan AA. Antibacterial efficacy of *Bacopa monnieri* leaf extracts against pathogenic bacteria. Asian Biomed. 2010;4:651–655.

**[2]** Rios JL, Recio MC. Medicinal plants and antimicrobial activity. J Ethnopharmacol. 2005;100:80–84.

**[3]** Singhal G, Bhavesh R, Kasariya K, Sharma AR, Singh RP (2011) Biosynthesis of silver nanoparticles using Ocimum sanctum (Tulsi) leaf extract and screening its antimicrobial activity. J Nanoparticles Res 13:2981–2988

**[4]** . Nahrstedt A, Butterweck V. Lessons learned from herbal medicinal products: the example of St. John's Wort. J Nat Prod. 2010;73:1015–1021.

**[5]** Rojas,.R., B.Bustamante, J.Bauer, I.Ferrandez, J.Alban and Lock. O. 2003.Antimicrobial activity of selected Peruvian medicinal plants. *J. Ethnopharmacology*., 88: 199-204.

**[6]** Harekrishna Bar, D.K.B., Gobindasahoo P, priyanka Sarkar, Sankar PD., "Green synthesis of silvernanoparticles using latex of Jatropha curcas. " colloid surface A, 2009. 39(3): 134-139.

**[7]** Dorman HJ, Deans SG. Antimicrobial agents from plants: activity of plant volatile oils. J Appl Microbiol.2000; 88:308–316.

**[8]** Siddique YH, Ara G, Beg T, Afzal M (2008) Possible modulating action of plant infusion of Ocimum sanctum L. on chromosomal aberrations and sister chromatid exchanges induced by chlormadinoneacetate in human lymphocytes in vitro. J Environ Biol 29(6): 845-848.

**[9]** Khan AV, Ahmad R, Khan AA, Shukla I. Antibacterial activity of *Oxystelma esculentum* leaf extracts against some hospital isolated human pathogenic bacterial strains. J Herb Med Toxicol. 2008;2:67–70.

**[10]** Baker C, Pradhan A, Pakstis L, Darrin JP, Ismat SS. Journal of Nanoscience Nanotechnology. 2005; 5 : 244–249.

**[11]** 2. Duwiejua, M., Zeitlin, I.J., Waterman, P.G., Chapman, J., Mhango, G.J. and Provan, G.J.1993. Anti-inflammatory activity of resins from some species of the plant family Burseraceae. *Planta Medica* **59**(1): 12-16.

**[12]** Fabricant, D.S. and Farnsworth, N.R. 2001. The value of plants used in traditional medicine for drug discovery. *Environmental Health Perspectives* **109(**1): 69-75.

**[13]** Engler AC, Wiradharma N, Ong ZY, Coady DJ, Hedrick JL, Yang Y (2012) Emerging trends in macromolecular antimicrobials to fight multi-drug resistant infections. Nano Today 7:201-222.

**[14]** Rakholiya K, Chanda S. In vitro interaction of certain antimicrobial agents in combination with plant extracts against some pathogenic bacterial strains. Asian Pacific Journal of Tropical Biomedicine. 2012; S876-S880.

**[15]** Kaviya S, Santhanalakshmi J, Vishwanathan B. Green synthesis of silver nanoparticles using Polyalthia longifolia leaf extracts along with D-sorbitol:study of antibacterial activity. Journal of Nanotechnology. 2011;doi:10.1155/2011/152970

**[16]** Chanda S, Rakholiya K, Nair R. Antimicrobial activity of Terminalia catappa L. leaf extracts against some clinically important pathogenic microbial strains. Chinese Medicine 2011; 2:171-177.

**[17]** Patel H, Vaghasiya Y, Vyas BRM, Chanda S. Emergence of methicillin-resistant Staphylococcus aureus (MRSA) as a publichealth threat and future directions of antibiotic therapy for MRSA infections. Anti-Infective Agents. 2012; 10:149-157.

**[18]** Willems, van den Wildenberg. Roadmap Report on Nanoparticles. W&W Espana s.l., Barcelona, Spain, 2005.

**[19]** Guzman M, Dille J, Godet S. Synthesis and antibacterial activity of silver nano particles against gram positive and gram negative bacteria. Nanomedicine:Nanotechnology, Biology and Medicine. 2012; 8:37-45.

**[20]** Gopinath P, Gogoi SK, Sanpoi P, Paul A, Chattopadhyay, Ghosh SS. Signaling gene cascade in silver nanoparticle induced apoptosis. Colloids and Surfaces B: Biointerfaces. 2010; 77:240-245.

**[21]** Shameli K, Ahmad MB, Al-Mulla EAJ, Ibrahim NA, Shabanzadeh P, Rustaiyan A, Abdollahi Y, Bagheri S, Abdol mohammadi S, Usman MS, Zidan M. Green biosynthesis of silver nanoparticles using Callicarpa maingayi stem bark extraction. Molecules. 2012 : 17, 8506-8517.

**[22]** Rajamanickam K, Sudha SS, Francis M, Sowmya T, Rengaramanujam J, Sivalingam P, Prabakar K. Microalgae associated Brevundimonas sp. MSK 4 as the nano particle synthesizing unit to produce antimicrobial silver nanoparticles. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2013; 113:10-14.

**[23]** Rodriques AG, Ping LY, Marcato PD, Alves OL, Silva MCP, Ruiz RC, Melo IS, Tasic L, DeSouza AO. Biogenic antimicrobial silver nanoparticles produced by fungi. Applied Microbiology Biotechnology. 2012; DOI:10.1007/00253-012-4209-7.

**[24]** Gopinath V, MubarakAli D, Priyadarshini S, Priyadharsshini MN, Thajuddin N, Velusamy P. Biosynthesis of silver nanoparticles from Tribulus terrestris and its antimicrobial activity: A novel biological approach. Colloids and Surfaces B: Biointerfaces. 2012 ; 96 :69-74.

**[25]** Prakash P, Gnanaprakasam P, Emmanuel R, Arokiyaraj S, Saravanan M. Green synthesis of silver nanoparticles from leaf extract of Mimusops elengi, Linn. for enhanced antibacterial activity against multi drug resistant clinical isolates. Colloids and Surfaces B: Biointerfaces. 2013; 108:255–259.

**[26]** Kumar CG, Mamidyala SK. Extracellular synthesis of silver nanoparticles using culture suspernatat of Pseudomonas aeruginosa. Colloids and Surfaces B:Biointerfaces. 2011; 80:462-466.
**[27]** Nagati VB, Alwala J, Koyyati R, Donda MR, Banala R, Padigya PRM. Green Synthesis of plant-mediated silver nanoparticles using Withania somnifera leaf extract and evaluation of their anti microbial activity. Asian Pacific Journal of Tropical Biomedicine. 2012; 1-5
**[28]** Prabakar K, Sivalingam P, Rabeek SIM, Muthuselvam M, Devarajan N , Arjunan A, Karthick R, SureshMM, Wembonyama JP. Evaluation of antibacterial efficacy of phyto fabricated silver nanoparticles using Mukia scabrella (Musumusukkai) against drug resistance nosocomial gram negative bacterial pathogens. Colloids and Surfaces B: Biointerfaces . 2013; 104:282– 288.
**[29]** Usha Rani P, Rajasekharreddy P. Green synthesis of silver-protein (core–shell) nanoparticles using Piper betle L. leaf extract and its ecotoxicological studies on Daphnia magna. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2011 ; 389 :188-194.
**[30]** Jebakumar IET, Sethuraman MG. Biogenic robust synthesis of Silver Nanoparticles using Punica granatum peel and its application as a green catalyst for the reduction of anthropogenic pollutant 4-nitrophenol. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2013; DOI: http://dx.doi.org/10.1016/j.saa. 2012.11.084.
**[31]** Sunkar S, Nachiyar CV. Microbial synthesis and characterization of silver nanoparticles using the endophytic bacterium Bacillus cereus: a novel source in the benign synthesis. Global Journal of Medical Research. 2012; 12:online ISSN:2249-4618.
**[32]** Garg S, Chandra A. Biosynthesis and anthelmintic activity o silver nanoparticles using aqueous extract of Saraca indica leaves. International Journal of Therapeutic Applications. 2012; 7: 9 – 12.
**[33]** Kumar R, Roopan SM, Prabhakarn A, Khanna VG, Chakroborty S. Agricultural waste Annona squamosa peel extract: Biosynthesis of silver nanoparticles. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012; 90:173- 176.
**[34]** Vidhu VK, Aromal SA, Philip D. Green synthesis of silver nanoparticles using Macrotyloma uniflorum. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2011; 83:392-397.
**[35]** Zayed MF, Eisa WH, Shabaka AA. Malva parviflora extract assisted green synthesis of silver nanoparticles. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012; 98:423–428.
**[36]** Santhosh kumar T, Rahuman AA, Bagavan A, Marimuthu S, Jayaseelan C, Vishnu Kirthi A, Kamaraj C, Rajakumar G Zahir AA, Elango G, Velayutham K, Iyappan M, Siva C, Karthik L, Rao VBK. Evaluation of stem aqueous extract and synthesized silver nanoparticles using Cissus quadrangularis against Hippobosca maculata and Rhipicephalus (Boophilus) microplus. Experimental Parasitology. 2012; 132: 156-165.
**[37]** Hamouda T, Baker Jr JR. Antimicrobial mechanism of action of surfactant lipid preparations in enteric gram-negative bacilli. Journal of Applied Microbiology . 2000;89:397-403.
**[38]** Ganesh Babu MM, Gunasekaran P. Extracellular synthesis of crystalline silver nano particles and its characterization. Material Letters. 2013; 90:162-164.
**[39]** Lukman AI, Gong B , Marjo CE, Roessner U and Harris AT. Facile synthesis, stabilization, and anti-bacterial performance of discrete Ag nanoparticles using Medicago sativa seed exudates. Journal of Colloid and Interface Science. 2011; 353:433–444.
**[40]** Mubarak Ali D, Thajuddin N, Jeganathan K, Gunasekaran M. Plant extract mediated synthesis of silver and gold nanoparticles and its antibacterial activity against clinically isolated pathogens. Colloids and Surfaces B: Biointerfaces. 2011; 85:360-365.
**[41]** Krishnaraj C, Ramachandran R, Mohan KKalaichelvan PT Optimization for rapid synthesis of silver nanoparticles and its effect on phytopathogenic fungi. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012; 93:95– 99.
**[42]** Kora AJ, Sashidhar RB, Arunachalam J Aqueous extract of gum olibanum (Boswellia serrata): A reductant and stabilizer for the biosynthesis of antibacterial silver nanoparticles. Process Biochemistry.2012; 47 :1516–1520.
**[43]** Morones JR, Elechiguerra JL, Camacho A, Holt K, Kouri JB, Ramfrez JT, Yacaman MJ. The bactericidal effect of silver nanoparticles. Nanotechnology. 2005; 16: 2346–2353.
**[44]** Danilczuk M, Lund A, Saldo J, Yamada H, Michalik J. Conduction electron spin resonance of small silver particles. Spectrochimaca Acta Part A.2006; 63:189 - 191.
**[45]** Kim JS, DVM, Kuk E, Yu KN, Kim J-H, Jin Park SJ, Lee HJ, Kim SH, Young Kyung Park YK, Park YH, Hwang C-Y, Kim YK, Lee YS, Jeong DH, Cho MH. Antimicrobial effects of silver nanoparticles. Nanomedicine: Nanotechnology, Biology, and Medicine. 2007; 3: 95– 101.
**[46]** Elechiguerra JL, Burt JL, Morones JR, Camacho BA, Gao X, Lara HH, Yacaman MJ. Interaction of silver nanoparticles with HIV-1. Journal of Nanobiotechnology 2005; 3: 6.
**[47]** Duran N, Marcato PD, Alves OL, Souza GI, Esposito E. Mechanistic aspects of biosynthesis of silver nanoparticles by several Fusarium oxysporum strains. Journal of Nanobiotechnology. 2005; 13: 3–8.
**[48]** Lee S, Yeo HJ, Jeong SY. Antibacterial effect of nanosized silver colloidal solution on textile fabrics. Journal of Material Science. 2003; 38:2199-2204.
**[49]** Pant G, Nayak N, Prasuna G 2012 Enhancement of antidandruff activity of shampoo by biosynthesized silver nanoparticles from Solanum trilobatum plant leaf. Applied Nanoscience DOI 10.1007/s13204-012-0164-y.
**[50]** Marimuthu S, Rahuman AA, Santhoshkumar T, Jayaseelan C, Kirthi AV, Bagavan A, Kamaraj C, Elango G, Zahir AA, Rajakumar G and Velayutham K. Lousicidal activity of synthesized silver nanoparticles using Lawsonia inermis leaf aqueous extract against Pediculus humanus capitis and Bovicola ovis . Parasitology Research. 2012; 111:2023–2033.
**[51]** Valodkar M, Nagar PS, Jadeja RN, Thounaojam MC, Devkar RV, Thakore S. Euphorbiaceae latex induced green synthesis of non-cytotoxic metallic nanoparticle solutions: A rational approach to antimicrobial applications. Colloids and Surfaces A: Physicochemical and Engineering Aspects . 2011; 384:337-344.
**[52]** Kaviya S, Santhanalakshmia J, Viswanathan B, Muthumary J, Srinivasan K. Biosynthesis of silver nanoparticles using citrus sinensis peel extract and its antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2011; 79:594-598.
**[53]** Ramamurthy CH, Padma M, I. Samadanam DM, MareeswaranR, Uyavaran A, Suresh Kumar M, Premkumar K, Thirunavukkarasu C. The extra cellular synthesis of gold and silver nanoparticles and their free radical scavenging and antibacterial properties. Colloids and Surfaces B: Biointerfaces. 2013; 102:802-815.

**[54]** Jebakumar IET, Sethuraman MG. Instant green synthesis of silver nanoparticles using Terminalia chebula fruit extract and evaluation of their catalytic activity on reduction of methylene blue. Process Biochemistry. 2012 ; 47:1351-1357.
**[55]** Amro NA, Kotra LP, Wadu-Mesthrige K, Bulychev A, Mobashery S,Liu G. High-resolution atomic force microscopy studies of the Escherichia coli outer membrane: structural basis for permeability. Langmuir. 2000; 16:2789- 2796.
**[56]** Suman TY, Radhika Rajasree SR, Kanchana A, Elizabeth SB. Biosynthesis, characterization and cytotoxic effect of plant mediated silver nanoparticles using Morinda citrifolia root extract. Colloids and Surfaces B: Biointerfaces. 2013; 106:74-78.
**[57]** Rajakumar G and, Rahuman AA. Larvicidal activity of synthesized silver nanoparticles using Eclipta prostrata leaf extract against filariasis and malaria vectors. Acta Tropica. 2011; 118 :196–203.
**[58]** Savithramma N, Rao ML, Rukmini K, Devi PS. Antimicrobial activity of silver nanoparticles synthesized by using medicinal plants. International Journal of ChemTech Research. 2011; 3: 1394–1402.
**[59]** Sathishkumar, M., Sneha, K., Won, S.W., Cho, C.W., Kim, S., Yun, Y.S. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nano-crystalline silver particles and its bactericidal activity. Colloids Surfaces B Biointerfaces. 2009; 73, 332–338.
**[60]** Bindhu MR, Umadevi M. Synthesis of monodispersed silver nanoparticles using Hibiscus cannabinus leaf extract and its antimicrobial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2013; 101:184-190.
**[61]** Shrivastava S, Bera T, Roy A, Singh G, Ramachandrarao P, Dash D.Characterization of enhanced antibacterial effects of novel silver nanoparticles. Nanotechnology 2007;18:225103.
**[62]** Raman N, Sudharsan S, Veerakumar V, Pravin N, Vithiya K. Pithecellobium dulce mediated extra-cellular green synthesis of larvicidal silver nanoparticles. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012; 96:1031-1037.
**[63]** Jayaseelan C, Rahuman AA, Rajakumar G, Kirthi AV, Santhoshkumar T, Marimuthu S, Bagavan A, Kamaraj C, Zahir AA, Elango G. Synthesis of pediculocidal and larvicidal silver nanoparticles by leaf extract from heartleaf moonseed plant, Tinospora cordifolia Miers. Parasitology Research. 2011; 109: 185–194.
**[64]** Mahendra R , Alka Y, Aniket G. Silver nanoparticles as a newgeneration of antimicrobials. Biotechnology Advances. (2009); 27:76–83.
**[65]** Baker C, Pradhan A, Pakstis L, Darrin JP, Ismat SS. Journal of Nanoscience Nanotechnology. 2005; 5 : 244–249.
**[66]** Sanghi R, Verma P. Biomimetic synthesis and characterization of protein capped silver nanoparticles. Bioresource Technology. 2009; 100:501-504.
**[67]** ] R.M. Gengan, K. Anand, A. Phulukdaree, A. Chuturgoon (2013) A549 lung cell line activity of biosynthesized silver nanoparticles using Albizia adianthifolia leaf. Colloids and Surfaces B: Biointerfaces 105:87-91.
**[68]** Sondi I, Salopek-Sondi B. Silver nanoparticles as antimicrobial agent: a case study on E. coli as a model for Gram-negative bacteria. Journal of Colloids Interface Science. 2004; 275: 177–182.
**[69]** Rai A, Singh A, Ahmad A, Sastry M. Role of halide ions and temperature on the morphology of biologically synthesized gold nanotriangles. Langmuir. 2006; 22:736-741.
**[70]** Sukirtha R, Priyanka KM, Antony JJ, Kamalakkannan S, Thangam R, Gunasekaran P, Krishnan M, Achiraman S. Cytotoxic effect of Green synthesized silver nanoparticles using Melia azedarach against in vitro HeLa cell lines and lymphoma mice model. Process Biochemistry. 2012; 47: 273–279.
**[71]** ] Kelly KL, Coronado E, Zhao LL, Schatz GC. The optical properties of metal nano particles: The influence of size, shape and dielectric environment. Journal of Physical Chemistry. 2003; 107:668-677.
**[72]** Guidelli EJ, Ramos AP, Zaniquelli AED, Baffa O. Green synthesis of colloidal silver nanoparticles using natural rubber latex extracted from Hevea brasiliensis. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2011; 82: 140– 145.
**[73]** Bhat R, Ganachari S, Raghunandan, Deshpande R, Ravindra G,Venkataraman A. Rapid biosynthesis of silver nanoparticles using Areca Nut (Areca catechu) extract under microwave-assistance. Journal of Cluster Science. 2012; DOI 10.1007/s10876- 012-0519-2.
**[74]** Mason C, Vivekanandhan S, Misra M, Mohanty AK. Switchgrass (Panicum virgatum) Extract Mediated Green Synthesis of Silver Nanoparticles. World Journal of Nano Science and Engineering. 2012; 2: 47-52 .
**[75]** Shenya DS, Joseph Mathew J, Philip D. Phytosynthesis of Au, Ag and Au–Ag bimetallic nanoparticles using aqueous extract and dried leaf of Anacardium occidentale. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy . 2011; 79:254-262.
**[76]** Jenkins R, Snyder RL. Introduction to X-ray Powder Diffractiometry, John Wiley and Sons, New York, 1996. 544.
**[77]** Zaved MF, Eisa WH, Shabaka AA. Malva parviflora extract assisted green synthesis of silver nanoparticles. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2012; 98:423-428.
**[78]** Zahir AA, Rahuman AA. Evaluation of different extracts and synthesised silver nanoparticles from leaves of Euphorbia prostrata against Haemaphysalis bispinosa and Hippobosca maculate. Veterinary Parasitology , 2012; 187:511-520.
**[79]** Wijnhoven SWP, Peijnenburg WJGM, Herberts CA, Hagens WI, Oomen AG, Heugens EHW, Roszek B, Bisschops J, Gosens I, Van de Meent D, Dekkers S, de Jong WH, Van Zijverden M, Sips AJAM, Geertsma RE. Nano-silver: a review of available data and knowledge gaps in human and environmental risk assessment. Nanotoxicology. 2009; 3:109.