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REVIEW ARTICLE

EVALUATING POTENTIALS OF PLANT AND MICROBE MEDIATED GREEN SYNTHESIS OF NANOPARTICLES- A REVIEW

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Abstract

Recent development in nanotechnology makes nanomaterial a promising agent with wide range of applications in major fields like medical, agriculture, bio-remediations, industries etc. Green synthesis of nanoparticle using plant and microbes is considered to be safe and environment friendly approach. Among various nanoparticles metal nanoparticle gain more attention due to their stability, catalytic abilities and applicability's. Diverse group of bacteria and plants are being employed for synthesis of metal nanoparticles. Characterization tool such as SEM, TEM, XRD, FTIR, DLS, AFM reveals morphology of synthesised particles. This review gives overall summary of various plants and bacteria mediated approaches used to synthesize metal nanoparticles, morphology and applications of synthesized particles. This Research would also include useful findings related to comparison between plants and bacteria mediated nanoparticles in terms of Morphology, size distributions and applications in various fields.

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Introduction:-

Nanotechnology is the combination of science and engineering used in production, characterization and application of structure by controlling diameter andmorphology at nanoscale. It involves study of structures at 1-100 nanoscale which possess novel properties and function attributed to their small size(Rajesh kumar, S., et. al. 2013).In modern times material science nanotechnology is one of the most promising and active area of research because nanoparticles have various novel properties such as size, morphology and distribution (Jain, D., et. al. 2009).To improve human race nanoparticles are considered as a strong candidate because of their applications in various fields(Vasantharaj, S., et. al. 2019). Fields such as agriculture, medicine, electronics have adapted the use of nanoparticles for betterment of human life (Hamed, A. A., et. al. 2020).Among various organic and inorganic nanoparticles, metal and metal oxide nanoparticles gain more attention due to their physical and chemical properties. Optical and electric properties of nanoparticles aids in various processes like catalysis, antimicrobial activity, anti-cancer, antioxidant activity, and bio- sensing, remediation of dyes and toxic compound (He, S., et. al. 2007; Attatsi, I. K., & Nsiah, F. 2020; Singh, A., et. al. 2020; Ahmed, S., et. al. 2016; Eustis, S., et. al. 2005;Ijaz, I., et. al.2020;Ma, H.,et. al. 2004).Many of the available methods for synthesis of nanoparticles among them physical and chemical methods having various drawback such as use and generation of hazardous product, high cost and limited applications in biological field. These drawbacks forces mankind to think in the area of 'green chemistry' (Ramakrishna, M., et. al. 2016).Metallic nanoparticles with zero valency such as silver, copperand gold have applications in various fields due to catalytic activity (El-Borady, O. M., et.al. 2020). These metal nanoparticles gain more attention nowadays due to ease in synthesis, environment friendly approach without requirements of fancy experiment and wide range of biological applicability (. Manimegalai, G., et. al.2014).

Nanoparticle'ssynthesis - approach

Synthesis of nanoparticles by physical, chemical and biological pathway classified in two classes. **1)Top-down approach 2)Bottom-up approach.** Nanoparticles can be synthesized by reinforcing smaller molecules such as atoms or by breaking bulk into the smaller particles. In top-down synthesis large bulky material is converted into smaller particle and in bottom-up approach smaller atoms combines to form nanoparticle -figure 1

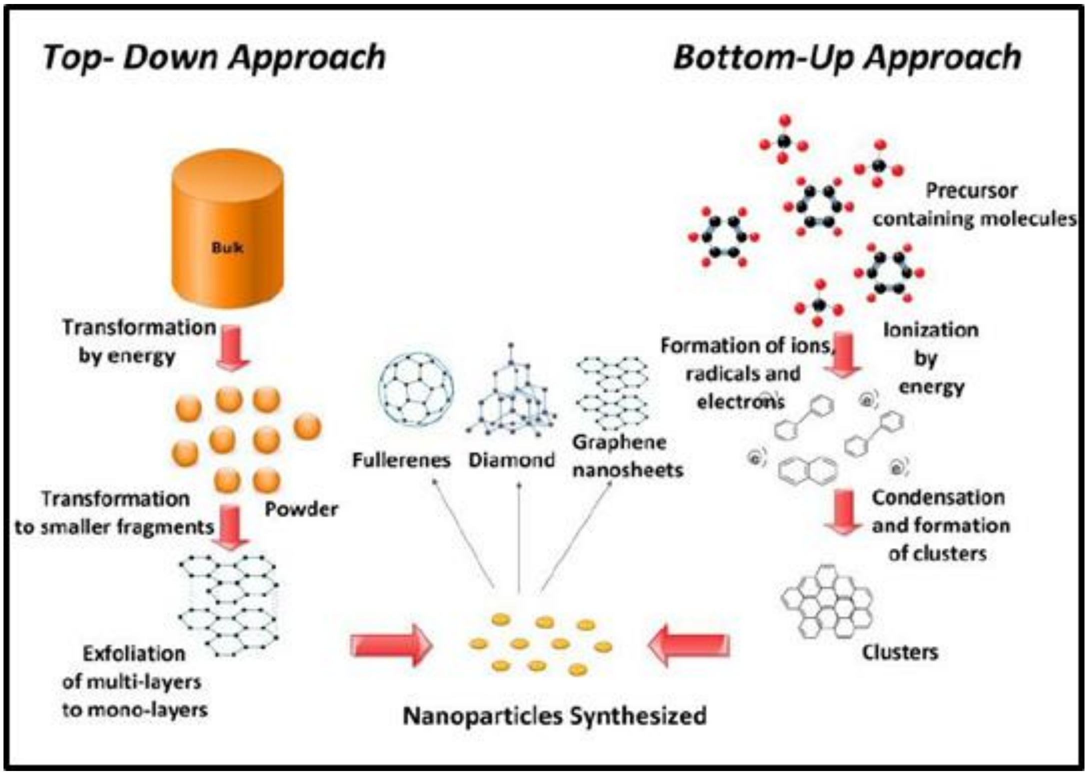

Fig. 1:- Nanoparticles synthesis pathway via biological, chemical and physical methods.

Methods for synthesis of metal nanoparticles

Many researchers tried to synthesis nanoparticles by various methods such as laser irradiation, electrochemical method, microwave assisted, ultrasonic irradiation, sodium borohydride, ascorbic acid, bacteria, plant, fungi. Morphology, stability and applicability of synthesized particles depends upon synthesis method (Ahmed, S., et. al. 2016; Eustis, S., et. al. 2005;Ijaz, I., et. al. 2020; Ma, H., et. al. 2004;Mohammed Fayaz, A., et. al. 2009;Nadagouda, M. N., et. al. 2011; Pugazhenthiran, N., et. al.2009; Zhou, Y., et. al. 1999)

Physical method

Evaporation-condensation method and laser ablation method are considered as most appropriate method for nanoparticle synthesis. Physical method has an advantage over chemical method as solvent contamination is absent in physical method (Iravani, S., et. al.2014).Also, hazardous chemical is not required for synthesis as radiation is used as a reducing agent (Zhang, X.-F., et. al.2016)

Chemical method

In this approach various chemicals are required to reduce metal salts into nanoparticles, capping agentsneeded for stability (Khan, A., et. al.2016).Chemicals such as ascorbic acid, sodium borohydride and potassium borohydride are used for synthesis. Chemical method has its own limitations.

Biological method

Chemical and physical method for nanoparticle synthesis required hazardouschemical, high pressure and temperature also needed that will cause high energy consumption and cause environmental pollution. To overcome this problem biological synthesis of nanoparticles using microorganisms and plant is a promising method due to its eco friendliness, simpler and cheaper (Akintelu, S. A., et. al. 2020) In contemporary research nanoparticle synthesis using plant extract is considered as a safe approach (Ahmed, S., et. al.2016)

Bacteria mediated synthesis of nanoparticle

Microbial synthesis of nanoparticles is of two types;1. Extracellular Synthesis.2. IntracellularSynthesis. Studies shows that extracellular synthesis of nanoparticles using cell filtrate which is beneficial over intracellular synthesis. Intracellular synthesis limits their application. Microorganisms turns the metal ions into the element metal by their metabolites. Intracellular synthesis of nanoparticles requires additional down step processing for recovery of nanoparticles treatments such as saponification, detergents treatments (. Kannan, N., &Subbalaxmi, S. (2011, Senapati, S., et. al.2012).Bacteria possess enzymes that required for reduction of metal salt to form metal nanoparticles such as gold and silver. Pseudomonas stutzeri AG259 isolated from silver mine was recorded as the first organism used to synthesize silver nanoparticles (Punjabi, K., et. al. 2017).Exopolysaccharide produced by bacteria act as a reducing agent and also provide stability to synthesized particles (Escárcega-González, C. E., et. al. 2018).In bacterial synthesis bacterial supernatant is used as reducing agent, in culture supernatant, metal salt isadded and is converted into nanoparticles, this approach is called top-downapproach (Iravani, S., et. al.2014). (Table 2 summarizes bacteria used for synthesis of different metal nanoparticles with methods used for characterization of synthesized particles.)

Table 2:- Bacteria mediated synthesis of nanoparticles.

Sr .No.	Microorganism	Nano-particle	SPR	Method for characterization	Shape	Size	Reference
1	Bacillus cereus	Silver	432	SEM, TEM, EDAX	Spherical	20-40	Sunkar, S., &Nachiyar, C. V. 2012
2	Lactobaciluus acidophilus	Silver	430	SEM, EDAX, UV-vis	Spherical	45-60	Namasivayam, S. K. R.,et. al. 2010
3	Bacillus megaterium	Silver	435	HR-TEM, XRD, UV-vis	-	10-20	Prakash, A.,et. al.2011
4	Bacillus megaterium	Lead	330	HR-TEM, XRD, UV-vis	-	10-20	Prakash, A.,et. al.2011
5	Bacillus megaterium	Cadmium	410	HR-TEM, XRD, UV-vis	-	10-20	Prakash, A.,et. al.2011
6	Enterococcus sp	Cadmium	410	SEM, EDAX, UV-vis	Spherical	50-180	Rajeshkumar, S.,et. al.2014
7	Rhodopseudomonascapsulata	Gold	540	TEM.XRD, UV-Vis	Spherical	10-20	He, S., et. al. 2007
8	Bacillus subtilis	Silver	410	TEM, UV-Vis	Spherical, triangular	5-60	Saifuddin, N.,et. al.2009
9	Morganellasp	Copper	610	TEM, FTIR, SAED, UV-Vis	Poly disperse	15-20	Ramanathan, R., et. al.2013
10	Idiomarina sp. PR58-8	Silver	450	TEM, EDAX, UV-vis	-	26	Seshadri, S.,et.al.2012
11	Aeromonas hydrophila	Zinc oxide	374	AFM, XRD, UV-vis	Spherical, oval	57.72	Jayaseelan, C.,et.al.2012
12	Streptomyces MHM38	Copper	550	EDAX, XRD, SEM,UV-vis	Spherical	1.72-13.49	Bukhari, S. I.,et.al.2021
13	Pseudomonas aeruginosa	Silver	436	TEM, FTIR, UV-Vis	Spherical	40-60	Deshmukh, S. D.,et. al.2012
14	Klebsiella pneumoniae	Gold	550	SEM, AFM,	Spherical	10-	Prema, P.,et.

				FTIR, XRD, UV-Vis		15	al.2016
15	Lactobacillus brevis	Silver	-	SEM, TEM, XRD, FTIR	Spherical	30-100	Riaz Rajoka, M. S.,et.al.2020

Plant mediated synthesis of nanoparticle

Plants possess various interesting biomolecules in the form of coenzyme, vitamin and intermediates, which reduce metal ions to nanoparticles in a single step. Synthesis of nanoparticles from plants are easy to process and has result based advantages coupled with relatively quicker applicational administrations, which make plants better and more favoured destinations (Malik, P., et.al.2014)

Table 3:- Plant mediated synthesis of nanoparticles.

S/N	Plant name	Nanoparticle	SPR peak (nm)	Technique used for characterization	Shape	Size	Reference
1	Cissus arnotiana	Copper	350-380	SEM, TEM, AFM XRD	Spherical	60-90	Rajeshkumar, S., Menon, S., et. al.2019
2	Zingiber officinale	Silver	400	XRD, TEM, SEM equipped with EDX, FTIR	Semi spherical	11-24	Eisa, W. H., et. al.2019
3	Vitex negundo	Silver	423-432	XRD, TEM, SEM, EDX, FTIR	Spherical	Less than 20	Zargar, M.,et. al. 2014
4	Pulicariaglutinosa	Silver	422-459	SEM, TEM, EDX, FTIR, XRD	Spherical	40-60	Siddiqui, M. R., Khan, M.,et. al. 2013
5	Azadirachta indica	Silver	436-446	DLS, TEM, EDX, FTIR, XRD	Spherical	-	Ahmed, S.,et. al.2016
6	Cacumen Platycladil	Gold	531	TEM.SAED, XRD, FTIR	Spherical	7.4	Zhan, G.,et. al. 2011
7	Agathosmabetulina	Zinc	-	TEM, EDX, XRD	Quasi-spherical	12-26	Thema, F. T.,et. al.2015
8	Cassia fistula	Zinc oxide	370	TEM, XRD, UV vis	Hexagonal	5-15	Suresh, D., et. al.2015
9	Deverratortuosa	Zinc oxide	-	HR-TEM, XRD, UV vis,FTIR	-	9.26-31.18	Selim, Y. A.,et. al.2020
10	Agathosmabetulina	Cadmium oxide	-	HRSEM, EDS, XRF, XRD, ATR-FTIR and Raman	Quasi-spherical	8	Thema, F. T.,et. al.2015
11	Nyctanthesarbortristis	Titanium dioxide	-	SEM.XRD, particle size analyser	Spherical	100-150	Sundrarajan, M., & Gowri 2011
12	Glycine max	Palladium	420	SEM, TEM, XRD,UV- vis	Spherical	15	Kumar Petla, R.,et. al. 2012
13	Azadirachta indica	Iron	216-265	XRD, SEM, UV-vis	Spherical	50	Pattanayak, M., & Nayak, P. L. 2013
14	Indigofera aspalathoides	Silver	420	SEM,EDAX,FTIR, UV- vis	Square	20-50	Arunachalam, K. D.,et. al.2013
15	Ziziphoratenuior	Silver	420	XRD, SEM, TEM,FTIR	Spherical	8-40	Sadeghi, B., &Gholamhoseinpoo

							r, F. 2015
16	Ocimumgratissimum	Silver	420-450	SEM, TEM, DLS,Zeta potential,FTIR	Spherical	16	Sharma, K., Guleria, S., &Razdan, V. K. 2020
17	Parthenium hysterophorus	Silver	-	TEM,SAED	Irregular	30-80	Ahsan, A.,et. al. 2020
18	Murrayakoenigii	Silver	420	SEM, FTIR, XRD, Uv-Vis	Spherical	40-80	Bonde, S. R.,et. al.2012
19	Galegaofcinalis	Silver	410	SEM.TEM, XRD, UV-Vis	Spherical	8-34	Manosalva, N.,et. al.2019
20	Crocus sativus L	Silver	450	XRD, SEM, TEM, UV-vis	Spherical	12-20	Bagherzade, G.,et. al.2017

Characterization of Nanoparticles:
Characterization of nanoparticles using methods like UV-Vis spectroscopy, Scanning electron microscopy, transmission electron microscopy, atomic force microscopy, dynamic light scattering, x-ray diffraction, zeta potential analyser revealed size, shape, size distribution and surface charges of synthesized particles (Table 3)

Table 3:- Characterization techniques for synthesized nanoparticle.

S/N	Techniques	Analyse	Reference
1	UV visible spectroscopy	Synthesis confirmation	Natarajan, K.,et. al.2010
2	Dynamic light scattering	Size distribution of particles	Otari, S. V.,et. al.2012
3	Scanning electron microscopy	Particle size and morphology	Verma, P., & Maheshwari, S. K. 2018
4	Transmission electron microscopy	Particle size and morphology	Kumar, P.,et. al.2012
5	Fourier transmission infrared spectroscopy	Functional group	Bhuyar, P.,et. al.2020
6	Atomic force microscopy	Size and morphology	Singh, T.,et. al.2017
7	X-ray diffraction	Nature of the particle	Ibrahim, S.,et. al.2021
8	Zeta potential	Surface charges	Kotakadi, V. S.,et. al. 2013

Application
Green synthesized nanoparticleshave a wide range of applications such as heavy metal sensing, antibacterial activity, anti-fungal activity, anti-oxidant, antihaemolytic activity, drug delivery system, bioremediations, seed germinations. Same is summarized in table 4 and table 5.

Table 4:- Applications of bacteria mediated synthesis nanoparticles.

Source	Type	Application	Reference
Bacillus cereus	Silver	Antibacterial activity against pathogenic bacteria like Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella typhiand Klebsiella pneumoniae.	Sunkar, S., &Nachiyar, C. V. 2012
Enterococcus sp	Cadmium	Anti-fungal against pathogenic Fungus Aspergillus niger and Aspergillus flavus	Rajeshkumar, S.,et. al.2014
Pseudomonas stutzeri	Palladium	Antioxidant and anti-haemolytic activity	Desai, M. P., et. al. 2020
Tenotrophomonasaidaminiphila	Selenium	Heavy metal sensing	Ahmed, F.,et. al.2020
Lactobacillus sp.	Silver	Anti-fungal activity	Matei, A.,et. al.2020

Table 5:- Applications of plant mediated synthesis nanoparticles.

Source	Type	Application	Reference
Butea monosperma	Gold	Nanoparticles based drug delivery systems using anticancer drug doxorubicin.	Patra, S.,et. al. 2015
Butea monosperma	Silver	Nanoparticles based drug delivery systems using anticancer drug doxorubicin.	Patra, S.,et. al.2015
Curcuma and tea extract	Ferric Oxide	Photocatalytic degradation of methylene orange dye	Alagiri, M., & Hamid, S. B. A. 2014
Synadiumgrantii	Zinc oxide	Photocatalytic degradation of rhbdye	Karthik, K. V., et. al. 2022
Parsley leaves	Gold	Catalytic, antioxidant, anticancer, And antibacterial activity	El-Borady, O. M.,et. al.2020
Ficus palmata	Zinc oxide	Anti-inflammatory andanti-diabetic activity	Sati, S. C., Kour, G.,et. al.2020
Aloe barbadensis	Zinc oxide	Effect on seed germination and seedling	Rani,P.,et. al.2020
Aloe barbadensis	Magnesium oxide	Effect on seed germination and seedling	Rani, P., et. al.2020

Conclusion:-

This review summarizes Nanoparticle have various advantages over bulk in contrast to their physical, chemical properties and ability to transport other molecules. Among various inorganic nanoparticles metal nanoparticles gain more attention because of its wide range of applicability. Green method for synthesis is considered safe as well as eco-friendly over physical and chemical method as any hazardous chemical is not required and any toxic by-product is not generated. In green synthesis plant and microorganism contains phytochemical and enzyme which act as a reducing agent as well as provide stability to the synthesized particle. Various characterization methodsreveal size, morphology and charges on the surface of the particle. Green synthesized particles have application in various fields like medicine, agriculture, industry and electronics. However, more study is needed to use nanoparticles to get maximum benefits of particles by formation of particles at higher production rate with desired size and shape as well as scale up for synthesis is desired for use as a drug delivery system, to conclude that plant and microbes mediated synthesized metal nanoparticles are almost similar in the terms of Morphology, Stability and Applications. So one cannot claim this to be better than theother

References:-

1. Ahmed, F., Dwivedi, S., Shaalan, N. M., Kumar, S., Arshi, N., Alshoaibi, A., & Husain, F. M. 2020. Development of Selenium Nanoparticle Based Agriculture Sensor for Heavy Metal Toxicity Detection. Agriculture, 10(12), 610. https://doi.org/10.3390/agriculture10120610
2. Ahmed, S., Ahmad, M., Swami, B. L., & Ikram, S. 2016. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise. Journal of Advanced Research, 7(1), 17–28. https://doi.org/10.1016/j.jare.2015.02.007
3. Ahmed, S., Saifullah, Ahmad, M., Swami, B. L., & Ikram, S. 2016. Green synthesis of silver nanoparticles using Azadirachta indica aqueous leaf extract. Journal of Radiation Research and Applied Sciences, 9(1), 1–7. https://doi.org/10.1016/j.jrras.2015.06.006
4. Ahsan, A., Farooq, M. A., Ahsan Bajwa, A., & Parveen, A. 2020. Green Synthesis of Silver Nanoparticles Using Parthenium Hysterophorus: Optimization, Characterization and In Vitro Therapeutic Evaluation. Molecules, 25(15), 3324. MDPI AG. http://dx.doi.org/10.3390/molecules25153324
5. Akintelu, S. A., Folorunso, A. S., Folorunso, F. A., &Oyebamiji, A. K. 2020. Green synthesis of copper oxide nanoparticles for biomedical application and environmental remediation. Heliyon, 6(7), e04508. https://doi.org/10.1016/j.heliyon.2020.e04508

6. Alagiri, M., & Hamid, S. B. A. 2014. Green synthesis of α-Fe2O3 nanoparticles for photocatalytic application. Journal of Materials Science: Materials in Electronics, 25(8), 3572–3577. https://doi.org/10.1007/s10854-014-2058-0
7. Arunachalam, K. D., Annamalai, S. K., Arunachalam, A. M., & Kennedy, S. 2013. Green Synthesis of Crystalline Silver Nanoparticles Using Indigofera aspalathoides- Medicinal Plant Extract for Wound Healing Applications. Asian J. Chem., 5.
8. Attatsi, I. K., & Nsiah, F. 2020. Application of silver nanoparticles toward Co(II) and Pb(II) ions contaminant removal in groundwater. Applied Water Science, 10(6), 152. https://doi.org/10.1007/s13201-020-01240-0
9. Bagherzade, G., Tavakoli, M. M., &Namaei, M. H. 2017. Green synthesis of silver nanoparticles using aqueous extract of saffron (Crocus sativus L.) wastages and its antibacterial activity against six bacteria. Asian Pacific Journal of Tropical Biomedicine, 7(3), 227–233. https://doi.org/10.1016/j.apjtb.2016.12.014
10. Bhuyar, P., Rahim, M. H. Ab., Sundararaju, S., Ramaraj, R., Maniam, G. P., & Govindan, N. 2020. Synthesis of silver nanoparticles using marine macroalgae Padina sp. And its antibacterial activity towards pathogenic bacteria. Beni-Suef University Journal of Basic and Applied Sciences, 9(1), 3. https://doi.org/10.1186/s43088-019-0031-y
11. Bonde, S. R., Rathod, D. P., Ingle, A. P., Ade, R. B., Gade, A. K., & Rai, M. K. 2012. Murrayakoenigii -mediated synthesis of silver nanoparticles and its activity against three human pathogenic bacteria. Nanoscience Methods, 1(1), 25–36. https://doi.org/10.1080/17458080.2010.529172
12. Bukhari, S. I., Hamed, M. M., Al-Agamy, M. H., Gazwi, H. S. S., Radwan, H. H., &Youssif, A. M. 2021. Biosynthesis of Copper Oxide Nanoparticles Using Streptomyces MHM38 and Its Biological Applications. Journal of Nanomaterials, 2021, 1–16. https://doi.org/10.1155/2021/6693302
13. Desai, M. P., Patil, R. V., & Pawar, K. D. 2020. Green biogenic approach to optimized biosynthesis of noble metal nanoparticles with potential catalytic, antioxidant and antihaemolytic activities. Process Biochemistry, 98, 172–182. https://doi.org/10.1016/j.procbio.2020.08.005
14. Deshmukh, S. D., Deshmukh, S. D., Gade, A. K., & Rai, M.2012. Pseudomonas aeruginosa Mediated Synthesis of Silver Nanoparticles Having Significant Antimycotic Potential Against Plant Pathogenic Fungi. Journal of Bionanoscience, 6(2), 90–94. https://doi.org/10.1166/jbns.2012.1078
15. Eisa, W. H., Zayed, M. F., Anis, B., Abbas, L. M., Ali, S. S. M., & Mostafa, A. M. 2019. Clean production of powdery silver nanoparticles using Zingiber officinale: The structural and catalytic properties. Journal of Cleaner Production, 241, 118398. https://doi.org/10.1016/j.jclepro.2019.118398
16. El-Borady, O. M., Ayat, M. S., Shabrawy, M. A., & Millet, P. 2020. Green synthesis of gold nanoparticles using Parsley leaves extract and their applications as an alternative catalytic, antioxidant, anticancer, and antibacterial agents. Advanced Powder Technology, 31(10), 4390–4400. https://doi.org/10.1016/j.apt.2020.09.017
17. Escárcega-González, C. E., Garza-Cervantes, J. A., Vázquez-Rodríguez, A., &Morones-Ramírez, J. R. 2018. Bacterial Exopolysaccharides as Reducing and/or Stabilizing Agents during Synthesis of Metal Nanoparticles with Biomedical Applications. International Journal of Polymer Science, 2018, 1–15. https://doi.org/10.1155/2018/7045852
18. Eustis, S., Krylova, G., Eremenko, A., Smirnova, N., Schill, A. W., & El-Sayed, M. 2005. Growth and fragmentation of silver nanoparticles in their synthesis with a fs laser and CW light by photo-sensitization with benzophenone. Photochemical & Photobiological Sciences, 4(1), 154. https://doi.org/10.1039/b411488d
19. Hamed, A. A., Kabary, H., Khedr, M., &Emam, A. N. 2020. Antibiofilm, antimicrobial and cytotoxic activity of extracellular green-synthesized silver nanoparticles by two marine-derived actinomycete. RSC Advances, 10(17), 10361–10367. https://doi.org/10.1039/C9RA11021F
20. He, S., Guo, Z., Zhang, Y., Zhang, S., Wang, J., & Gu, N. 2007. Biosynthesis of gold nanoparticles using the bacteria Rhodopseudomonascapsulata. Materials Letters, 61(18), 3984–3987. https://doi.org/10.1016/j.matlet.2007.01.018
21. Ibrahim, S., Ahmad, Z., Manzoor, M. Z., Mujahid, M., Faheem, Z., & Adnan, A. 2021. Optimization for biogenic microbial synthesis of silver nanoparticles through response surface methodology, characterization, their antimicrobial, antioxidant, and catalytic potential. Scientific Reports, 11(1), 770. https://doi.org/10.1038/s41598-020-80805-0
22. Ijaz, I., Gilani, E., Nazir, A., & Bukhari, A. 2020. Detail review on chemical, physical and green synthesis, classification, characterizations and applications of nanoparticles. Green Chemistry Letters and Reviews, 13(3), 223–245. https://doi.org/10.1080/17518253.2020.1802517
23. Iravani, S., Korbekandi, H., Mirmohammadi, S. V., &Zolfaghari, B. 2014. Synthesis of silver nanoparticles: Chemical, physical and biological methods. 22.

24. Jain, D., Daima, H. K., Kachhwaha, S., & Kothari, S. L. 2009. synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their anti microbial activities. 7. https://doi.org/10.1016/j.btre.2020.e00427
25. Jayaseelan, C., Rahuman, A. A., Kirthi, A. V., Marimuthu, S., Santhoshkumar, T., Bagavan, A., Gaurav, K., Karthik, L., & Rao, K. V. B. 2012. Novel microbial route to synthesize ZnO nanoparticles using Aeromonas hydrophila and their activity against pathogenic bacteria and fungi. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 90, 78–84. https://doi.org/10.1016/j.saa.2012.01.006
26. Kannan, N., &Subbalaxmi, S. 2011. Green Synthesis of Silver Nanoparticles using Bacillus subtillus IA751 and its Antimicrobial Activity. Research Journal of Nanoscience and Nanotechnology, 1(2), 87–94. https://doi.org/10.3923/rjnn.2011.87.94
27. Karthik, K. V., Raghu, A. V., Reddy, K. R., Ravishankar, R., Sangeeta, M., Shetti, N. P., & Reddy, C. V. 2022. Green synthesis of Cu-doped ZnO nanoparticles and its application for the photocatalytic degradation of hazardous organic pollutants. Chemosphere, 287, 132081. https://doi.org/10.1016/j.chemosphere.2021.132081
28. Khan, A., Rashid, A., Younas, R., & Chong, R. 2016. A chemical reduction approach to the synthesis of copper nanoparticles. International Nano Letters, 6(1), 21–26. https://doi.org/10.1007/s40089-015-0163-6
29. Kotakadi, V. S., Rao, Y. S., Gaddam, S. A., Prasad, T. N. V. K. V., Reddy, A. V., & Gopal, D. V. R. S. 2013. Simple and rapid biosynthesis of stable silver nanoparticles using dried leaves of Catharanthus roseus. Linn. G. Donn and its anti microbial activity. Colloids and Surfaces B: Biointerfaces, 105, 194–198. https://doi.org/10.1016/j.colsurfb.2013.01.003
30. Kumar Petla, R., Vivekanandhan, S., Misra, M., Kumar Mohanty, A., & Satyanarayana, N. 2012. Soybean (<i>GlycineMax</i>) Leaf Extract Based Green Synthesis of Palladium Nanoparticles. Journal of Biomaterials and Nanobiotechnology, 03(01), 14–19. https://doi.org/10.4236/jbnb.2012.31003
31. Kumar, P., Selvi, S. S., Prabha, A. L., Kumar, K. P., Ganeshkumar, R. S., &Govindaraju, M. 2012. Synthesis of Silver Nanoparticles from Sargassum Tenerrimum and Screening Phytochemicals for Its Antibacterial Activity. Nano Biomedicine and Engineering, 4(1), 12–16. https://doi.org/10.5101/nbe.v4i1.p12-16
32. Ma, H., Yin, B., Wang, S., Jiao, Y., Pan, W., Huang, S., Chen, S., & Meng, F. 2004. Synthesis of Silver and Gold Nanoparticles by a Novel Electrochemical Method. ChemPhysChem, 5(1), 68–75. https://doi.org/10.1002/cphc.200300900
33. Malik, P., Shankar, R., Malik, V., Sharma, N., & Mukherjee, T. K. (2014). Green Chemistry Based Benign Routes for Nanoparticle Synthesis. Journal of Nanoparticles, 2014, 1–14. https://doi.org/10.1155/2014/302429
34. Manimegalai, G., Shanthakumar, S., & Sharma, C. 2014. Silver nanoparticles: Synthesis and application in mineralization of pesticides using membrane support. International Nano Letters, 4(2), 105. https://doi.org/10.1007/s40089-014-0105-8
35. Manosalva, N., Tortella, G., Cristina Diez, M., Schalchli, H., Seabra, A. B., Durán, N., & Rubilar, O. 2019. Green synthesis of silver nanoparticles: Effect of synthesis reaction parameters on antimicrobial activity. World Journal of Microbiology and Biotechnology, 35(6), 88. https://doi.org/10.1007/s11274-019-2664-3
36. Matei, A., Matei, S., Matei, G.-M., Cogălniceanu, G., & Cornea, C. P. 2020. Biosynthesis of silver nanoparticles mediated by culture filtrate of lactic acid bacteria, characterization and antifungal activity. The EuroBiotech Journal, 4(2), 97–103. https://doi.org/10.2478/ebtj-2020-0011
37. Mohammed Fayaz, A., Balaji, K., Kalaichelvan, P. T., & Venkatesan, R. 2009. Fungal based synthesis of silver nanoparticles—An effect of temperature on the size of particles. Colloids and Surfaces B: Biointerfaces, 74(1), 123–126. https://doi.org/10.1016/j.colsurfb.2009.07.002
38. Nadagouda, M. N., Speth, T. F., & Varma, R. S. 2011. Microwave-Assisted Green Synthesis of Silver Nanostructures. Accounts of Chemical Research, 44(7), 469–478. https://doi.org/10.1021/ar1001457
39. Namasivayam, S. K. R., Gnanendra, E. K., &Reepika, R. 2010. Synthesis of silver nanoparticles by Lactobaciluus acidophilus 01 strain and evaluation of its in vitro genomic DNA toxicity. Nano-Micro Letters, 2(3), 160–163. https://doi.org/10.1007/BF03353635
40. Natarajan, K., Selvaraj, S., &Murty, V. R. 2010. Microbial production of silver nanoparticles. Digest Journal of Nanomaterials and Biostructures, 5(1), 135-140..
41. Otari, S. V., Patil, R. M., Nadaf, N. H., Ghosh, S. J., & Pawar, S. H. 2012. Green biosynthesis of silver nanoparticles from an actinobacteria Rhodococcus sp. Materials Letters, 72, 92–94. https://doi.org/10.1016/j.matlet.2011.12.109
42. Patra, S., Mukherjee, S., Barui, A. K., Ganguly, A., Sreedhar, B., & Patra, C. R. 2015. Green synthesis, characterization of gold and silver nanoparticles and their potential application for cancer therapeutics. Materials Science and Engineering: C, 53, 298–309. https://doi.org/10.1016/j.msec.2015.04.048

43. Pattanayak, M., & Nayak, P. L. (2013). Green Synthesis and Characterization of Zero Valent Iron Nanoparticles from the Leaf Extract of Azadirachta indica (Neem). 5.
44. Prakash, A., Sharma, S., Ahmad, N., Ghosh, A., & Sinha, P. 2011. Bacteria mediated extracellular synthesis of metallic nanoparticles. 10.
45. Prema, P., Iniya, P. A., & Immanuel, G. 2016. Microbial mediated synthesis, characterization, antibacterial and synergistic effect of gold nanoparticles using Klebsiella pneumoniae (MTCC-4030). RSC Advances, 6(6), 4601–4607. doi:10.1039/c5ra23982f
46. Pugazhenthiran, N., Anandan, S., Kathiravan, G., Udaya Prakash, N. K., Crawford, S., &Ashokkumar, M. 2009. Microbial synthesis of silver nanoparticles by Bacillus sp. Journal of Nanoparticle Research, 11(7), 1811–1815. https://doi.org/10.1007/s11051-009-9621-2
47. Punjabi, K., Yedurkar, S., Doshi, S., Deshapnde, S., & Vaidya, S. 2017. Biosynthesis of silver nanoparticles by Pseudomonas spp. Isolated from effluent of an electroplating industry. IET Nanobiotechnology, 11(5), 584–590. https://doi.org/10.1049/iet-nbt.2016.0172
48. Rajeshkumar, S., Malarkodi, C., Paulkumar, K., Vanaja, M., Gnanajobitha, G.,& Annadurai, G. 2013.Intracellular and extracellular biosynthesis of silver nanoparticles by using marine bacteria vibrio alginolyticus. Nanoscience and Nanotechnology: An International Journal 2013; 3(1): 21-25
49. Rajeshkumar, S., Menon, S., Venkat Kumar, S., Tambuwala, M. M., Bakshi, H. A., Mehta, M., Satija, S., Gupta, G., Chellappan, D. K., Thangavelu, L., &Dua, K. 2019. Antibacterial and antioxidant potential of biosynthesized copper nanoparticles mediated through Cissus arnotiana plant extract. Journal of Photochemistry and Photobiology B: Biology, 197, 111531. https://doi.org/10.1016/j.jphotobiol.2019.111531
50. Rajeshkumar, S., Ponnanikajamideen, M., Malarkodi, C., Malini, M., & Annadurai, G. 2014. Microbe-mediated synthesis of antimicrobial semiconductor nanoparticles by marine bacteria. Journal of Nanostructure in Chemistry, 4(2), 96. https://doi.org/10.1007/s40097-014-0096-z
51. Ramakrishna, M., Rajesh Babu, D., Gengan, R. M., Chandra, S., & Nageswara Rao, G. 2016. Green synthesis of gold nanoparticles using marine algae and evaluation of their catalytic activity. Journal of Nanostructure in Chemistry, 6(1), 1–13. https://doi.org/10.1007/s40097-015-0173-y
52. Rani, P., Kaur, G., Rao, K. V., Singh, J., & Rawat, M. 2020. Impact of Green Synthesized Metal Oxide Nanoparticles on Seed Germination and Seedling Growth of Vigna radiata (Mung Bean) and Cajanus cajan(Red Gram). Journal of Inorganic and Organometallic Polymers and Materials, 30(10), 4053–4062. https://doi.org/10.1007/s10904-020-01551-4
53. Riaz Rajoka, M. S., Mehwish, H. M., Zhang, H., Ashraf, M., Fang, H., Zeng, X., Wu, Y., Khurshid, M., Zhao, L., & He, Z. 2020. Antibacterial and antioxidant activity of exopolysaccharide mediated silver nanoparticle synthesized by Lactobacillus brevis isolated from Chinese koumiss. Colloids and Surfaces B: Biointerfaces, 186, 110734. https://doi.org/10.1016/j.colsurfb.2019.110734
54. Sadeghi, B., &Gholamhoseinpoor, F. 2015. A study on the stability and green synthesis of silver nanoparticles using Ziziphoratenuior (Zt) extract at room temperature. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 134, 310–315. https://doi.org/10.1016/j.saa.2014.06.046
55. Saifuddin, N., Wong, C. W., &Yasumira, A. A. N. 2009. Rapid Biosynthesis of Silver Nanoparticles Using Culture Supernatant of Bacteria with Microwave Irradiation. E-Journal of Chemistry, 6(1), 61–70. https://doi.org/10.1155/2009/73426435. Ramanathan, R., Field, M. R., O'Mullane, A. P., Smooker, P. M., Bhargava, S. K., & Bansal, V. (2013). Aqueous phase synthesis of copper nanoparticles: A link between heavy metal resistance and nanoparticle synthesis ability in bacterial systems. Nanoscale, 5(6), 2300–2306. https://doi.org/10.1039/C2NR32887A
56. Sati, S. C., Kour, G., Bartwal, A. S., & Sati, M. D. 2020. Biosynthesis of Metal Nanoparticles from Leaves of Ficus palmata and Evaluation of Their Anti-inflammatory and Anti-diabetic Activities. Biochemistry, 59(33), 3019–3025. https://doi.org/10.1021/acs.biochem.0c00388
57. Selim, Y. A., Azb, M. A., Ragab, I., & H. M. Abd El-Azim, M. 2020. Green Synthesis of Zinc Oxide Nanoparticles Using Aqueous Extract of Deverratortuosa and their Cytotoxic Activities. Scientific Reports, 10(1), 3445. https://doi.org/10.1038/s41598-020-60541-1
58. Senapati, S., Syed, A., Moeez, S., Kumar, A., & Ahmad, A. 2012. Intracellular synthesis of gold nanoparticles using alga Tetraselmiskochinensis. Materials Letters, 79, 116–118. https://doi.org/10.1016/j.matlet.2012.04.009
59. Seshadri, S., Prakash, A., &Kowshik, M. 2012. Biosynthesis of silver nanoparticles by marine bacterium, Idiomarina sp. PR58-8. Bulletin of Materials Science, 35(7), 1201–1205. https://doi.org/10.1007/s12034-012-0417-0

60. Sharma, K., Guleria, S., &Razdan, V. K. 2020. Green synthesis of silver nanoparticles using Ocimumgratissimum leaf extract: Characterization, antimicrobial activity and toxicity analysis. Journal of Plant Biochemistry and Biotechnology, 29(2), 213–224. https://doi.org/10.1007/s13562-019-00522-2
61. Siddiqui, M. R., Khan, M., Khan, Adil, Tahir, Tremel, W., Khathlan, &Warthan. 2013. Green synthesis of silver nanoparticles mediated by Pulicariaglutinosa extract. International Journal of Nanomedicine, 1507. https://doi.org/10.2147/IJN.S43309
62. Singh, A., Gautam, P. K., Verma, A., Singh, V., Shivapriya, P. M., Shivalkar, S., Sahoo, A. K., &Samanta, S. K. 2020. Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review. Biotechnology Reports, 25, e00427. https://doi.org/10.1016/j.btre.2020.e00427
63. Singh, T., Jyoti, K., Patnaik, A., Singh, A., Chauhan, R., & Chandel, S. S. 2017. Biosynthesis, characterization and antibacterial activity of silver nanoparticles using an endophytic fungal supernatant of Raphanus sativus. Journal of Genetic Engineering and Biotechnology, 15(1), 31–39. https://doi.org/10.1016/j.jgeb.2017.04.005
64. Sundrarajan, M., & Gowri, S. 2011. Green synthesis of titanium dioxide nanoparticles by nyctanthesarbor tristis leaves extract. 5.
65. Sunkar, S., &Nachiyar, C. V. 2012. Biogenesis of antibacterial silver nanoparticles using the endophytic bacterium Bacillus cereus isolated from Garcinia xanthochymus. Asian Pacific Journal of Tropical Biomedicine, 2(12), 953–959. https://doi.org/10.1016/S2221-1691(13)60006-4
66. Suresh, D., Nethravathi, P. C., Udayabhanu, Rajanaika, H., Nagabhushana, H., & Sharma, S. C. 2015. Green synthesis of multifunctional zinc oxide (ZnO) nanoparticles using Cassia fistula plant extract and their photodegradative, antioxidant and antibacterial activities. Materials Science in Semiconductor Processing, 31, 446–454. https://doi.org/10.1016/j.mssp.2014.12.023
67. Thema, F. T., Beukes, P., Gurib-Fakim, A., &Maaza, M. 2015. Green synthesis of MonteponiteCdO nanoparticles by Agathosmabetulina natural extract. Journal of Alloys and Compounds, 646, 1043–1048. https://doi.org/10.1016/j.jallcom.2015.05.279
68. Thema, F. T., Manikandan, E., Dhlamini, M. S., &Maaza, M. 2015. Green synthesis of ZnO nanoparticles via Agathosmabetulina natural extract. Materials Letters, 161, 124–127. https://doi.org/10.1016/j.matlet.2015.08.052
69. Vasantharaj, S., Sathiyavimal, S., Saravanan, M., Senthilkumar, P., Gnanasekaran, K., Shanmugavel, M., Manikandan, E., &Pugazhendhi, A. 2019. Synthesis of ecofriendly copper oxide nanoparticles for fabrication over textile fabrics: Characterization of antibacterial activity and dye degradation potential. Journal of Photochemistry and Photobiology B: Biology, 191, 143–149. https://doi.org/10.1016/j.jphotobiol.2018.12.026
70. Verma, P., & Maheshwari, S. K. 2018. Preparation of Sliver and Selenium Nanoparticles and Its Characterization by Dynamic Light Scattering and Scanning Electron Microscopy. Journal of Microscopy and Ultrastructure, 6(4), 6.
71. Zargar, M., Shameli, K., Najafi, G. R., & Farahani, F. 2014. Plant mediated green biosynthesis of silver nanoparticles using Vitex negundo L. extract. Journal of Industrial and Engineering Chemistry, 20(6), 4169–4175. https://doi.org/10.1016/j.jiec.2014.01.016
72. Zhan, G., Huang, J., Du, M., Abdul-Rauf, I., Ma, Y., & Li, Q. 2011. Green synthesis of Au–Pd bimetallic nanoparticles: Single-step bioreduction method with plant extract. Materials Letters, 65(19–20), 2989–2991. https://doi.org/10.1016/j.matlet.2011.06.079
73. Zhang, X.-F., Liu, Z.-G., Shen, W., &Gurunathan, S. 2016. Silver Nanoparticles: Synthesis, Characterization, Properties, Applications, and Therapeutic Approaches. International Journal of Molecular Sciences, 17(9), 1534. https://doi.org/10.3390/ijms17091534
74. Zhou, Y., Yu, S. H., Wang, C. Y., Li, X. G., Zhu, Y. R., & Chen, Z. Y.1999. A Novel Ultraviolet Irradiation Photoreduction Technique for the Preparation of Single-Crystal Ag Nanorods and Ag Dendrites. Advanced Materials, 11(10), 850–852. https://doi.org/10.1002/(SICI)1521-4095(199907)11:10<850::AID-ADMA850>3.0.CO;2-Z.