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Review Article

Green Synthesis of Nanoparticles Using Plant Extracts and Their Pharmaceutical Applications

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ABSTRACT

Green synthesis of nanoparticles has become a sustainable, economical, and environmentally beneficial method in nanotechnology. Because plants contain a variety of phytochemicals, including flavonoids, alkaloids, terpenoids, phenolics, tannins, and proteins that function as stabilising and reducing agents, plant-mediated nanoparticle manufacturing has attracted a lot of attention. Green synthesis minimises toxicity, lowers environmental risks, and improves biocompatibility as compared to traditional physical and chemical techniques. Antimicrobial, antioxidant, anticancer, anti-inflammatory, wound healing, drug delivery, antiviral, and diagnostic applications are just a few of the amazing medicinal uses for nanoparticles made from plant extracts. The principles, methodologies, mechanisms, characterisation techniques, factors influencing synthesis, benefits, drawbacks, and medicinal uses of green synthesised nanoparticles utilising plant extracts are all covered in this review article. The essay also discusses new developments and prospects for green nanotechnology.

INTRODUCTION

One of the scientific disciplines that is expanding the fastest is nanotechnology, which deals with the manipulation of materials at the nanoscale level, which is between 1 and 100 nm.(31) Because of their small size and high surface area to volume ratio, nanoparticles have special physical, chemical, optical, electrical, and biological capabilities. Nanoparticles are very helpful in pharmaceutical, biological, agricultural, cosmetic, dietary, and environmental applications because of these special qualities.

Conventional techniques for creating nanoparticles include chemical and physical processes. Chemical procedures use dangerous solvents and toxic reducing agents that may be harmful to the environment and biological systems, whereas physical methods sometimes call for high temperatures, pressures, and energy usage. As a result, scientists have concentrated on

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creating sustainable, affordable, and ecologically acceptable green synthesis techniques. Green synthesis is the process of creating nanoparticles using biological resources like fungi, algae, bacteria, and plant extracts. Because plant extracts contain naturally occurring phytochemicals that can reduce metal ions into nanoparticles, plant-mediated synthesis is thought to be quite beneficial among these.

Plant extracts are rich in bioactive compounds such as:

- Flavonoids
- Alkaloids
- Polyphenols
- Tannins
- Terpenoids
- Proteins
- Saponins
- Glycosides

During the creation of nanoparticles, these phytochemicals serve as capping, stabilising, and reducing agents.

Safer nanoparticles with improved biocompatibility and decreased toxicity are produced by the green synthesis method, making them appropriate for use in pharmaceutical applications

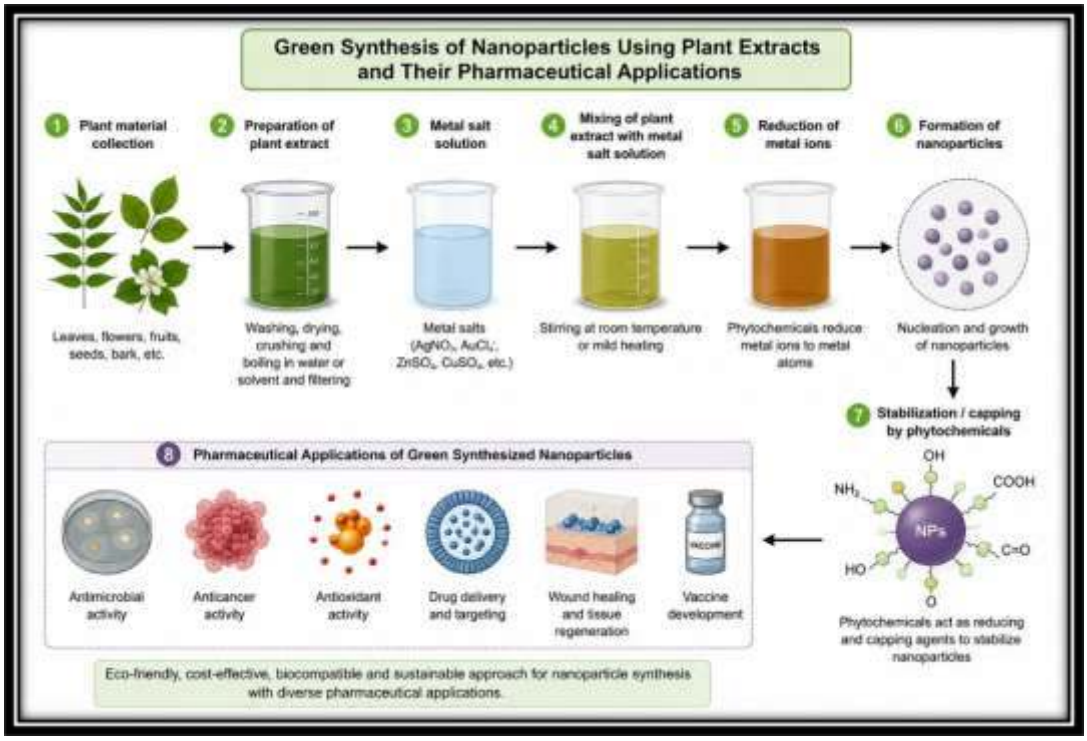

Figure 1: Overview of Green Synthesis of Nanoparticles

2. History and Development of Nanotechnology:-

In his 1959 speech "There's Plenty of Room at the Bottom," physicist Richard Feynman initially presented the idea of nanotechnology. Later, Norio Taniguchi came up with the name "nanotechnology" in 1974.

Table no 1 :- Important milestones in nanotechnology

Year	Development
1959	Richard Feynman introduced nanotechnology concepts
1974	Norio Taniguchi coined the term nanotechnology
1981	Development of scanning tunneling microscope
1985	Discovery of fullerenes
1991	Discovery of carbon nanotubes
2000 onwards	Rapid growth in nanoparticle synthesis and applications

The development of nanotechnology has greatly benefited medicine, particularly in the areas of therapeutic systems, diagnostics, and targeted medication delivery.

NANOPARTICLES :-

Ultrafine particles with sizes ranging from 1 to 100 nm are called nanoparticles. Nanoparticles have better physicochemical characteristics and increased reactivity because of their nanoscale size.

Classification of Nanoparticles

A. Based on Composition

1. Metallic nanoparticles

- Silver nanoparticles
- Gold nanoparticles
- Copper nanoparticles
- Zinc nanoparticles

2. Metal oxide nanoparticles

- Zinc oxide nanoparticles
- Titanium dioxide nanoparticles
- Iron oxide nanoparticles

3. Polymeric nanoparticles

4. Lipid nanoparticles

5. Carbon-based nanoparticles

- **Carbon nanotubes**
- Fullerenes
- Graphene nanoparticles

B. Based on Origin

- Natural nanoparticles
- Synthetic nanoparticles

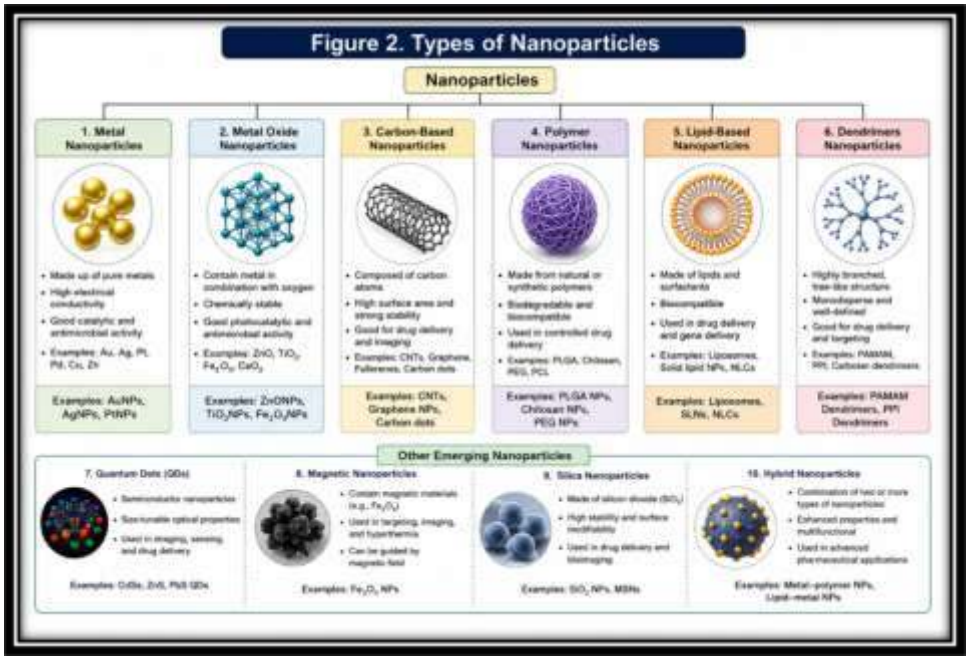

Fig 2 :-Types of Nanoparticles

4. Green Synthesis of Nanoparticles :-

Green synthesis is the use of biological systems to produce nanoparticles in an environmentally sustainable manner. It stays away from hazardous reagents and toxic compounds.

4.1 Principles of Green Synthesis :-

The principles of green synthesis include:

- Use of eco-friendly solvents
- Reduction of hazardous substances
- Energy efficiency
- Sustainable methods
- Renewable raw materials
- Reduced waste generation

Biological Sources for Green Synthesis :-

Various biological systems are used for nanoparticle synthesis:

Biological Source	Examples
1.Plant	Neem, Tulsi, Aloe vera
2.Bacteria	Bacillus species
3.Fungi	Aspergillus species
4.Algae	Marine algae
5.Yeast	Saccharomyces cerevisiae

Plant-mediated synthesis is favoured among them due to its ease of usage, speed, and scalability.

5. Plant-Mediated Synthesis of Nanoparticles :-

Plant extracts are used in plant-mediated synthesis to reduce metal ions into nanoparticles.

5.1 Steps in Plant-Mediated Synthesis:-

1. Collection of plant material
2. Washing and drying
3. Preparation of plant extract
4. Filtration
5. Mixing with metal salt solution
6. Formation of nanoparticles

7. Purification and characterization

5.2 Mechanism of Plant-Mediated Synthesis :-

- Reduction of metal ions
- Nucleation process
- Growth of nanoparticles
- Stabilization by phytochemicals

Flavonoids and phenolics are examples of phytochemicals that give electrons to metal ions, resulting in the production of nanoparticles.

6. Phytochemicals Involved in Nanoparticle Synthesis :-

Plant extracts contain a variety of phytochemicals that contribute to the creation of nanoparticles.

Phytochemical Role in Synthesis :-

Phytochemical	Role in synthesis
1. Flavonoids	Reducing agents
2. Phenolics	Stabilizing agents
3. Alkaloids	Capping agents
4. Proteins	Stabilization
5. Terpenoids	Reduction of metal ions
6. Tannins	Prevention of aggregation

These substances aid in the creation of stable, biocompatible nanoparticles.

7. Common Plants Used for Green Synthesis :-

A number of therapeutic plants are frequently utilised in the production of nanoparticles.

Plant Name	Nanoparticle synthesized	Application
1. Azadirachta indica (Neem)	Silver nanoparticles	Antimicrobial
2. Aloe vera	Gold nanoparticles	Wound healing
3. Ocimum sanctum (Tulsi)	Silver nanoparticles	Antioxidant
4. Moringa oleifera	Zinc oxide nanoparticles	Anticancer
5. Curcuma longa (Turmeric)	Gold nanoparticles	Anti-inflammatory

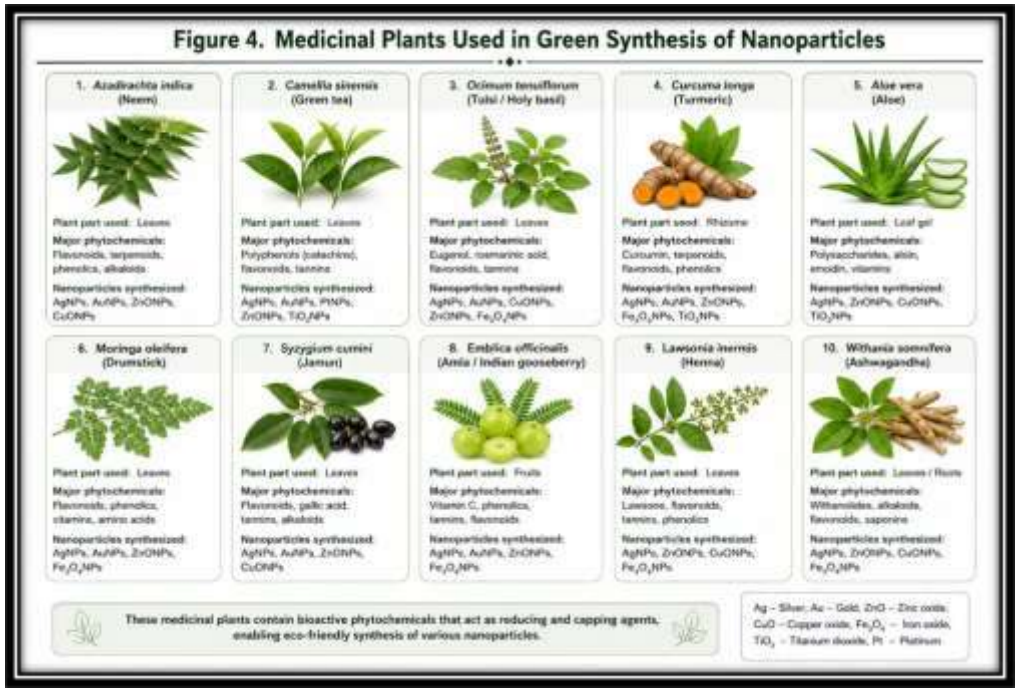

Fig no 4 Medicinal Plant used in green synthesis

8.Types of Green Synthesized Nanoparticles :-

8.1 Silver Nanoparticles (AgNPs) :- Due to their potent antibacterial qualities, silver nanoparticles are used extensively.

Properties

- Antibacterial activity
- Antifungal activity
- Antiviral activity
- High surface reactivity

Applications

- Wound dressings
- Drug delivery
- Antimicrobial coatings
- Medical devices

8.2 Gold Nanoparticles (AuNPs) :-

Gold nanoparticles have outstanding optical and biocompatibility qualities.

Applications

- Cancer therapy
- Drug delivery
- Biosensors
- Diagnostic imaging

8.3 Zinc Oxide Nanoparticles (ZnO NPs)

ZnO nanoparticles have UV protection and antibacterial qualities.

Applications

- Sunscreens
- Antibacterial agents
- Cosmetics
- Drug formulations

8.4 Iron Oxide Nanoparticles

Iron oxide nanoparticles are mostly utilised in MRI imaging and targeted medication administration.

9. Characterization Techniques of Nanoparticles :-

Determining the size, shape, structure, and stability of particles requires characterization.

Technique	Purpose
1. UV-Visible Spectroscopy	Confirmation of nanoparticle formation
2. FTIR	Identification of functional groups
3. XRD	Crystalline structure analysis
4. SEM	Surface morphology
5. TEM	Particle size and shape
6. DLS	Particle size distribution
7. Zeta potential	Stability analysis

10. Advantages of Green Synthesis :-

Green synthesis offers several benefits compared to conventional methods.

Green Synthesis Advantages

- Eco-friendly
- Low toxicity
- Cost-effective
- Biocompatible

- Simple process
- Scalable production
- Reduced environmental pollution

11. Limitations of Green Synthesis (31) :-

- Despite several advantages, green synthesis (31) has some limitations.
- Difficulty in large-scale production
- Variability in plant extract composition
- Limited control over particle size
- Stability issues
- Need for standardization

12. Pharmaceutical Applications of Green Synthesized Nanoparticles

There are many uses for green synthesized nanoparticles in medicine.

1. Antimicrobial Activity :-

Strong antibacterial action is demonstrated by nanoparticles against both Gram-positive and Gram-negative bacteria.

Mechanism :-

- Cell membrane disruption
- Generation of reactive oxygen species
- Protein denaturation
- DNA damage

Commonly Used Nanoparticles

- Silver nanoparticles
- Zinc oxide nanoparticles

Applications

- Wound healing
- Antimicrobial coatings
- Medical textiles

2. Anticancer Activity :-

Green synthesized nanoparticles are being researched extensively for the treatment of cancer.

Mechanism

- Induction of apoptosis
- DNA fragmentation
- Oxidative stress generation
- Targeted delivery to cancer cells
- Gold and silver nanoparticles show significant cytotoxic effects against cancer cells.

Advantages

- Reduced side effects
- Targeted therapy
- Enhanced drug delivery

3. Drug Delivery Systems

Nanoparticles improve drug delivery by enhancing solubility, bioavailability, and targeting efficiency.

Benefits

- Controlled drug release
- Reduced toxicity

- Improved therapeutic efficacy
- Site-specific delivery

Examples

- Polymeric nanoparticles
- Lipid nanoparticles
- Magnetic nanoparticles

4. Antioxidant Activity

Plant-based nanoparticles exhibit excellent antioxidant activity due to phytochemical coating.

Mechanism

- Free radical scavenging
- Prevention of oxidative stress
- Protection of cellular components

5. Anti-inflammatory Activity

Green synthesized nanoparticles reduce inflammation by inhibiting inflammatory mediators.

Applications

- Arthritis treatment
- Skin inflammation
- Wound healing

6. Antiviral Activity

Nanoparticles exhibit antiviral properties against various viruses.

Mechanism

- Inhibition of viral attachment
- Prevention of viral replication
- Disruption of viral proteins

7. Wound Healing Applications

Nanoparticles enhance wound healing by:

- Preventing microbial infections
- Promoting collagen formation
- Increasing tissue regeneration

Silver nanoparticles are commonly incorporated into wound dressings.

13.Recent advancements include:

- Development of multifunctional nanoparticles
- Smart drug delivery systems
- Nano-biosensors
- Hybrid nanoparticles
- Plant-based quantum dots
- Nanoparticles for gene delivery

Artificial intelligence and machine learning are also being integrated into nanoparticle design and optimization.

14. Future Perspectives :-

Future research in green synthesis should focus on:

- Large-scale production
- Clinical trials
- Standardization of methods

- Toxicological studies
- Regulatory approval
- Advanced targeted drug delivery

REFERENCES

1. Ahmed S, Ahmad M, Swami BL, Ikram S. A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications. J Adv Res. 2016;7(1):17-28.
2. Iravani S. Green synthesis of metal nanoparticles using plants. Green Chem. 2011;13(10):2638-2650.
3. Mittal AK, Chisti Y, Banerjee UC. Synthesis of metallic nanoparticles using plant extracts. Biotechnol Adv. 2013;31(2):346-356.
4. Khalil MMH, Ismail EH, El-Baghdady KZ, Mohamed D. Green synthesis of silver nanoparticles using olive leaf extract. Arab J Chem. 2014;7(6):1131-1139.
5. Singh P, Kim YJ, Zhang D, Yang DC. Biological synthesis of nanoparticles from plants and microorganisms. Trends Biotechnol. 2016;34(7):588-599.
6. Rai M, Yadav A, Gade A. Silver nanoparticles as a new generation of antimicrobials. Biotechnol Adv. 2009;27(1):76-83.
7. Sharma VK, Yngard RA, Lin Y. Silver nanoparticles: green synthesis and their antimicrobial activities. Adv Colloid Interface Sci. 2009;145(1-2):83-96.
8. Narayanan KB, Sakthivel N. Green synthesis of biogenic metal nanoparticles. Adv Colloid Interface Sci. 2010;156(1-2):1-13.
9. Makarov VV, Love AJ, Sinitsyna OV, et al. Green nanotechnologies: synthesis of metal nanoparticles using plants. Acta Naturae. 2014;6(1):35-44.
10. Prasad R, Pandey R, Barman I. Engineering tailored nanoparticles with microbes. Biotechnol Adv. 2016;34(5):524-537.
11. Jain D, Daima HK, Kachhwaha S, Kothari SL. Synthesis of plant-mediated silver nanoparticles. Dig J Nanomater Biostruct. 2009;4(3):557-563.
12. Ankamwar B. Biosynthesis of gold nanoparticles using plant extracts. J Nanosci Nanotechnol. 2010;10(1):1-12.
13. Gurunathan S, Han JW, Dayem AA, et al. Green synthesis of nanoparticles. Int J Nanomedicine. 2015;10:4203-4215.
14. Vahabi K, Mansoori GA, Karimi S. Biosynthesis of silver nanoparticles by fungus. Insciences J. 2011;1(1):65-79.
15. Li X, Xu H, Chen ZS, Chen G. Biosynthesis of nanoparticles by microorganisms and their applications. J Nanomater. 2011;2011:1-16.
16. Shankar SS, Rai A, Ahmad A, Sastry M. Rapid synthesis of Au, Ag nanoparticles using plant extracts. J Colloid Interface Sci. 2004;275(2):496-502.
17. Mohanpuria P, Rana NK, Yadav SK. Biosynthesis of nanoparticles. J Nanopart Res. 2008;10:507-517.
18. Thakkar KN, Mhatre SS, Parikh RY. Biological synthesis of metallic nanoparticles. Nanomedicine. 2010;6(2):257-262.
19. Bhattacharya D, Gupta RK. Nanotechnology and potential of microorganisms. Crit Rev Biotechnol. 2005;25(4):199-204.
20. Kharissova OV, Dias HVR, Kharisov BI, et al. The greener synthesis of nanoparticles. Trends Biotechnol. 2013;31(4):240-248.
21. Song JY, Kim BS. Rapid biological synthesis of silver nanoparticles using plant leaf extracts. Bioprocess Biosyst Eng. 2009;32(1):79-84.

22. Sathishkumar M, Sneha K, Won SW, Cho CW, Kim S, Yun YS. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nano-crystalline silver particles. Colloids Surf B Biointerfaces. 2009;73(2):332-338.
23. Dubey SP, Lahtinen M, Sillanpää M. Green synthesis and characterizations of silver and gold nanoparticles using leaf extract of Rosa rugosa. Colloids Surf A Physicochem Eng Asp. 2010;364(1-3):34-41.
24. Gardea-Torresdey JL, Gomez E, Peralta-Videa JR, et al. Alfalfa sprouts: a natural source for the synthesis of silver nanoparticles. Langmuir. 2003;19(4):1357-1361.
25. Parveen K, Banse V, Ledwani L. Green synthesis of nanoparticles: their advantages and disadvantages. AIP Conf Proc. 2016;1724:020048.
26. Bankar A, Joshi B, Kumar AR, Zinjarde S. Banana peel extract mediated synthesis of gold nanoparticles. Colloids Surf B Biointerfaces. 2010;80(1):45-50.
27. Raveendran P, Fu J, Wallen SL. Completely green synthesis and stabilization of metal nanoparticles. J Am Chem Soc. 2003;125(46):13940-13941.
28. Kumar V, Yadav SK. Plant-mediated synthesis of silver and gold nanoparticles and their applications. J Chem Technol Biotechnol. 2009;84(2):151-157.
29. Krishnaraj C, Jagan EG, Rajasekar S, et al. Synthesis of silver nanoparticles using Acalypha indica leaf extracts and its antibacterial activity. Colloids Surf B Biointerfaces. 2010;76(1):50-56.
30. El-Rafie HM, El-Rafie MH, Zahran MK. Green synthesis of silver nanoparticles using polysaccharides. Carbohydr Polym. 2010;80(3):779-7822
31. Preeti thakur, P.B Sharma, Atul Thakur. Bioscience, Earth Science, Engineering and Technology, Environmental and agriculture, Environment and sustainability. Page 481, Nanoparticles for pollution management.2026 edition 1.

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