"Green Synthesis, Characterisation and Biomedicinal Applications of *Rutaceae* Family Plant Mediated Metal Nanoparticles: A Review"

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Abstract

Nanotechnology is the emerging trend in recent era. Green synthesis of nanoparticles is a safe alternative for metal nanoparticles synthesis as compare to direct chemical synthesis of nanoparticles. Plant-based green chemistry uses a reduction process mediated by phytoconstituents to create nanoparticles. Because it makes alternative, sustainable, safer, less hazardous, and environmentally friendly methods easier to create nanoparticles, the green synthesis of nanoparticles is becoming more and more popular. The synthesis of novel nanoparticles with the desired properties needed for the development of biosensors, biomedicine, cosmetics, and nanobiotechnology, as well as for electrochemical, catalytic, antibacterial, anticancer, electronics, sensing, and other applications, is thus made possible by green nanotechnology using plant extract.

Plants naturally synthesize different kind of bioactive chemicals which includes terpenoids, alkaloids, polyphenols, and flavonoids which are working as a reducing or stabilising agents, which contributed in the formation of metal nanoparticles. The biocompatibility, environmental friendliness, scalability, cost-effectiveness stability, and biodegradability are important and main aspects of green synthesis of plant mediated nanomaterials. The combination of metal nanoparticles using plant extract also provides chances to use diverse plant wastes or by-products, which reduces waste overall.

In this review article *Rutaceae* family plant nanoparticles and its diverse applications has been denoted. Antimicrobial, anticancer, antidiabetic, cosmetic, water treatment, catalyst and medication delivery are just a few of the many potential application of different metal nanoparticles. Using plant extracts as a green pathway to synthesis metal nanoparticles is an effective and sustainable way to get nanoparticles with interesting features and possible uses.

Keywords
Green Synthesis, Plants Metal Nanoparticles, Single step, Characterisation, Applications.

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1. Introduction:

In recent years, nanotechnology has emerged as a major focus of scientific research. Nanoparticles are particularly noteworthy due to their high surface-to-volume ratio, unique properties, ease of synthesis and handling, and a wide range of beneficial features, including biological and phytochemical characteristics [1]. Because their size ranges from 1 to 100 nanometres, nanoparticles are not visible to the naked eye. At the nanoscale, materials exhibit properties that differ significantly from their bulk counterparts. This scale—one billionth of a meter—can alter the chemical and physical characteristics of many bulk materials. Their distinct shape, structure, and morphological absorption peak, known as their "fingerprint area," are key features that draw scientific attention [2].

Today, researchers are increasingly focused on synthesizing nanoparticles and biological extracts using metals as precursors, as illustrated in Figure 1. This is because nanoparticle production can be more cost-effective, safer, and environmentally friendly. Among the available methods, green synthesis is considered the simplest and most sustainable alternative to traditional physical and chemical approaches. Previously, nanoparticle synthesis was primarily conducted through chemical methods, which relied heavily on synthetic substances as stabilizing agents and other strong reagents. However, these chemical methods pose significant drawbacks, including environmental harm, toxicity, high costs, and the need for numerous parameters to control the system [3].The "green synthesis" approach has emerged as a solution to overcome these limitations. Plant extracts containing secondary metabolites possess both reducing and stabilizing properties, enabling them to effectively facilitate nanoparticle formation. Moreover, components within these extracts help reduce metal ions to nanoparticles. This method is not only effective but also aligns with environmentally friendly and sustainable practices [4].

In the early 1900s, plants were studied for their potential as reducing and capping agents; however, no significant follow-up research was conducted at the time. Over the past three to four decades, however, substantial progress has been made in this area, and interest has grown significantly in recent years [5].

Plants contain numerous bioactive compounds, primarily secondary metabolites such as glycosides, tannins, saponins, polyphenols, resins, flavonoids, alkaloids, and steroids. These compounds act as reducing agents, facilitating the reduction of metal ions or metal salts to form extremely small particles known as nanoparticles [6]. In this nanoparticle formation process, various parts of the plant—such as leaves, stems, roots, fruits, flowers, and bark—serve as key sources for extract preparation and further application [7]. Different techniques are used for plant extraction, which can be broadly categorized into conventional and modern methods. Conventional techniques are often preferred because they are practical, easy to handle, generally natural, and require simple setups. These methods include maceration, digestion, infusion, decoction, percolation, and Soxhlet extraction.

On the other hand, modern techniques—such as Accelerated Solvent Extraction (ASE), microwave-assisted extraction, ultrasound-assisted extraction, supercritical fluid extraction, and chiral chromatography—are more advanced but tend to be expensive, require specialized skills, and involve complex instrumentation [8].Various solvents are used for extraction, including polar, nonpolar, and amphoteric types. Commonly used solvents include water (known as the universal solvent), methanol, chloroform, acetone, ether, petroleum ether, xylene, hexane, and ethanol. Each solvent has a different ability to dissolve compounds from plant materials and form extracts.

When selecting a solvent, several parameters must be considered, including boiling point, absorption capacity, safety, solubility, viscosity, toxicity, and cost [9]. Additionally, factors such as pH, extraction time, temperature, concentration, solvent efficiency, and purity also significantly influence the extraction process. Different temperatures can produce different reactions.

Furthermore, masking unwanted reactions or compounds is also important. By carefully controlling all these factors, successful synthesis and extraction can be achieved [10].

According to numerous researchers, metal salts dissolve readily in deionized water. A common indicator of nanoparticle formation is the observable color change in the solution before and after treatment with plant extract, which signifies the formation of new particles—this visual change is an essential indication. The reduction process is initiated when the extract is added to the metal solution, altering its characteristics by affecting the oxidation state of the metal ions or complex compounds [11].

The activity and properties of nanoparticles are analysed using various instruments, which highlight their unique features. Each technique provides valuable information regarding the nanoparticles' structure, geometry, nature, and functional characteristics [12]. There are three main methods of nanoparticle synthesis: physical, chemical (synthetic), and green synthesis. Nanoparticles are generally classified into four major categories: metal/metal oxide-based, carbonbased, bioorganic-based, and composite-based nanoparticles. During the synthesis process, various types of nanoparticles are formed, each with distinct roles and properties. These categories include a wide range of metals and their compounds such as oxides, sulfides, chlorides, and nitrates [13].

Numerous metals—including silver (Ag), gold (Au), zinc (Zn), zirconium (Zr), carbon (C), calcium (Ca), copper (Cu), tin (Sn), lead (Pb), magnesium (Mg), and iron (Fe)—are utilized across various sectors such as biomedicine, agriculture, fertilizer production, pesticide development, drug delivery systems, and more [14]. Nano-sized materials also find broad applications in industries such as textiles, fragrance manufacturing, nanomedicine, pigments, solar energy systems, and supercapacitors. Additionally, they are increasingly used in environmental applications like wastewater treatment (e.g., from ponds, drainage systems, rivers, and oceans), as well as in biosensors and the aerospace industry [15]

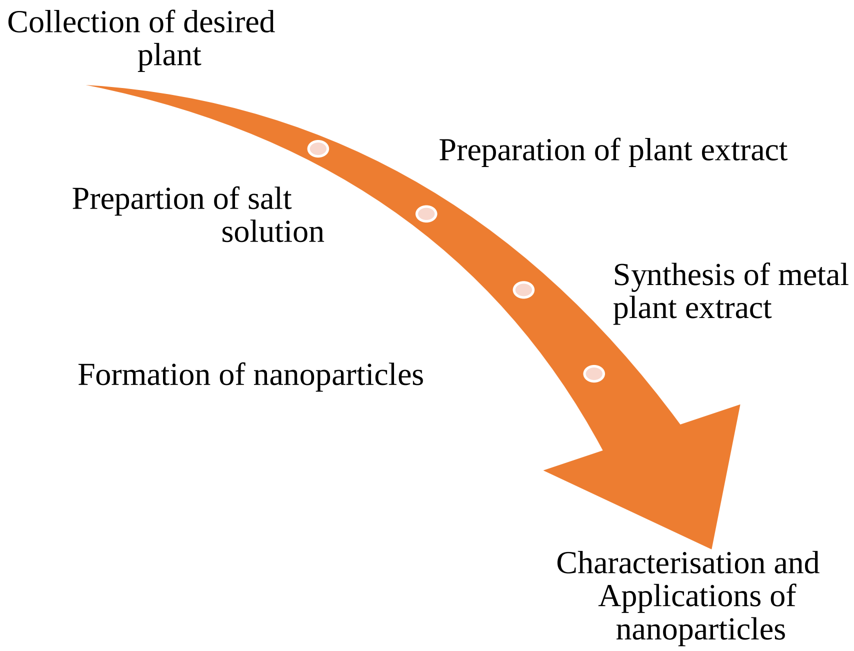

Fig.1 Formation of plant metal nanoparticles

Green nanoparticles synthesized using plant extracts have demonstrated significant potential in various fields, including drug delivery, encapsulation, water pollution control, and the development of electronic devices. They also exhibit important biological activities, acting as anticancer, antiviral, antimicrobial, and antioxidant agents [16]. Various synthesized nanoparticles offer a wide range of applications, such as antifungal and gastrointestinal treatments, management of leucorrhoea, and oral health conditions. They are also used as photoprotective agents, sensors, and in the treatment of viral diseases [17].

For example, zinc nanoparticles synthesized from plant extracts have been extensively studied for their diverse applications. These include use in solar cell and diode production, as well as in the treatment of medical conditions such as diabetes, Parkinson's disease, and central nervous system disorders. Additionally, zinc nanoparticles play a role in the manufacturing of rubber, paints, and cosmetics [18].Gold nanoparticles are particularly valuable in both medical and industrial fields due to their exceptional stability, purity, uniqueness, and versatility [19]. They are non-toxic, easily synthesized, and widely used in cancer treatment, blood circulation improvement, and targeted drug delivery systems [20].

Calcium has been identified as possessing both photocatalytic and medicinal properties, making it valuable across various industries due to its remarkable characteristics [21]. Platinum nanoparticles, which are core-centred in structure, have been synthesized and shown to exhibit a wide range of biological activities. They have demonstrated promising results as anticancer agents, particularly in the treatment of four types of malignant cancers, such as HePG-2 and HCT-116 cell lines [22]. Iron nanoparticles have also been synthesized and exhibit paramagnetic behaviour. They are widely applied in the production of dyes, as well as in magnetic resonance imaging (MRI), magnetic particle imaging (MPI), bioengineering, and biosensing applications [23]. Due to their unique properties and broad applicability, nanoparticles are extensively used in laboratories and industries around the world. Their applications include biofuels, gene therapy, catalysis, inhibition, and numerous other scientific and technological domains [24]. In light of these developments, this review highlights the emergence of a new era: nanoparticle synthesis using medicinal plants. This innovative approach offers a sustainable and eco-friendly pathway with broad potential. The green synthesis of nanoparticles is environmentally conscious, minimizes risk, utilizes natural resources, ensures safety, produces fewer by-products, is biodegradable, and holds great promise for practical, everyday applications

2. Techniques for the Synthesis of Nanoparticles approaches from the Top down and Bottom Up:

The innovative field of nanotechnology has made significant strides with the development of plant-based nanoparticles, promoting green synthesis methods for their production. In addition to being environmentally safe, biologically synthesized nanoparticles offer several advantages, such as non-toxicity, high yield, scalability, and enhanced control over morphological design. The green synthesis of nanoparticles represents a major shift from conventional chemical synthesis methods, emphasizing eco-friendly and sustainable production processes. This approach—i.e., the formation of nanoparticles through green synthesis—is safe, sustainable, and easy to manage, making it highly attractive for a wide range of applications. Researchers have extensively reviewed various green synthesis methods, highlighting their vast potential in fields such as biomedicine and agriculture [25].

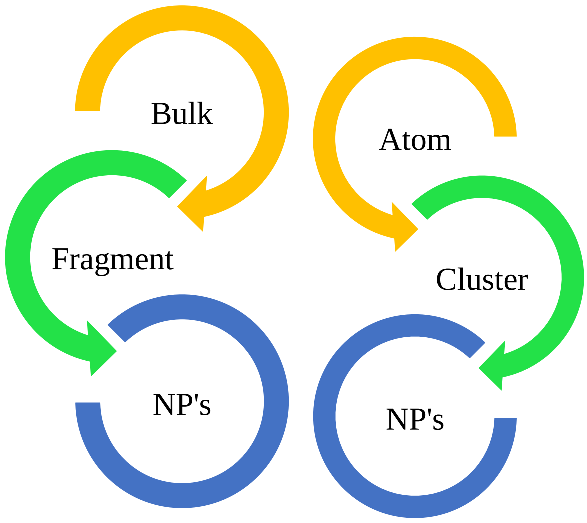

Figure 2: Methods from the top down and the bottom up.

Both the **“Top-down” (and "hierarchical"**) and **"Bottom-up"** (or **"base-up"**) approaches are employed to synthesize green nanoparticles from plants. The top-down method involves starting with larger particles and reducing them to the nanoscale. This reduction is typically achieved through mechanical processes or by using acidic chemicals to break down the material. Common techniques associated with the top-down approach include thermal decomposition, lithography, sputtering, ball milling, laser ablation, and other energy-intensive procedures that require advanced instrumentation and precise operational control.

In contrast, the bottom-up approach begins nanoparticle formation at the atomic or molecular level, where atoms or molecules self-assemble into nanoscale structures. This technique utilizes methods such as chemical vapor deposition (CVD), sol-gel synthesis, spinning, and pyrolysis. The bottom-up approach allows for precise control over particle size, distribution, and shape. It is often favored over the top-down method due to its lower energy requirements and greater ability to produce nanoparticles with specific, desirable properties.

Significant improvements in nanoparticle applications are often realized through bottom-up strategies, as they typically yield particles with higher purity and better crystallinity. This approach is especially important in green chemistry because it frequently employs natural agents—such as plant extracts—as reducing and stabilizing agents, eliminating the need for harsh or toxic chemicals. As a result, the nanoparticles produced are more biocompatible, making them ideal for use in fields such as agriculture and medicine.

In conclusion, green synthesis of plant-based nanoparticles utilizes both hierarchical (topdown) and base-up (bottom-up) methods. These complementary approaches reflect the dynamic and rapidly advancing field of nanotechnology, which continues to evolve in alignment with ecological and sustainable development principles [26].

3. The Environmental Impact on Different Nanoparticle Synthesis:

There has been growing interest in the green synthesis of nanoparticles, particularly those utilizing plant-based components, due to the method's high efficiency and minimal environmental impact. The shape and size of plant-derived nanoparticles can be precisely controlled by adjusting key variables such as pH, temperature, reaction time, and reactant concentration. These parameters significantly influence the physicochemical properties of the resulting nanoparticles.

For instance, pH levels affect cloud seeding and the nanoparticle formation process by altering the charge and solubility of plant biomolecules. Temperature also plays a vital role in synthesizing stable nanoparticles, as it accelerates reaction kinetics and facilitates the reduction of metal ions. Moreover, fine-tuning these variables during the reaction period ensures a controlled and repeatable synthesis process. This level of control positions the biological method as a promising approach for sustainable nanotechnology and material science [27]. There are four key factors that influence green nanoparticle synthesis, as outlined below [28]

A. pH :-

The size, distribution, and shape of nanoparticles are significantly influenced by the pH of the reaction environment, which is a critical factor in the eco-friendly synthesis of plant-mediated nanoparticles. Biomolecules act as reducing agents during biosynthesis, and their charge and availability are governed by the pH level. This, in turn, affects the nanoparticle formation process during both nucleation and growth stages. At higher pH levels, there are more nucleation sites, which accelerates the formation of metal nanoparticles. Adjusting the pH also enables precise control over the nanoparticles' shape, allowing for the fine-tuning of their physicochemical properties for various applications. To ensure that plant-derived nanoparticles synthesized via green methods are suitable for environmental, medicinal, or technological uses, it is crucial to maintain an optimal pH during synthesis.

B. Temperature :-

Researchers worldwide are exploring the intricate relationship between temperature control and the synthesis of plant-based nanoparticles. Temperature has proven to be a critical factor influencing the morphology, structure, and overall efficiency of nanoparticle synthesis. By carefully adjusting the temperature, various nanoparticle forms, such as triangles, octahedral platelets, spheres, and rods, can be achieved. Temperature significantly impacts nanoparticle characteristics, altering their physical dimensions and morphology during the synthesis process. As the temperature increases, the rate of chemical reactions also increases, accelerating the formation of nucleation sites, which are essential for nanoparticle development. Particularly in the biosynthesis of nanoparticles, where environmentally friendly methods are used, the duration of the reaction plays a vital role. It greatly influences the morphology, size distribution, and final yield of the nanoparticles produced.

C. Reaction time:-

Response time plays a pivotal role in the green synthesis of plant-based nanoparticles, as it significantly influences their structural morphology and resulting properties. Green synthesis utilizes plant extracts as reducing agents, promoting environmentally friendly pathways for nanoparticle formation and eliminating the need for harsh chemicals. By carefully controlling the response time, researchers can manipulate the size, shape, and dispersion of the synthesized nanoparticles, which are crucial for their applications in various fields. A prolonged reaction time may lead to well-defined, larger nanoparticles, whereas a shorter reaction time may favor the production of smaller, less uniform particles. Therefore, in the field of plant-mediated nanoparticle synthesis, mastering response time is essential to achieving the desired characteristics for specific industrial and biomedical applications

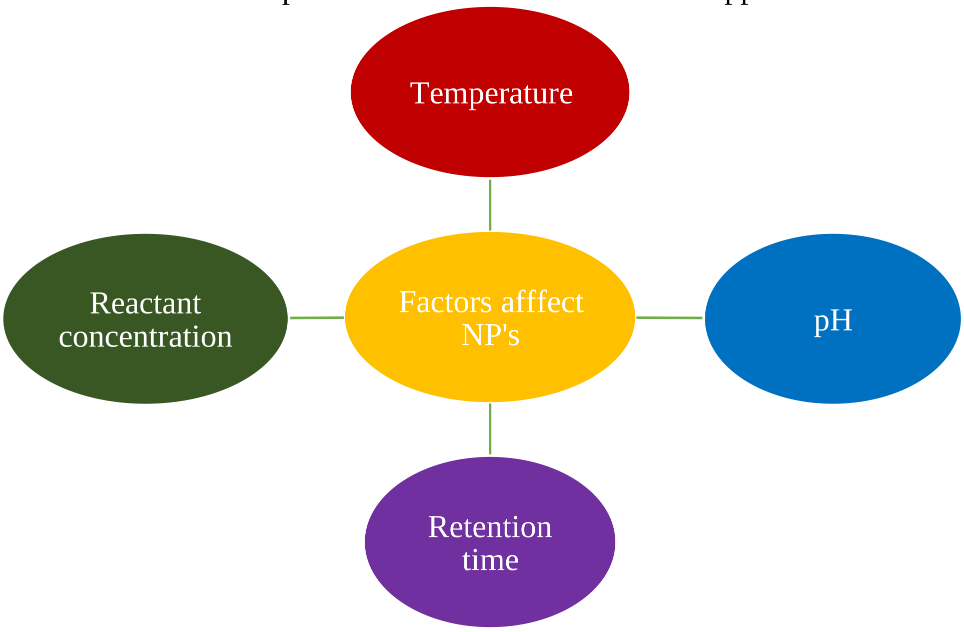

Fig.3 Factors affecting nanoparticles

D. Reactant concentration:-

The use of plant-derived nanoparticles is revolutionizing the field of biogenic synthesis by offering an eco-friendly approach to chemical reactions. In green synthesis processes, these plantbased nanoparticles play a crucial role as reactants, often acting as catalysts to enhance reaction rates while maintaining lower toxicity levels compared to traditional synthetic methods. The concentration of these plant nanoparticles is carefully optimized to ensure efficient reactions, minimizing waste and reducing the overall environmental footprint of the synthesis. Furthermore, the intrinsic properties of these plant-sourced nanoparticles, influenced by their concentration, allow for precise control over the synthesis process, resulting in higher selectivity and improved product yield. Highlighting the importance of reactant concentration, scientists continue to explore the vast potential of plant nanoparticles in green synthesis, aiming to develop sustainable and cost-effective methods for producing chemicals and materials.

4. Characterization of Nanoparticles

The article mentions several physical and chemical instrumentation techniques for characterizing nanoparticles, including X-ray diffraction (XRD), atomic force microscopy (AFM), dynamic light scattering (DLS), atomic absorption spectroscopy (AAS), energy dispersive spectroscopy (EDS), and X-ray photoelectron spectroscopy (XPS).

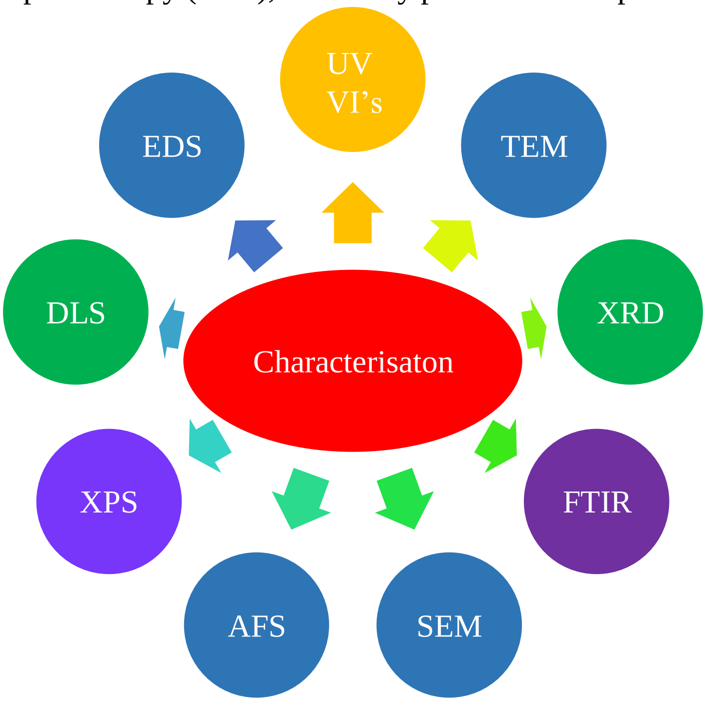

Fig.4 Characterisation techniques of nanoparticles.

A. UV-VI's spectroscopy :

UV-visible absorption spectroscopy is a crucial characterization tool used in the study of plantbased nanoparticles, particularly in the analysis of pigments and compounds produced by plants. This technique provides valuable insights into the molecular structure and concentration of various substances by monitoring their ability to absorb light within the UV and visible spectrum regions. In the context of nanotechnology, UV-visible spectroscopy is instrumental for characterizing nanoparticles, helping researchers determine optical properties and size-dependent behaviour of these tiny structures. By measuring the absorption peaks at specific wavelengths, scientists can deduce the presence and concentration of various nanoparticles synthesized from plant extracts or used for enhancing plant growth and protection. Additionally, the method is non-destructive and allows for rapid sample analysis, making it an indispensable tool for researchers in both plant science and nanomaterials [29]

B. TEM:

TEM stands at the forefront of characterization techniques for examining nanoparticles, providing unparalleled insights into their structural intricacies. This sophisticated analytical tool is indispensable for determining the morphology, size, and state of nanoparticles with remarkable precision. Through TEM, scientists can visualize the atomic arrangement and obtain detailed size distributions, which are essential for customizing nanoparticle properties for specific applications. The technique's high magnification and resolution capabilities make it the gold standard in nanotechnology, allowing researchers to draw correlations between the actual structure of nanoparticles and their material behaviour. As such, TEM has become a fundamental instrument in the development and characterization of nanoscale materials across a wide spectrum of scientific endeavours [29].

C. XRD:

X-ray diffraction (XRD) is a powerful analytical tool widely used to investigate the structural properties of crystalline materials. By directing X-rays onto a sample and observing the diffracted beams, XRD reveals unique patterns that are characteristic of the atomic arrangement within the crystal. These patterns are then used to deduce the material's crystal structure, phase composition, and other structural parameters, such as lattice constants, which are essential for understanding the material's properties. One important application of XRD is the determination of crystalline grain size; the Scherrer equation relates the broadening of the diffraction peaks to the size of these crystalline domains. Consequently, XRD is an indispensable technique in nanoscience, geology, chemistry, and physics for analysing solid materials [29]

D. FTIR :

Fourier Transform Infrared (FTIR) spectroscopy stands out as a powerful scientific technique for characterizing nanoparticles, offering detailed insights into their chemical composition and structure. By employing this technique, researchers can precisely analyze the molecular fingerprints of nanoparticles, revealing critical information about functional groups and bonding patterns on their surfaces. FTIR's sensitivity allows for the detection of nanoparticle surface chemistry, even at the most minute levels, which is particularly beneficial when assessing their potential reactivity and interactions with other substances. Furthermore, the ability to identify specific reactive surface sites through FTIR spectroscopy enables scientists to understand and manipulate the properties of nanoparticles, preparing them for use in fields such as catalysis, drug delivery, and materials science. As a non-destructive and rapid characterization tool, FTIR has become indispensable in the field of nanotechnology, providing critical data that drives innovation in the design and application of nanoparticle systems [30].

E. SEM :

Scanning electron microscopy (SEM) is an indispensable tool for characterizing nanoparticles, providing in-depth insights into the microscopic world of nanoparticles . This sophisticated imaging technique allows for detailed analysis of particle sizes, offering clear resolution even at the micro- and nanoscale levels. By employing SEM, scientists and researchers can better understand the size distributions and shapes of various nanomaterials, which is crucial for evaluating their potential applications. Additionally, SEM excels in revealing the surface morphologies of synthetic particles, highlighting textural features that influence their chemical and physical properties. As such, SEM plays a pivotal role in advancing nanotechnology by enabling precise characterization and investigation of nanoparticles, thereby driving innovation across multiple scientific disciplines [30].

F. AFM :

The Atomic Force Microscope (AFM) is an essential tool for characterizing materials at the nanoscale, enabling researchers to map surface topography with remarkable precision. It works by scanning a sharp tip, attached to a cantilever, across a sample to generate high-resolution images, thus defining material properties such as texture, size, and shape. Unlike electron microscopy, AFM does not require a vacuum environment and can characterize samples in ambient air or even in a fluid environment, making it versatile for various applications. The non-destructive nature of AFM allows for the investigation of delicate biological samples. By offering three-dimensional characterization capabilities, AFM has become indispensable in fields ranging from materials science to biology, providing an essential link between structure and function at the atomic level [31].

G. XPS :

X-ray photoelectron spectroscopy (XPS) is a powerful characterization technique widely used to analyze the surface chemistry of nanoparticles (NPs). It allows researchers to gain insights into the elemental composition, chemical states, and electronic structure of NP surfaces, which is crucial for tailoring their properties for various applications. By accurately measuring the binding energies of electrons ejected from the NP surface, XPS can reveal detailed information about coatings, shells, and potential contamination that may be present on the nanoparticles. Proper sample preparation, including cleaning and mounting, is essential to ensure the reliability of XPS data collection and subsequent analysis. This quantitative approach provided by XPS is invaluable for developing advanced materials and ensuring consistent nanoparticle performance in both research and industrial settings [31].

H. DLS :

Photon correlation spectroscopy, dynamic light scattering (DLS), or semi-flexible light scattering are all terms used to describe the same powerful analytical technique that can be used to determine the particle size distribution in a colloidal solution. By measuring the fluctuations in light intensity scattered by particles as they undergo Brownian motion, DLS can deduce the hydrodynamic size of particles ranging from a few nanometers to several microns in diameter. The technique is highly sensitive, non-invasive, and provides rapid results, making it a popular choice for characterizing the size and stability of nanoparticles, proteins, and polymers in solution. Moreover, DLS can be used to monitor particle aggregation and assess the consistency of particle size distribution over time, which is critical for quality control in industries such as pharmaceuticals, cosmetics, and materials science. Consequently, DLS plays a pivotal role in nanotechnology research and development, enabling researchers and engineers to better understand and manipulate the behavior of complex suspensions at the nanoscale [32].

I. EDS :

When characterizing nanoparticle composites derived from plants, energy-dispersive X-ray spectroscopy, commonly known as EDS, is a fundamental analytical tool. By detecting X-rays emitted by the sample when it is bombarded with an electron beam, this technique enables the chemical and elemental characterization of nanoparticles. Researchers utilize EDS in the investigation of plant synthesis processes to ensure that the resulting nanoparticles have the desired composition and purity. The specificity of EDS is crucial when studying the complex interactions between plant-derived compounds and the nanoparticles they help form. Through this technique, researchers can gain a better understanding of the structure and composition of bio-inspired nanoparticles, paving the way for advancements in green nanotechnology and various applications in medicine, electronics, and environmental science [32].

5. Plant mediated metal nanoparticles and its applications

I. Applications of environmentally friendly copper nanoparticles production:

This study primarily aims to replicate the work of Angajala, G. et al. (2014) by exploring the development of copper nanoparticles utilizing an aqueous extract of *Aegle marmelos* leaves as a reducing agent. In order to characterize the synthesized Cu-NPs, experiments were conducted using UV-Vis spectroscopy, FT-IR, XRD, SEM, and AFM. The prominent absorption bands observed at 3446.79 and 3437.15 cm^{-1} in the FTIR spectrum align with the O-H stretching vibrations observed in Cu-NPs. Research on anti-inflammatory effects in vitro was conducted using the albumin denaturation assay and the membrane stabilization test. Using scanning electron microscopy, the spherical-shaped Cu-NPs exhibited a typical size of 50-100 nm at 60°C and 100-200 nm at 100°C. The ability of copper nanoparticles to kill larvae was also tested [33].

Kulkarni et al. (2014) investigated whether extracts from *Aegle marmelos* leaves could be used to synthesize copper nanoparticles. As the nanoparticles formed, the solution's color changed from light blue to a rich green. By using XRD and Fourier Transform Infrared (FTIR) spectroscopy, two techniques for material characterization, it was determined that the synthesized Cu nanoparticles had a size of 48 nm [34].

Copper nanoparticles derived from *Murraya koenigii* leaf extract were reported by Anandhavalli, N. et al. (2015). Using UV-Vis spectroscopy, the photocatalytic activity was evaluated. Shape analysis revealed a spherical shape with an average size ranging from 33 to 40 nanometers. Characterization studies enabled the completion of several additional experiments, with Energy Dispersive X-ray (EDX) being crucial in identifying the elemental composition [35].

In their 2018 study, Sumathi et al. synthesized copper nanoparticles using extracts from *Aegle marmelos* and *Moringa oleifera* leaves. The presence of copper nanoparticles was confirmed through EDX analysis. UV-Vis spectra showed absorption peaks at 439 nm and 362 nm. The nanoparticles were observed to be spherical in shape through SEM analysis. Furthermore, the researchers used the agar well diffusion method to assess the antibacterial activity of the nanoparticles against both Gram-positive and Gram-negative bacteria [36].

Deepika, T. et al. (2018) conducted the synthesis of copper nanoparticles from *Murraya Koenigii*. To comprehend how the nanoparticles were made, a number of analytical tools were used. Spindleshaped and spherical nanoparticles were identified by scanning electron microscopy. A 410 nm absorption peak was further validated by UV-Vis spectroscopy. Additionally, the Agar Well dispersion test was utilized to explore the antibacterial viability of the bio-fabricated copper oxide nanoparticles [37].

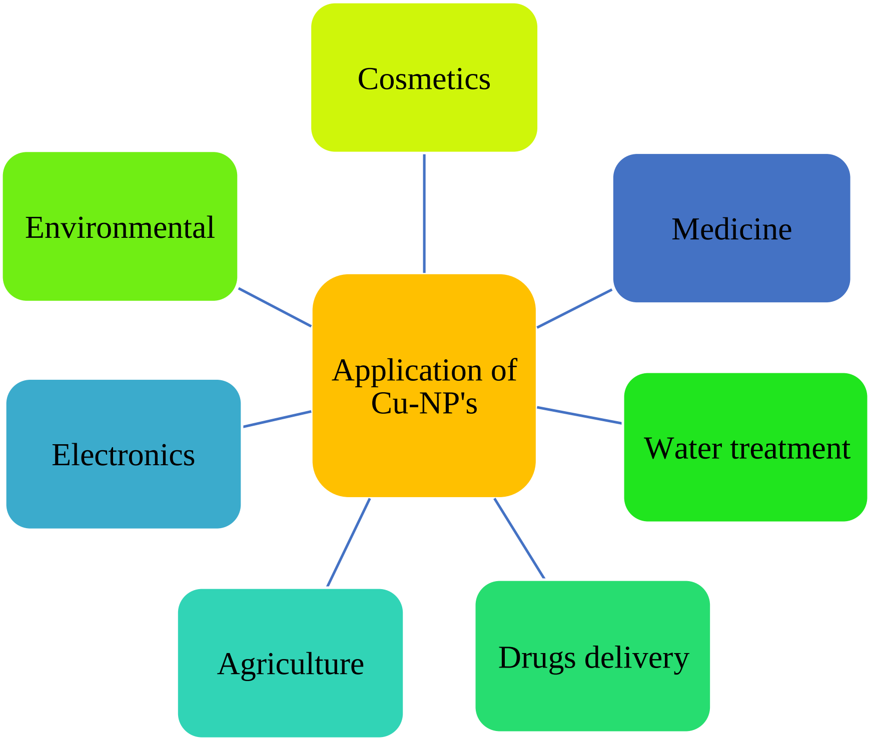

Fig.5 **Applications ofCu-Nanoparticles**

Mirza, A. U. et al. (2019) synthesized copper oxide nanomaterials using a green method by employing the plant species *Zanthoxylum armatum* and *Berberis lycium*. The development of the materials was confirmed through FT-IR, ATR, UV-visible, XRD, TEM, SEM, EDX, TGA, and PL techniques. EDX analysis provided confirmation of the formed nanoparticles. Copper oxide nanomaterials ranged from 40 nm to 58.05 nm and 44 nm to 58 nm, as observed through TEM analysis. To evaluate antibacterial activity, the agar well diffusion technique was used, and DPPH assays were utilized for assessing antioxidant properties[38].

Shamsuddin, M. et al. (2019) created copper nanoparticles by electroplating *Murraya koenigii* leaves with water. The electron microscopy images showed that the CuO NPs were spherical and had a typical diameter of 8.4 nm. The surface adsorption of bioactive components found in the leaf extract as reducing and stabilizing agents for the metal nanoparticles was confirmed by FTIR spectroscopic analysis. UV-vis spectroscopy demonstrated absorption between 200 nm and 500 nm. An evaluation was conducted on the catalytic efficiency of the nanoparticles[39].

Roy, P. et al. (2019) conducted a review to explore the synthesis of copper nanoparticles using *Murraya koenigii* leaf extract. According to Dynamic Light Scattering (DLS) analysis, the diameter of the copper nanoparticles in the curry leaf extract was 133.4 nm. Absorption peaks at wavelengths of 340 nm and 560 nm were observed in the UV spectrum of Cu-NPs synthesized via the green chemistry route. The Cu-NPs produced using plant extracts exhibited a particle size of 133.4 nm. Antibacterial testing was conducted on the synthesized nanoparticles against *E. coli* and grampositive bacteria to assess their antibacterial efficacy[40]. Kale et al. (2019) utilized an extract from lime leaves to synthesize copper nanoparticles. As the nanoparticles formed, the solution's color changed from blue to green. The nanoparticles were examined using Transmission Electron Microscopy (TEM), which revealed that their diameters ranged from 5 nm to 30 nm, with an average size of 22 nm. Absorption peaks at 580 nm and 590 nm were observed in the UV-Vis spectra. A band corresponding to the amide I protein was detected in the FTIR analysis, confirming the presence of leaf extract components. This was further validated by a signal at 1635 cm^{-1} [41].

Asghar, M. A. et al. (2020) employed six different leaf extracts—*Azadirachta indica*, *Avicennia marina*, *Datura stramonium*, *Murraya koenigii*, *Eucalyptus camaldulensis*, and *Rosa rubiginosa*— to synthesize copper nanoparticles. Transmission Electron Microscopy (TEM) analysis showed that the average nanoparticle sizes across the different plant extracts ranged from 29 to 48 nm. Additionally, the spherical morphology of the nanoparticles was confirmed through Scanning Electron Microscopy (SEM). FTIR spectroscopy verified the presence of phytochemical compounds responsible for the reduction, capping, and stabilization of the nanoparticles. A series of antibacterial tests were conducted against both gram-positive and gram-negative bacterial strains to evaluate the antimicrobial efficacy of the synthesized copper nanoparticles [42].

A straightforward, economical, and ecologically benign approach to producing copper oxide nanoparticles through *Murraya koenigii* leaf extricate was presented by Pantawane, P. K. et al. (2020). Electron spectroscopy and morphological verification using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR), and ultraviolet-visible spectroscopy (UV-Vis) confirmed the artificial CuO NPs' wear. In the UV-VIS spectra, a Surface Plasmon Reverberation top at 320 nm was seen, which showed that CuO NPs underwent phytochemical degradation. The TEM results showed that the particles have a size extent of 40-50 nm. The antimicrobial properties of the conveyed CuO NPs were too examined in a test using Escherichia coli, Klebsiella pneumoniae, Salmonella yellow, and Escherichia faecalis[43].

Selvan, D. A et al (2021) The copper and silver nanoparticle green mix was made by decomposing the leaves of Murraya *koenigii* and *Zingiber officinale*. The absorbance maxima at around 290 nm and 460 nm were shown by the UV analysis. The creation of nanocomposites was affirmed by XRD designs, which showed the monoclinic and FCC crystalline character. SEM revealed a spherical shape. TEM examinations showed that the nanoparticles were 18-22 nm in size. The αamylase, αglucosidase, and glucose-6-phosphatase compounds were utilized to evaluate the in vitro antidiabetic efficacy[44].

Conducted novel synthesis of copper nanoparticles using *Citrus lemon* extracts, wrote Amer, M. W. et al. (2021). For the purpose of characterizing the nanoparticles, XRD, SEM, TEM, and FTIR examinations were utilized. As demonstrated by the delayed consequences of the UV-vis maintenance spectra, the frequency is around 579 nm. The XRD examination affirmed the presence of a translucent design in the Cu-NPs, with a regular crystallite size of 30 nm. Results showed that the nanoparticles were successful against both Gram-positive and Gram-negative microbes when tried for their antibacterial activities[45].

Verma, R. et al (2021) This study's overarching goal is to learn more about how *Atalantia monophylla* leaf extract is utilized in the improvement of copper oxide nanoparticles. Pure copper oxide nanoparticles, going in structure from circular to pole formed and with a typical size of around 23 nm, were validated by their optical and structural characteristics. The crystalline nanoparticles were shown by XRD analysis. Consistent with the pertinent results, the UV-Vi spectra showed two ingestion tops at 319 nm and 269 nm for the Atalantia monophylla leaf extract. Carbohydrates, alkaloids, phenolic chemicals, saponins, glycosides, gum, mucilage, and phytosterols were all verified by FTIR analysis to be present in the extract. The cancer prevention agent movement was estimated utilizing the DPPH and ABTS examines, and the antibacterial action was thought about rather than both gram-positive and gram-negative microscopic organisms[46].

Mazhar, T. et al. (2021) *Citrus limon* used to form a bimetallic zinc copper nanoparticle, and various techniques such as FTIR, Powder-XRD, and SEM-EDX were employed to examine the nanoparticles. The size of the, still up in the air by XRD studies, was 26.76 nm. The anti-biofilm action of the integrated Zn-Cu particles was surveyed utilizing a 96-well microtiter plate and the crystal violet assay, while the antimicrobial movement was resolved utilizing the well dissemination strategy[47].

Atiq, M. et al. (2022) *Eucalyptus globulus* plant extract was utilized to analyze copper and Ag-NPs by a green synthesis approach. The antibacterial activity was assessed using nutrient agar media[48].

Prem Jose Vazhacharickal et al (2022) an article of Zinc and copper were recovered from *Azadirachta indica* and *Glycosmis pentaphylla* respectively. The agar well dissemination technique was utilized for antifungal tests. Characterization was performed using various tools. An excessive peak was seen at 435 nm with refined water and propane for the leaf concentrates of Glycosmis pentaphylla and Azadirachta indica, and at 680 nm with hexane, acetone and methanol dissolvable concentrates, while using different solvents. Additionally, the maximum peak observed for the extract of Glycosmis pentaphylla and Azadirachta indica, using each solvent, was found to be at 385 nm[49].

Jothiramalingam, R. et al. (2022) employed a green synthesis method to create copper nanoparticles using *Citrus lemon* blossom extract. The nanoparticles formed were analyzed using SEM, TEM, XRD, and DRS. SEM revealed both rectangular and spherical morphologies. An absorption peak was observed at 220 nm using UV-Vis spectroscopy. The antibacterial activity of the nanoparticles was evaluated against pathogenic bacteria [50].

In 2023, Alarfaj et al. synthesized copper nanoparticles using *Aegle marmelos* leaf extract. Several characterization methods were applied, identifying a surface plasmon resonance peak at 389.5 nm. The crystalline nature of the CuO nanoparticles was confirmed by X-ray diffraction (XRD), while energy-dispersive X-ray (EDX) spectroscopy verified the purity of the synthesized CuO nanoparticles. Their antimicrobial potential was assessed using the agar well diffusion method, and DNA fragmentation analysis was also performed [51].

C. Sivakumar et al. (2023) synthesized both silver and copper nanoparticles using *Murraya koenigii* extract. The nanoparticles were characterized using SEM, TEM, UV-Vis, and FTIR, yielding promising results. UV-Vis spectroscopy showed an absorption peak at 807 nm for copper nanoparticles and 445 nm for silver nanoparticles. SEM revealed that silver nanoparticles had cubical and rectangular shapes, while copper nanoparticles exhibited cubical, rectangular, triangular, and orbicular morphologies. TEM analysis showed that silver nanoparticles ranged from 5–25 nm in size, while copper nanoparticles ranged from 5–20 nm [52].

In a 2023 study, Pullapukuri et al. used *Aegle marmelos* leaf extract to synthesize copper nanoparticles in an eco-friendly manner. UV-Vis spectroscopy revealed an absorption peak at 310 nm. SEM analysis indicated that the nanoparticle sizes ranged from 15–26 nm. FTIR analysis identified a prominent signal at 3233 cm^{-1}, corresponding to hydrogen-bonded O–H stretching. Antifungal activity was assessed using the agar well diffusion method, while antibacterial efficacy was tested against various bacterial strains. Additionally, in vitro testing was performed to evaluate anticancer activity on HeLa cell lines [53].

Ali, S. G. et al. (2023) synthesized copper oxide nanoparticles using *Aegle marmelos* leaf extract via a green synthesis approach. Further characterization was performed using multiple techniques. UV-Vis spectroscopy showed an absorption peak at 330 nm. XRD confirmed the crystalline nature of the copper oxide nanoparticles. TEM analysis revealed an average particle size of 32 nm, while SEM indicated that the nanoparticles were agglomerated. Their antimicrobial effect was evaluated using the well diffusion assay [54].

Table No. 1 of Plant extract Cu-NP's

Metal Type	Plant Name	Plant part	Shape of nanoparticles	Size	Application	Author
Cu	*Aegle marmelos*	leaf	spherical	50–100 nm	anti-inflammatory Larvicidal activity	Angajala, G. et al. (2014)
Cu	*Aegle marmelos*	leaf	---	48nm	----	Kulkarni, V.et al. (2014)
Cu	*Murraya koenigii*	leaf	round and	33-40nm	------	Anandhavalli, N. et al. (2015)
Cu	*aegle marmelos moringa oleifera*	leaf	spherical	3nm and 60.36 nm	antibacterial	Sumathi, V. et al. (2018)
Cu	*Murraya Koenigii*	leaf	Spherical, spindle	---	antimicrobial	Deepika, T. et al. (2018)
Cu	*Zanthoxylum armatum and Berberis lycium*	leaf	crystal	40 nm to 58.05 nm, 44 nm to 58 nm	Antibacterial, antioxidant	Mirza, A. U. et al. (2019)
Cu	*Murraya Koenigii*	leaf	spherical	8.4 nm	catalytic	Shamsuddin, M.et al. (2019)
Cu	*Murraya Koenigii*	leaf	-------		antibacterial	Roy, P. et al. (2019)
Cu	*lime*	leaf	ellipsoidal	22 nm	---------	Kale, P. et al. (2019)

Cu	*The plants listed include Murraya koenigii, Avicennia marina, Datura stramonium, Murraya indica, and Eucalyptus camaldulensis.*	leaf	spherical	29 to 48 nm	antibacterial	Asghar, M. A. et al. (2020)
Cu	*Murraya koenigii*	leaf	microspheres	40-50 nm	microbial	P. K. et al. (2020)
Cu ,Ag	*Murraya koenigii and Zingiber officinale*	leaf	spherical	18 to 22 nm	in vitro antidiabetic	Selvan, D. A et al (2021)
Cu	*Citrus lemon*	fruit	crystalline	30 nm	antibacterial	Amer, M. W. et al. (2021)
Cu	*Atalantia monophylla*	leaves	spherical to rod-shaped	23 nm	antibacterial antioxidant	Verma, R. et al (2021)
Cu, Zn	*Citrus limon*	leaf	----	27.76nm	anti-biofilm antimicrobial	Mazhar, T. et al. (2021)
Cu, Ag	*Eucalyptus globulus*	leaf	----	-------	antibacterial	Atiq et al. (2022)
Cu, Zn	*Glycosmis pentaphylla and Azadirachta indica*	leaf	----	------	antifungal	Prem Jose Vazhachari ckal et al. (2022)
Cu	*Citrus lemon*	flowe r	spherical	-----	Antibacterial	Jothiramali ngam, R. et al. (2022)
Cu	*Aegle marmelos*	leaf	Cylindrical	-----	Antimicrobial DNA fragmentation	Alarfaj, A. A. et al. (2023)

Cu, Ag	*Murraya koenigii*	leaf	cubical, rectangular, triangular, ball-shaped, orbicular	5 to 20 nm, 5 to 25	------	C Sivakumar et al. (2023)
Cu	*Aegle marmelos*	leaf	spherical	15–26 nm	Antifungal, antibacterial, anticancer	Pullapukuri, K. et al. (2023)
Cu	*Aegle marmelos*	leaves	amassed	32 nm	Antimicrobial	Ali, S. G. et al. (2023)

II. Applications for environmentally friendly silver nanoparticles:

Bonde, S. R. et al (2010) estimated the silver nanoparticles ply an extract from *Murraya koenigii*. Through UV-noticeable spectroscopic examination, they noticed an absorbance tower at around 420 nm. Residence of proteins as capping agents was affirmed by FTIR spectroscopy. The round condition of the nanoparticles and their size scope of 40-80 nm were noticed utilizing SEM. The antimicrobial properties of the nanoparticles were examined by exposing them to harmful microorganisms[55].

Prathna, T. C. et al. (2010) detailed the amalgamation of silver nanoparticles utilizing a watery concentrate from *Citrus lemon*. Different instruments were utilized to decide the shape, size, and ingestion degree of the nanoparticles. A peak in absorption between 400 and 500 nm was detected using UV-visible spectroscopy. Research using Fourier transform infrared spectra pointed to citric acid as the most probable stabilizing factor. X-beam diffraction concentrate on uncovered subtleties on the interesting elements of the silver nanoparticles[56].

Christensen, L. et al. (2011) silver nanoparticles were generated from *Murraya koenigii* extract and analysed using different techniques. XRD investigation uncovered their face-loped cubic (FCC) nature. TEM assessment of the example showed a size scope of 10-25 nm, which was affirmed as the round size of the nanoparticles by AFM. The ingestion apex of the nanoparticles was observed at 435 nm[57].

Vankar, P. S. et al. (2011) synthesized an extract from *Citrus lemon* leaves with silver metal. Fluorescence transfer spectroscopy (FT-IR), scanning electron microscopy (SEM), atomic absorption spectroscopy (AAM), transmission electron microscopy (TEM), and ultraviolet-visible spectroscopy (UV-visible) were utilized to describe the nanoparticles. The particles were consistently sized according to SEM photos and TEM studies, which placed the widths of the particles some place in the scope of 8 and 15 nm. Testing the nanoparticles' antifungal activity with Fusarium oxysporum and Alternaria brassicicola was done using the agar dissemination approach on material[58].

Lokina, S. et al. (2011) conducted silver nanoparticle synthesis using an extract from *Aegle marmelos* plant. We used X-beam diffraction, high-goal transmission electron microscopy, ultraviolet-visible absorption spectroscopy, and elemental density-functional theory (EDX) analysis to characterize the material. An absorption spectrum at 420 nm was found by UV-apparent spectroscopy. HRTEM pictures showed round glasslike silver nanoparticles with an equator of 0.91.2 nm. TGA measurements used for weight loss of the nanoparticles at different temperatures under controlled conditions. The antimicrobial action of the nanoparticles against microorganisms was assessed utilizing the well-dissemination strategy on supplement agar[59].

Suganya, A. et al. (2013) conducted a biosynthesis of silver nanoparticles using *Murraya koenigii* remove. SEM imaging uncovered the presence of circular and cubic designs with size 20-35 nm. UV-VI analysis showed a distinct resonance at 410 nm. The natural piece was determined using EDX examination. The few practical gatherings present in the atom were recognized by FTIR examination[60].

Jagajjanani Rao, K. et al. (2013) used a green and eco-accommodating way to deal with orchestrate silver nanoparticles utilizing a leaf separate from the *Aegle marmelos* plant. The nanoparticles were viewed as 60 nanometres in size and to have a round form, according to FESEM analysis. The presence of polyphenols was affirmed by FT-IR spectroscopy, which revealed a peak at 1072 cm^{-1}. Additionally, the nanoparticles underwent analysis using HPLC and TGA techniques[61].

Krupa, N. et al (2014) *Aegle marmelos* plant concentrate for the biosynthesis of silver nanoparticles. The absorption band of AgNPs in UV-VIs is 423 nm. The translucency of NPs is determined using XRD. The presence of flavonoids and terpenoids in the A. marmelos natural product remove may be determined by the strong and intense peaks at 1645.28 cm^{-1} and 1631.78 cm^{-1}, respectively, caused by the -C=O- and -C=C- stretching vibrations. Using a microtiter plate approach, we were able to determine the underground mobility of the AgNPs' insect biofilm. The antimicrobial mobility was examined in relation to the germs that form biofilms[62].

Aegle marmelos leaf extract has the ability to potentially synthesis silver nanoparticles, according to research by Dandapat, S. et al. (2014). The plant material contained phytonutrients such as saponins, polyphenols, flavanones, tannins, terpenoids, alkaloids, and so on. The colour shifts from light yellow to lessen brown as the UV-clear spectra show a wide band at 474 nm and the maximum absorption at 200 nm. FFT-IR spectroscopy confirmed the presence of alcohols and phenols by showing transmission peaks at 3275 cm^{-1}, 1604 cm^{-1}, 1384 cm^{-1}, 1072 cm^{-1}, 825 cm^{-1}, and 750 cm^{1}, respectively, for O-H and H-stretch, C=C stretch, N=O bend, C=N stretch, symmetric P=O-C stretching, and C-Cl and C-H bending. Through scanning electron microscopy, the round or cubical AgNPs, which may be green in colour, were seen to have a typical size of 70 nm and a width somewhere in the range of 60 and 120 nm[63].

Christopher, J. G. et al. (2015) a harmless to the ecosystem cycle was utilized to make silver nanoparticles from *Aegle marmelos* leaf separate. By creating a peak in the 400–420 nm range of UV–Vi's spectroscopy, the description of silver nanoparticles was checked. When creating silver nanoparticles, pH is believed to be a significant element. Growth curve investigation was utilized to evaluate the germicidal action of silver nanoparticles[64].

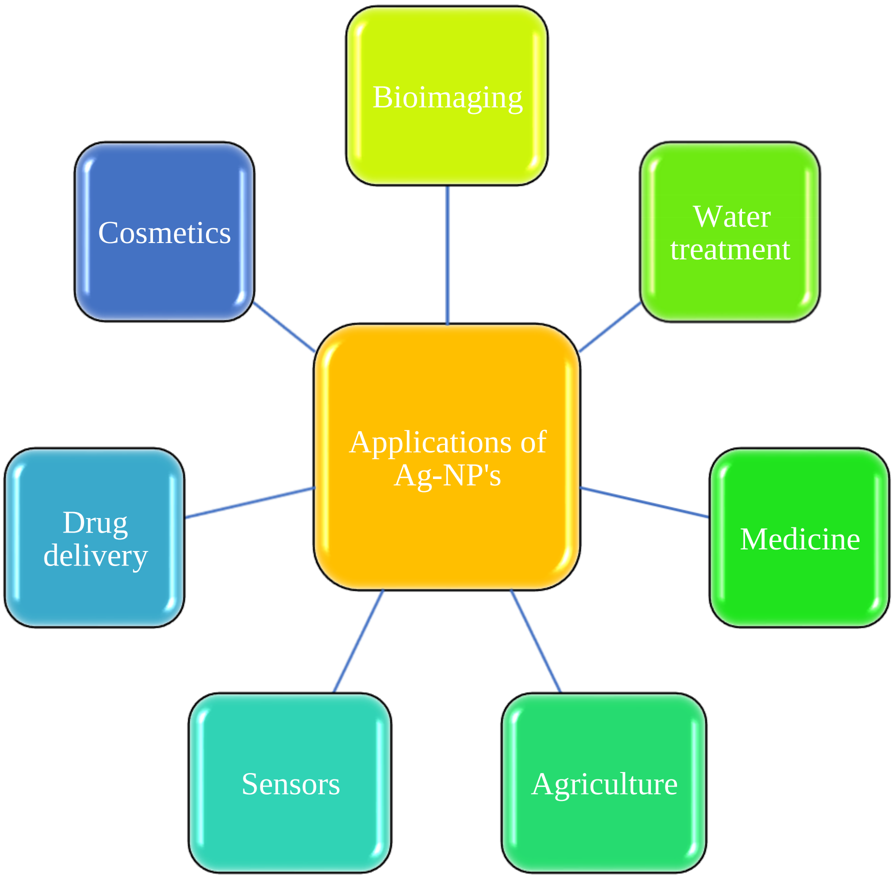

Fig. 6 Application of silver nanoparticles

Murugan, K. et al. (2015) synthesis *Toddalia asia*tica by using silver nitrate. Characterization was done by using various devices to form nanoparticles. The leaf separate went from being drab to looking more like a yellowish brown. Mosquitocidal activity of extract nanoparticles was also examined. Antibacterial activities were tried against *B. subtilis*, *K. pneumoniae*, and *S. typhi* microscopic organisms. SEM shows annular figure with a 25–30 nm size. EDX gives formed nanoparticles are crystalline in nature. pH was an important factor here[65].

K. Jagajjanani Rao et al. (2015) Ag and Au nanoparticles were examined of leaves extract of *Aegle marmelos*. Characterization was done by various analytical techniques. In between 400-600 nm, it shows the absorption maxima of silver and gold nanoparticles. TEM shows Ag-NP's as spherical shape and size as ~13.83 ± 4.89 nm. Gold displays a non-uniform shape along with ~23 nm average size. The antimicrobial effects of Ag and Au NPs were investigated using a zone-of-inhibition assay on *E. coli*[66].

K, S. et al (2015) An extract from the *murraya koenigii* plant was utilized to union silver nanoparticles. The created silver nanoparticles were focused on using splendid evident spectroscopy, separating electron microscopy, and energy dispersive X-shaft spectroscopy. The UV-Vis spectra created by the response media have an absorbance top at 435 nm. The state of the created nanoparticle is globular, with a breadth of 130 nm, according to SEM examination. Evidence of nanoparticle evolution is supported by EDX. The antibacterial effect of the silver nanoparticles was shown against various microorganisms, including Bacillus, E. coli, Staphylococcus, Klebsiella, and Micrococcus[67].

The researchers Patil, S. et al. (2015) utilized a concentrate from the *Aegle marmelos* plant to make silver nanoparticles. Logical methodologies like XRD, electron thickness utilitarian hypothesis (EDX), bright noticeable spectroscopy, filtering electron microscopy (SEM), zeta possible investigation, and examining electron microscopy were utilized to portray the metal nanoparticles. The discoveries showed that the nanoparticles had a circular structure and were somewhere in the scope of 15 and 30 nm in ordinary size. Around 450 nm, the UV-VI retention top is seen. Investigation of the Aegle marmelos leaves remove utilizing Fourier change infrared spectroscopy found that coumarins, tannins, and alkaloids are the essential impetuses for the decrease of silver particles to silver nanoparticles. Using a well-distribution technique, we tested silver nanoparticles for their antibacterial properties against harmful microbes[68].

Reenaa, M. et al. (2017) *Citrus sinensis*, *Citrus limon*, and *Citrus limetta* were collected and used for extract and synthesis with AgNO3 to form silver nanoparticles. When the peak value comes in between 400 and 500 nm, the investigation using the UV-visible spectrophotometer shows that silver nanoparticles are present. Recently organized silver nanoparticles were tried for their antibacterial survivability against *Salmonella typhimurium*, *Pseudomonas aeruginosa*, and *Escherichia coli*[69].

Raju, N. et al. (2017) silver nanoparticles were made by green route from *Murraya koenigii* plant. UV shows an absorption peak at 400 nm. The sample did, in fact, contain elemental silver, according to the EDX results. Mueller Hinton Agar plates were prepared to check its antibacterial activity[70].

Ashtaputrey, S. D. et al. (2017) Leaf extracts from the *Murraya koenigii* plant were used to make silver nanoparticles in an economical manner. A mix of filtering electron microscopy, bright noticeable spectra, what's more, Fourier change infrared spectroscopy was used to investigate the silver nanoparticles. The UV-noticeable spectra showed the trademark surface plasmon reverberation retention top at 340 nm, which affirmed the development of silver nanoparticles. The examining electron micrographs show a spherical form that is not perfectly symmetrical[71].

Linh, D. H. T. et al. (2018) combination of silver nanoparticles of *citrus lemon* separate. By utilizing bright apparent retention spectroscopy at the recurrence extent of 400-450 nm, the game plan of AgNPs was actually affirmed. Separating electron microscopy and transmission electron microscopy showed the got AgNPs was round and the size dispersing was uniform with the nanosize of 4-24 nm. Serum poison action against E. coli, B. subtilis and B. cereus bacteria was done[72].

Samreen, F. G. et al. (2018) carried out silver nanoparticle green synthesis from *citrus lemon* peel extract. NPs. The portrayal of created AgNPs was directed using a Bright Apparent Spectrophotometer, FTIR, and XRD. The well dissemination procedure was utilized to assess the antibacterial properties of the delivered AgNPs. Absorption peak was found out between 405-425 nm. The typical molecule size was 2-5 nm, which was examined[73].

Roshni, K. et al. (2018) silver nanoparticle synthesis by using *murraya koenigii* leaf extract. Portrayal was finished, and at 428 nm, by utilizing UV, it shows a retention band. Arranged particles went in size from 80.62 to 100.50 nm and were round in shape, as shown by the SEM assessment, the presence of silver avowed by EDX. Also the potential anticancer properties of silver nanoparticles were tested on HT-29 Colon Cancer Cells[74].

Natarajan, M. et al. (2018) silver nanoparticles leaf extract of *glycosmis pentaphylla* was done and it characterisation by various methods was carried. To determine antibacterial activity, the conventional Kirby-Bauer disk diffusion technique was used. Miniature weakening is ordinarily utilized methods to pass judgment on the MIC of antimicrobial specialists. The UV-vis spectroscopic retention scope of the AgNPs at 415nm. FTIR shows tops trotted at 3395, 2201, 1573, 1397, 1124, 832,761cm^{-1} in the locale of 400-4000 cm^{-1}. SEM gives a circular shape and threesided calculation with a mean size of 30 nm. As indicated by the EDX investigation, the essential arrangement of AgNPs comprised of silver (72.39%), chloride (16.32%), and oxygen (11.28%)[75]. P.H.S. et al. (2018) found that efficient, cost-effective silver nanoparticles were made from leaf extract of *murraya koenigii*. TEM, FTIR, and UV-VI's utilised to identify formed nanoparticle characterization. The UV-noticeable spectra show a top at 428 nm. Synthesized nanoparticles are smaller, as seen by the narrow peak. You may see alkene functional groups, N-O, C=O, and O-H in the FTIR spectra. The data from the transmission study reveals that it is monomorphic, with a typical size of 18 nm. An assessment of the cancer prevention agent action of silver nanoparticles was conducted using the DPPH test[76].

T. Leon Stephan Raj. et al (2018) Using an environmentally friendly and long-term approach, silver nanoparticles (AgNPs) were delivered utilizing a concentrate from the *Murraya koenigii* plant. The FTIR and X-beam diffraction analyses characterised the silver nanoparticles with green integration. Using the plate dispersion procedure, the antibacterial activity of Ag-NPs was tried against a scope of microorganisms. XRD analysis revealed seven distinct peaks. The synthesised particles, which came in cubic and hexagonal forms, had a typical size of 15 nm. In terms of size, they ranged from 10 to 50 nm[77].

A study was conducted by Samrot, A. V. et al. (2019) to investigate the biosynthesis of silver nanoparticles utilizing *Datura metel, Aegle marmelos, Annona reticulata,* and *Saraca indica*. An ethanol concentrate of Saraca indica, Annona reticulata, and Aegle marmelos shows tops between 600 and 630 nm, according to the results. Silver nanoparticles' size distribution, as seen by scanning electron microscopy (SEM), ranged from 45 to 120 nm. So, gram-negative bacterial strains were tested to see how well these nanoparticles worked as antibacterial. Antioxidant tests, using the FRAP and DPPH assays, were done[78].

The researchers Qais, F. A. et al. (2019) used *Murraya koenigii* leaf fluid concentration to create a silver nanoparticle combination. The mixed MK-AgNPs were tried for their antibacterial properties against MRSA and a few ESβL-conveying gastrointestinal microbes by the utilization of UV-vis spectroscopy, FTIR, XRD, SEM, and TEM strategies. The greater part of the nanoparticles, measuring 5–20 nanometres in diameter, had a spheroidal form. The antimicrobial action of the agar well dispersion was considered. The UV examination of the ingestion spectrum shows a clear peak at 410 nm. On the other hand, a broad peak about 3404 cm^{-1} is shown by the FTIR study, which suggests that the hydroxyl group is extensively vibrating[79].

In their 2019 study, Devi et al. incorporated silver nanoparticles from *aegle marmelos* natural product extricate involving methanol as a dissolvable. As indicated by the aftereffects of the UVVis heavenly examination, the pinnacle maintenance happened at 436 nm. The XRD examination showed that the AgNPs were straightforward. To confirm the size of the particles, photon connection spectroscopy was used. To investigate the surface geology of silver nanoparticles, an AFM technique was utilized. To figure out how viable the anti-infection was, the Agar Well Dispersion Strategy was utilized[80].

Ghosh, P. et al. (2019) carried out a green synthesis of silver nanoparticles from *Glycosmis pentaphylla* and *Heliotropium indicum* plant extract. From phytochemical analysis, it was viewed that as both the plants HI and GP contain significant measures of flavonoids and phenolics .Characterization has been done using various instruments like SEM, TEM, UV-VI, etc. In that between 400-500 nm absorption peak, as defined by UV-VI's. It shows uniform geometry. 13-58 nm is the range shown by the formed nanoparticles. The antibacterial activity was checked on two different bacterial species, specifically, Staphylococcus aureus and Escherichia coli by the Kirby Bauer circle dissemination procedure[81].

R. Amutha et al. (2019) described the use of *murraya koenigii* extract in the green combination of silver. Analysed nanoparticles using XRD, TEM, and FTIR in addition to UV-visible spectroscopy. The transmission electron micrograph uncovered the development of scattered silver nanoparticles all through the 5-25 nm range. UV-noticeable spectroscopic investigation showed the absorbance top at around 420 nm. The plate dispersion strategy was applied to assess the antimicrobial action of murraya koenigii leaf separate[82].

Gaikwad, D. et al. (2020) synthesized silver nanoparticles using the herbal plant *Murraya koenigii* and characterized them. FTIR analysis identified the presence of alkyl halides and alkene functional groups on the nanoparticles. Scanning Electron Microscopy (SEM) revealed their spherical shape, while UV-Vis spectroscopy showed a characteristic absorption peak at 700 nm. The anticancer activity was tested against THP-1 cancer cell lines, and antibacterial efficacy was also evaluated [83].

M. Padmaa Paarakh et al. (2020) synthesized silver nanoparticles using the leaves of *Murraya koenigii* and the fruit peel of *Punica granatum*. UV-Vis spectroscopy showed a maximum absorbance (λmax) at 460 nm, confirming the formation of silver nanoparticles. TEM analysis revealed average particle sizes of 17.44 nm for *M. koenigii* and 22.02 nm for *P. granatum*. Antitubercular activity was evaluated using the Microplate Alamar Blue Assay (MABA), which utilized Alamar Blue as the indicator dye [84].

Tiwari, M. et al. (2020) conducted an antibacterial assay using silver nanoparticles synthesized from *Phyllanthus emblica*, *Ocimum tenuiflorum*, and *Murraya koenigii* plant extracts. Antibacterial activity was specifically tested against a carbapenem-resistant strain (RS-307) of *Acinetobacter baumannii* [85].

R, K. et al. (2020) synthesized silver nanoparticles using an ethanolic extract of *Toddalia asiatica* with silver nitrate as a precursor. The nanoparticles were characterized using UV-Vis, EDX, Zeta Potential (ZP), FTIR, and SEM. An absorption maximum around 450 nm was observed. The particles were spherical, with sizes ranging from 30–50 nm. DLS analysis confirmed a typical particle size of around 50 nm [86].

Ali, S. A. et al. (2020) used an eco-friendly green synthesis approach to produce silver nanoparticles from *Casimiroa edulis* and *Glycosmis pentaphylla* leaf extracts. Phytochemical screening revealed fourteen phenolic compounds in *C. edulis* leaves and twelve in *G. pentaphylla*. The synthesized nanoparticles were evaluated for antioxidant activity and DNA damage protection [87].

Nayaka, S. et al. (2020) synthesized silver nanoparticles using *Zanthoxylum rhetsa* plant extract along with silver nitrate. UV-Vis spectral analysis showed a maximum absorption peak at 426 nm. AFM, TEM, and SEM confirmed that the AgNPs were spherical and polydispersed, with sizes ranging from 10 to 68 nm. FTIR analysis confirmed the presence of proteins on the nanoparticle surfaces. The MTT assay revealed strong anticancer activity against the A549 lung cancer cell line. Antibacterial activity was tested against *E. coli, S. pneumoniae, Enterococcus faecalis,* and *S. aureus* [88].

Sampath, G. et al. (2021) performed a natural synthesis of silver nanoparticles using aqueous leaf extract of *Aegle marmelos*. The AgNPs were characterized by UV-Vis, FTIR, XRD, HR-TEM, AFM, and zeta potential analyses. Particle sizes ranged from 5 to 30 nm. UV-Vis spectroscopy confirmed the presence of AgNPs with a peak at 416 nm. Antimicrobial activity was evaluated using a disc diffusion assay. The nanoparticles also showed larvicidal activity against *Culex quinquefasciatus* and *Aedes aegypti*. Photocatalytic activity was studied through the degradation of methylene blue under visible light exposure [89].

Antropova, I. G. et al. (2021) synthesized AgNPs using water-ethanol extracts of *Murraya paniculata*. The DPPH assay was used to assess the antiradical (antioxidant) properties. The nanoparticles ranged in size from 20–50 nm, with UV-Vis absorption spectra observed at 460–480 nm. Antimicrobial activity was tested using the serial dilution method [90].

Niluxsshun, M. C. D. et al (2021) green combination of silver nanoparticle from natural product concentrate of *citrus lemon, Citrus tangerine* and *Citrus sinensis* were completed. These coordinated silver nanoparticles have an admission top at around 440 nm in their UV-obvious digestion range. TEM uncovered that nanoparticles might be somewhere in the scope of 5 to 80 nm in size and can have a few structures, including circular, three-sided, hexagonal, and bar. AgNPs showed an extensive variety of antibacterial activity against both Gram-negative and Gram-positive microorganisms[91].

After adding *lemon* juice extract to a silver nitrate plan, the shade of the game-plan changed from light yellow to brown, as demonstrated by Rajeshkumar, S. et al. (2021). At two different wavelength ranges, 420 nm and 470 nm, UV-VIs exhibit a blotting peak. FTIR reveals a band spanning from 3273 to. An extending vibration of =C-H in the alkyne bunch was related with 20 cm-1. Under the magnifying lens, the particles show a uniform scope of sizes, with a mean breadth of around 200 nm. The antibacterial movement was researched utilizing the Agar Well Dispersion Strategy. I also use the agar well approach to test for antifungal activity[92].

T. Dutta et al. (2021) (1921) The organic extract of the *Glycosmis Pentaphylla* plant was used to make silver nanoparticles, which were then, at that point, used in a novel, eco-friendly, one-pot solution. Transmission electron microscopy (TEM), dynamic light dissipating (DLS), and bright vis spectroscopy (UV-Vis) all checked that the blend created stable, monodispersed AgNPs with an ordinary size of 17 nm. There was a 417 nm surface plasmon absorbance band found in the UV-Vi spectra of AgNPs. Combined AgNPs were considered for their antifungal properties in contrast to a scope of parasitic diseases. To guarantee antimicrobial action in vitro, the agar-well dissemination strategy was utilized. We used the fungicide Bavistin and the antibiotic Streptomycin to see whether they had a synergistic impact[93].

Elumalai, K. et al. (2022) Specialists led a green blend of leaf concentrate of *Atalantia monophylla* silver nanoparticles, bringing about a harmless to the ecosystem interaction. At 421 nm, the UVVis spectra showed a surface reverberation top. SEM investigation uncovered a spherical morphology, while TEM analysis showed a morphology ranging from 18 to 25 nm. Using bloodsucking vectors, the larvicidal experiment was conducted on the aqueous leaf extract and produced silver nanoparticles[94] .

Rama, P. et al. (2022) Ag-NP's green synthesis of by expending fresh leaves extract of *Murraya paniculata*. MP-derived AgNPs exhibit a face-focused cubic morphology, characterized by a circular shape and a typical molecule size of 23 nm. The substance's underlying examination exhibits the presence of distinctive peaks of AgNPs, as observed through UV-vis spectrometers at 438 nm. Using the well diffusion approach, we examined the antibacterial impact of produced AgNPs against a small number of human diseases Potential of antioxidant of AgNPs was checked against DPPH activity and reduced potential activity. Anticancer activity was checked versus a human umbilical vein endothelial cell line (HUVEC) by using a MTT assay[95].

Ravikumar, R. et al. (2022) carried out a green combination of silver from leaf, stem concentrate of *Todalia asiatica*. It shows spherical morphology with the band at 240 nm. Phytochemical analysis is performed by using quantitative tests and GC-MS spectroscopy. The cell reinforcement movement of the watery concentrate of three pieces of the plant was assessed utilizing DPPH examine, the ferric reducing ability of plasma (FRAP), and the SASC. The antibacterial movement of the three pieces of the plant was additionally analysed against the bacterial kinds of gram positive and negative microorganisms[96].

Y Pradhyumna, S. et al. (2022) Eco-accommodating union of silver was synthesized by *Murraya koenigii* . The antimicrobial test was checked against the Kirby–Bauer Disk Diffusion Susceptibility Test method. A semi-circular state of AgNPs might be found in the SEM picture. On MCF-7 and HeLa cells anticancer activity was checked. [97].

Alaallah, N. J. et al (2023) biosynthesised silver nanoparticles with *citrus lemon* essence and found all these cool uses for them. Absorption bands at 430 nm were seen in the UV-VI characterization. By using FTIR analysis, the bio-molecules that were likely to cause the reduction of silver ions were identified. Transmission electron microscopy (TEM) creates a spherical form with sizes between 10 and 50 nanometres. We tested AgNPs' antimicrobial efficacy using the well diffusion method. To verify the antioxidant activity, laboratory tests were conducted using the DPPH revolutionary rummaging examine, complete cancer prevention agent measure, and lessening power test. Using the MTT measure, the anticancer capability of the MCF-7 human chest illness cell line was evaluated. We used ANOVA to do the statistical comparison[98]. kanumuru, R. et al. (2023) biosynthesis of *citrus lemon* extract and formed silver nanoparticles. Fresh extract was made and analysed. Antibacterial movement of nanoparticles against the strain Staphylococcus aureus, Bacillus, and E.coli. by Mueller Hinton Agar method. Antifungal activity was tested on an agar well dissemination examine[99].

Chowdhury, S. et al. (2023) The process of synthesizing silver nanoparticles from the extract of *Glycosmis pentaphylla* fruit is known as biosynthesis. Eco-friendly nature synthesis has been done. Characterization by SEM it gives roughly spherical structure with 75 ± 5 nm size of formed nanoparticles. UV-VI's shows 420-430 nm absorption band. In order to determine the antimicrobial movement of AgNPs against different harvest pathogenic parasites, the agar well method was employed. Bactericidal properties were demonstrated against positive negative bacteria. Also it shows antifungal activity[100].

Farshina et al (2018) A harmless to the ecosystem strategy was utilized to orchestrate silver nanoparticles utilizing *Murraya Koenigii*. Using ultraviolet spectroscopy, the synthesised silver nanoparticles were characterised. The absorbance peak of the ultraviolet (UV) spectra of the silver nanoparticles delivered in the response medium is at 435 nm. The typical size of the organized silver nanoparticles was 146 nm. The antibacterial action of the silver nanoparticles was demonstrated against Staphylococcus, Bacillus, Klebsiella, E. coli, and Micrococcus. Reduced turbidity, pH, hardness, Body, and other parameters are achieved by means of this silver nanoparticle in wastewater[101].

Table No. 2 of Plant extract Ag-NP's

Ag	*Murraya koenigii*	leaf	circular	40-80 nm	antiseptic	Bonde, S. R. et al (20 10)
Ag	*Citrus lemon*	fruit	spherical	<50 nm	----	Prathna, T. C. et (2010) al.
Ag	*Murraya koenigii*	leaf	round	10-25 nm	---	Christensen, L. et al. (2011)
Ag	*Citrus lemon*	leaves	uniform	8 to 15 nm	antifungal	Vankar, P. S. et (2011) al.
Ag	*Aegle marmelos*	leaf	spherical	0.9-1.2 nm	antimicrobial	Lokina, S. et al. (2011)
Ag	*Murraya koenigii*	leaf	spherical and cubic	20-35 nm	----	Suganya, A. et al. (2013)
Ag	*Aegle marmelos*	leaf	spherical	60	------	Jagajjanani Rao, K. et al. (2013)
Ag	*Aegle marmelos*	fruit	spherical	---	Biofilm, Antibacterial	Krupa, N. et al (2014)
Ag	*Aegle marmelos*	leaf	spherical and cubical	70 nm	-----	Dandapat, S. et al. (2014)
Ag	*Aegle marmelos*	leaf	Spherical	2-100nm	germicidal	Christopher, J. G. et al. (2015)
Ag	*Toddalia asiatica*		annular	25–30 nm	Mosquitocidal, Antibacterial	Murugan, K. et al. (2015)
Ag, Au	*Aegle marmelos*	leaf	Spherical, non-uniform	~13.83 ± 4.89 nm, ~23 nm	Antibacterial	K. Jagajjanani Rao et al. (2015)
Ag	*murraya koenigii*	leaf	globular	130nm	antibacterial	K, S. et al (2015)
Ag	*Aegle marmelos*	leaf	spherical	15 -30 nm	antibacterial	PATIL, S. et al. (2015)
Ag	*Citrus sinensis, Citrus limon, and Citrus limetta*	fruit	---	----	antibacterial	Reenaa, M. et al. (2017)
Ag	*Murraya koenigii*	leaf	-----	------	antibacterial	Raju, N. et al. (2017)

Ag	*Murraya koenigii*	leaf	spherical	-----	------	Ashtaputrey, S. D. et al. (2017)
Ag	*citrus lemon*	plant	spherical	4-24 nm	Antibiotic	Linh, D. H. T. et al. (2018)
Ag	*citrus lemon*	peel	spherical	2-5 nm	antimicrobial	Samreen, F. G. et al. (2018)
Ag	*murraya koenigii*	leaf	spherical	80.62 to 100.50 nm	anticancer	Roshni, K. et al. (2018)
Ag	*glycosmis pentaphylla*	leaf	Spherical and triangular	30 nm	antimicrobial	Natarajan, M. et al. (2018)
Ag	*murraya koenigii*	leaf	sphere	18 nm	antioxidant	P.H.S. et al. (2018)
Ag	*Murraya koenigii*	leaf	cubic and hexagonal	15 nm	antibacterial	T. Leon Stephan Raj. et al (2018)
Ag	*Datura metel, Aegle marmelos, Annona reticulata, and Saraca indica*	leaf	round	45 t o 120 nm	Antibacterial, antioxidant	Samrot, A. V. et al. (2019)
Ag	*Murraya koenigii*	leave s	Spheroidal	5–20 nm	Antibacterial	Qais, F. A. et al (2019)
Ag	*aegle marmelos*	fruit	-----	--------	antimicrobial	Devi, M. et al. (2019)
Ag	*Glycosmis pentaphylla and Heliotropiu m indicum*	leaf	spherical	13-58 nm	antibacterial	Ghosh, P. et al. (2019)
Ag	*murraya koenigii*	leaf	spherical	5-25 nm	antimicrobial	R. Amutha et al. (2019)
Ag	*murraya koenigii*	leaf	circular	1-239.6 n m	anti cancer	Gaikwad, D. et al. (2020)
Ag	*Murraya koenigii, Punica granatum*	Leaf, peel	-----	17.44 and 22.02 nm	antitubercular	M Padmaa Paarakh. et al. (2020)

Ag	*Phyllanthus emblica, Ocimum tenuiflorum, and Murraya koenigii*	leaf	-----	-----	Antibacterial	Tiwari, M. et al. (2020)
Ag	*Toddalia asiatica*	leaf	round	30–50 nm	-------	R, K. et al. (2020)
Ag	*Casimiroa edulis and Glycosmis pentaphylla*	leaf	------	-------	Antioxidant, DNA damage	Ali, S. A. et al. (2020)
Ag	*Zanthoxylu m rhetsa*	seed	Spherical	10 nm to 68 nm	Anticancer, antibacterial	NAYAKA, S. et al. (2020)
Ag	*Aegle marmelos*	leaf	spherical and polydispersed	5 to 30 nm	Antimicrobia l, Larvicidal, photocatalyti c	Sampath, G. et al (2021)
Ag	*M. paniculata*	leaf	-------	20–50 nm	Antiradical, antimicrobial	Antropova, I. G. et al (2021)
Ag	*citrus lemon, Citrus tangerine and Citrus sinensis*	fruit	spherical, triangular, hexagonal, and rod	5 to 80 nm	antibacterial	Niluxsshun, M. C. D. et al (2021)
Ag	*citrus lemon*	fruit	uniform	200 nm	Antibacterial, antifungal	Rajeshkumar, S. et al. (2021)
Ag	*Glycosmis Pentaphylla*	leaf	monodisperse d	17 nm	Antifungal, In vitro antibacterial, Synergistic effect	Dutta, T. et al. (2021)
Ag	*Atalantia monophylla*	leaf	spherical	18 t o 25 nm	larvicidal	Elumalai, K. et al. (2022)
Ag	*Murraya paniculata*	leaf	circular	23 nm	Antimicrobia l, antioxidant, Anticancer	Rama, P. et al. (2022)
Ag	*Todalia asiatica*	leaf, stem	spherical	------	Antioxidant, Antibacterial	Ravikumar, R. et al. (2022)

Ag	*Murraya koenigii*	leaf	spherical	------	Antibacterial, anticancer	Y Pradhyumna, S. et al. (2022)
Ag	*citrus lemon*	leaf	spherical	10-50 nm	Antibacterial, Antioxidant, Anticancer	Alaallah, N. J. et al (2023)
Ag	*citrus lemon*	seed	-----	------	Antibacterial, Antifungal	kanumuru, R. et al. (2023)
Ag	*Glycosmis pentaphylla*	fruit	spherical	75 ± 5 nm	Bactericidal, antifungal	Chowdhury, S. et al. (2023)
Ag	*Murraya Koenigii*	leaf	sphere	146 nm	Antibacterial, wastewater	Farshina et al (2018)

III. Applications for environmentally friendly zinc nanoparticles:

Elumalai et al. (2016) synthesized zinc oxide nanoparticles using *Murraya koenigii* leaf extract. FTIR spectra clearly indicated that O-H stretching played a significant role in the formation of ZnO nanoparticles due to its pronounced shift. Atomic Force Microscopy (AFM) confirmed the presence of smooth, homogeneous, and densely packed fine grains over the scanned surface area. Field Emission Scanning Electron Microscopy (FESEM) revealed round-shaped nanoparticles with vibrant, self-assembled morphology. The particle size was determined using Transmission Electron Microscopy (TEM). The in vitro antimicrobial activity was evaluated using the disc diffusion method [102].

Lingaraju, K. et al. (2016) achieved the green synthesis of zinc nanoparticles using *Ruta graveolens* stem extract. Characterization was carried out using UV-Vis spectroscopy, SEM, TEM, and XRD. A distinct absorption band was observed at 355 nm in the UV-Vis spectrum. TEM analysis showed spherical nanoparticles with sizes ranging from 20 to 30 nm. Antimicrobial activity was assessed using the agar well diffusion method. Additionally, antioxidant potential was evaluated through the DPPH assay [103].

Kumara, K. N. et al. (2016) synthesized zinc and magnesium oxide nanoparticles via a green synthesis route using *Murraya koenigii* leaf extract and investigated their photocatalytic activity. Characterization was conducted using multiple techniques. TEM analysis showed that zinc oxide nanoparticles were spherical, while magnesium oxide nanoparticles exhibited a hexagonal shape, both with an average size of approximately 200 nm. Photocatalytic studies were conducted using 75–150 mm batch reactors [104].

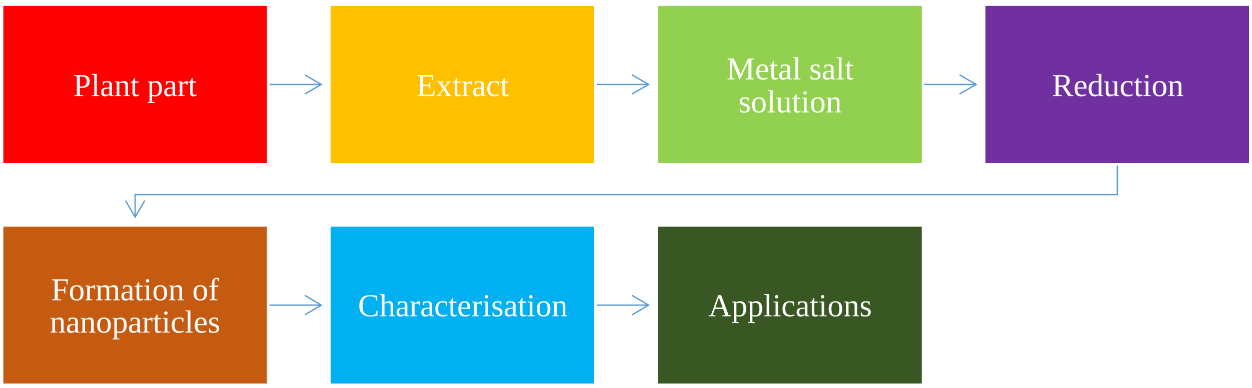

Fig.7 Process of synthesis of nanoparticles

Sundaraselvan, G. et al. (2017) synthesized zinc oxide nanoparticles using *Murraya koenigii* through a green synthesis approach and characterized them using various techniques. UV spectroscopy indicated a maximum absorption at 330 nm. XRD analysis revealed a face-centered cubic (FCC) structure. SEM images showed diverse shapes including spherical, triangular, spiral, hexagonal, rod-like, and square structures. TEM analysis indicated particle sizes around 100 nm. The antibacterial activity of the synthesized ZnO nanoparticles was tested against both Gramnegative and Gram-positive bacteria using the disc diffusion method [105].

Sriramulu, M. et al. (2018) synthesized zinc nanoparticles using a green method involving *Aegle marmelos* leaf extract. Characterization was performed using UV, SEM, FTIR, and other methods. UV-Vis analysis revealed an absorption peak at 500 nm. VSM confirmed the magnetic properties of the nanoparticles, and XRD analysis showed a cubic structure. SEM showed agglomerated and irregular shapes. Antibacterial activity was evaluated using the well diffusion method. The nanoparticles were also tested for use as drug delivery agents [106].

Vijayakumar, S. et al. (2018) synthesized ZnO nanoparticles using methanol leaf extract of *Glycosmis pentaphylla*. Characterization was done using UV-Vis, fluorescence spectroscopy, XRD, FTIR, SEM with EDAX, and TEM. UV-Vis and photoluminescence peaks were observed at 351 and 410 nm, respectively. FTIR confirmed functional groups, while XRD confirmed the crystalline nature. EDAX showed 20.70% pure ZnO content. SEM analysis confirmed morphology, and TEM showed particle sizes ranging from 32 to 36 nm. Antimicrobial activity was assessed using the agar well diffusion method [107].

Vijayakumar, S. et al. (2018) also described the biosynthesis of ZnO nanoparticles using *Atalantia monophylla* leaf extract. A strong UV-Vis absorption peak appeared at 352 nm. FTIR analysis showed functional group vibrations between 547 and 3340 cm^{-1}. EDAX confirmed 48.81% zinc oxide content. SEM revealed spherical morphology, and TEM indicated a size of 30 nm. Antibacterial activity was evaluated using the agar well diffusion method [108].

Hossain, A. et al. (2019) synthesized ZnO and TiO_2 nanoparticles using *Citrus limon* fruit extract. ZnO nanoparticles showed a characteristic SPR peak at 388 nm. TiO_2 showed a peak at 410 nm. FTIR analysis indicated bands at 448 cm^{-1} and 538 cm^{-1} for ZnO, and around 534 cm^{-1} for Ti-O. SEM and TEM showed spherical, rod-like, and irregular geometries. Antibacterial activity against *Dickeya dadantii* was assessed using agar diffusion assays [109].

Fowsiya, J. et al. (2019) used *Aegle marmelos* extract for the green synthesis of ZnO nanoparticles. FTIR analysis confirmed phenolic groups responsible for ZnO formation. TEM revealed semicircular shapes with an average size of 18 ± 2 nm. SEM showed finely shaped spherical ZnO NPs. EDAX reported 30.51% zinc and 69.49% oxygen. Antibacterial activity was tested against *Proteus vulgaris*, *E. coli*, and *Bacillus cereus*. Antifungal activity was evaluated against *Aspergillus flavus* and *Aspergillus niger* [110].

Kumar, M. R. A. et al. (2019) synthesized zinc nanoparticles using *Ruta chalepensis*. SEM revealed spherical structures under 100 nm. FTIR showed various absorption peaks. Photocatalytic activity was tested with methylene blue and indigo carmine, and electrochemical properties were studied as well [111].

Akl M. Awwad et al. (2020) synthesized ZnO nanoparticles using aqueous extract from *Ailanthus altissima* fruit. Characterization using SEM, UV-Vis, and XRD showed particle sizes between 5 and 18 nm. FTIR indicated reduction and capping processes. Antibacterial activity was tested against *E. coli* and *Staphylococcus aureus* [112].

Sowmya, B. et al. (2020) synthesized ZnO nanoparticles using *Citrus limon* peel extract. UV-Vis showed absorption at 310 nm. XRD confirmed a hexagonal wurtzite structure. FTIR showed an absorption band at 3344.57 cm^{-1} indicating alcohol/phenol groups. SEM revealed particle sizes ranging from 100 to 190 nm. Antibacterial activity was assessed using the well diffusion method, and antioxidant activity was evaluated with the DPPH assay [113].

Lakshmikandhan, T. et al. (2020) investigated eco-friendly synthesis of ZnO nanoparticles using *Murraya koenigii* extract. FTIR showed strong bands at 3491 and 3382 cm^{-1}, associated with O-H stretching from alcohol or phenol groups. The synthesized nanocrystals had an average size of 19.53 nm. FESEM confirmed spherical morphology [114].

Li, F. et al. (2020) used a cost-effective green route to synthesize ZnO nanoparticles from *Clausena lansium*. UV-Vis showed an absorption peak at 350 nm. TEM revealed particle sizes between 25– 30 nm with spherical morphology. Anticancer activity was evaluated against SH-SY5Y neuroblastoma cells [115].

Dhayalan, M. et al. (2021) synthesized ZnO nanoparticles using *Aegle marmelos* fruit extract. A color change from dark green to red confirmed nanoparticle formation. UV-Vis showed maximum absorbance at 385 nm. XRD indicated semi-crystalline nature. TEM showed 50 nm particles with spherical geometry. Anticancer activity was tested on MCF-7 cells using the MTT assay [116]. Shah, N. I. et al. (2021) synthesized chromium-doped ZnO nanoparticles using *Citrus reticulata*. XRD confirmed a wurtzite structure. SEM revealed spherical morphology. Antioxidant activity was evaluated using the DPPH assay. Antibacterial activity was assessed using the disc diffusion method [117].

Tiwari, A. et al. (2022) synthesized ZnO nanoparticles from *Murraya paniculata* leaves. UV-Vis absorption peaked at 355 nm. XRD indicated a spherical structure with agglomeration. SEM showed spherical morphology, and TEM revealed a particle size of 32 nm. Antibacterial bioassays were conducted using the agar well diffusion method [118].

Aparna, P. et al. (2022) synthesized ZnO nanoparticles using *Citrus reticulata* for waste management. UV-Vis showed a peak at 357 nm, indicating 36 nm particle size. FTIR showed a strong peak at 651 cm^{-1} due to covalent bonding between zinc and oxygen. SEM analysis revealed predominantly spherical morphology [119].

Metwally, R. et al. (2022) synthesized ZnO nanoparticles using lemon peel. A color change from yellow to yellowish-white marked nanoparticle formation. HRTEM showed sizes ranging from 13.58 to 30.70 nm. Antifungal activity was evaluated against three *Candida* species using the agar well diffusion method. Anticancer activity was tested on MRC-5 human lung fibroblast cells using the MTT assay [120].

Sakthivel, S. et al. (2022) synthesized ZnO nanoparticles using *Citrus limon* seed water extract. UV-Vis showed an absorption peak at 380 nm. FTIR confirmed the presence of ZnO. SEM analysis showed spherical morphology. Antimicrobial activity was tested against four clinical bacterial strains [121].

Table No. 3 of Plant extract Zn-NP's

Zn	*Murraya koenigii*	leaf	spherical	23 nm	vitro antimicrobial	Elumalai, K. et al. (2016)
Zn	*Ruta graveolens*	stem	spherical	20–30 nm	Antibacterial, Antioxidant	Lingaraju, K. et al (2016)
Zn, Mg	*Murraya koenigii*	leaf	Spherical hexagonal	200 nm	Photocatalytic	Kumara, K. Ns et al. (2016)
Zn	*Murraya koenigii*	leaf	spherical, triangle, radial, hexagonal, rod, and rectangle	100 nm	Antibacterial	Sundaraselvan, G. et al. (2017)
Zn	*Aegle marmelos*	leaf	agglomerated and irregular	----	Antibacterial, drug delivery	Sriramulu, M.et al. (2018)
Zn	*Glycosmis Pentaphylla*	leaf	spherical	32 to 36 nm	Antimicrobial	Vijayakumar, S. et al. (2018)
Zn	*Atalantia monophylla*	leaf	spherical	30 nm	Antimicrobial	Vijayakumar, S. et al. (2018)
Zn, Ti	*citrus lemon*	fruit	spherical or rod	20–200 nm	Antibacterial	Hossain, A. et al (2019)
Zn	*Aegle marmelos*	leaf	quasispherical	18 ± 2 nm	Antibacterial, antifungal	Fowsiya, J. et al. (2019)
Zn	*Ruta chalepensis*	leaf	spherical	below 100 nm	Photocatalytic	Kumar, M. R. A. et al (2019)
Zn	*Ailanthus altissima*	fruit	spherical	5 to 18 nm	Antibacterial	Akl M. Awwad et al (2020)
Zn	*citrus lemon*	peel	hexagonal	100–190 nm	Antibacterial, antioxidant	Sowmya, B. et al. (2020)
Zn	*Murrraya koenigii*	leaf	spherical	19.53 nm	------	Lakshmikandhan, T. et al (2020)
Zn	*Clausena lansium*	seed	Spherical	25–30 nm	Anticancer	Li, F. et al (2020)
Zn	*Aegle marmelos*	leaf	spherical	50 nm	Anticancer	Dhayalan, M.et al. (2021)
Zn	*Citrus reticulate*	leaf	Spherical	---	Antioxidant, Antibacterial	Shah, N. I. et al (2021)
Zn	*Murraya paniculata*	leaf	spherical	32 nm	antibacterial	Tiwari, A. et al (2022)

Zn	*citrus reticulate*	peel	spherical	36 nm	-----	Aparna, P. et al. (2022)
Zn	*lemon*	peel	Rod	13.58 to	antifungal , Anticancer	Metwally, R. et al. (2022)
				30.70 nm		
Zn	*Citrus limon*	seed	spherical	52.65 ± 0.5 nm	Antibacterial	Sakthivel, S. et al (2022)

IV. Applications of green gold nanoparticles:

Pandey, S. et al. (2012) synthesized gold nanoparticles using citrus lemon for various applications. Characterization was done using UV-Vis spectroscopy, SEM, TEM, and XRD. A surface plasmon resonance (SPR) peak was observed at 418 nm. The nanoparticles synthesized from lemon pulp were predominantly spherical, as confirmed by HRTEM. XRD analysis confirmed the stability of the nanoparticles [122].

Rao, K. J. et al. (2014) carried out a green synthesis of gold nanoparticles using *Aegle marmelos* leaf extract. Characterization revealed, through TEM, that the particles had a spherical shape with an average size of 38.2 ± 10.5 nm. FT-IR analysis indicated the presence of polyphenols, which acted as reducing and stabilizing agents. Zeta potential measurements confirmed the presence of capping agents. A UV absorption peak was observed at 425 nm [123].

Jha, A. K. et al. (2015) synthesized gold nanoparticles using *Aegle marmelos* leaf extract. Reduction was facilitated by metabolites such as terpenoids, alkaloids, and coumarins. UV-visible analysis revealed surface plasmon resonance at 540 nm. TEM analysis showed nearly spherical nanoparticles with sizes ranging from 4 to 10 nm [124].

Balasubramani, G. et al. (2015) synthesized gold nanoparticles using *Chloroxylon swietenia* extract. Characterization was performed using various techniques. UV-Vis spectroscopy showed an absorption peak at 545 nm. GC-MS studies were conducted on the synthesized nanoparticles. Highresolution TEM revealed spherical morphology, with particle sizes ranging between 18 and 37 nm. The larvicidal activity of these nanoparticles was evaluated against *Anopheles stephensi* (malaria vector) and *Aedes aegypti* (dengue vector) [125].

Mahmood, H. et al. (2021) carried out green synthesis of gold nanoparticles using *Citrus limonum* extract. The nanoparticles were characterized using XRD, UV-Vis spectroscopy, FTIR, and SEM combined with EDX. A UV absorption peak at 550 nm confirmed the formation of gold nanoparticles. XRD analysis showed that the nanoparticles were crystalline in nature, with an average crystallite size of approximately 32 ± 8 nm. Antimicrobial activity was tested against human pathogens and multidrug-resistant bacteria [126].

Saha, M. et al. (2023) focused on synthesizing gold nanoparticles using leaf extracts of *Citrus limon* and *Citrus aurantifolia*. UV-Vis spectroscopy revealed absorption peaks between 500–550 nm for both plant extracts. DLS measurements indicated that the particle sizes of gold nanoforms mediated by *C. limon* and *C. aurantifolia* leaf extracts ranged from 7.123 nm to 17.54 nm. Antioxidant activity was evaluated using the DPPH assay. Antibacterial activity was assessed using the disk diffusion method [127].

Table No. 4 of Plant extract Au-NP's

Au	*citrus lemon*	fruit	circular	10-100nm	------	Pandey, S. et al. (2012)
Au	*Aegle marmelos*	leaf	spherical	38.2 ±10.5 nm	Vitamin-B	Rao, K. J. et al. (2014)
Au	*Aegle marmelos*	leaf	spherical	4–10 nm	-----	Jha, A. K. et al. (2015)
Au	*Chloroxylon swietenia*	leaf	spherical	18 - 37 nm	larvicidal	Balasubramani, G. et al. (2015)
Au	*citrus limonum*	leaf	crystallite	~ 32 ± 8 nm	Antimicrobial	Mahmood, H et al. (2021)
Au	*Citrus limon and Citrus aurantifolia*	leaf	----	7.123 nm to 17.54 nm	Antioxidant, Bacterial	Saha, M. et al. (2023)

V. Applications of Green Iron Nanoparticles :

Jassal, V. et al. (2016) biosynthesized iron nanoparticles using leaf extract of *Aegle marmelos*. The nanoparticles were characterized using FESEM, XRD, and FTIR. The results showed a spherical structure. The photocatalytic activity of the nanoparticles was also investigated [128]. Saikia, I. et al. (2017) described the silica-supported synthesis of iron oxide nanoparticles using *Zanthoxylum rhetsa*. A brown color indicated the formation of nanoparticles. SEM revealed a sheetlike morphology, while HRTEM analysis showed nanoparticle sizes ranging from 5.0–0.3 to 21.0 ± 1.4 nm. These nanoparticles were further utilized as catalysts in the *ipso*-hydroxylation of boronic acid reactions in water [129].

Amutha, S. et al. (2018) synthesized iron nanoparticles using an aqueous leaf extract of *Glycosmis mauritiana*. The synthesized Fe-NPs were characterized using UV-Vis spectrometry, DLS, XRD, FTIR, SEM, and TEM. Results revealed that the iron oxide nanoparticles exhibited an absorption peak at 404 nm, had a spherical shape, and an average particle size of under 100 nm. The antimicrobial activity was evaluated using the disk diffusion method [130].

Ramesh, A. V. et al. (2018) illustrated the synthesis of iron nanoparticles using leaf extract from *Zanthoxylum armatum*. Plant metabolites acted as reducing agents to facilitate nanoparticle formation. Characterization was performed using FESEM, TEM, XRD, and FTIR. The FTIR spectrum of the aqueous extract displayed distinct bands at 3417, 2925, 1631, 1441, 1243, 1105, and 617 cm^{-1}, indicating the presence of functional groups. XRD confirmed the crystalline nature of the nanoparticles. SEM and TEM revealed a spherical shape with a size of approximately 17 nm. The magnetization curve exhibited a sigmoidal shape without a hysteresis loop, indicating superparamagnetic behavior, with a saturation magnetization value of 128 emu/g at room temperature [131].

Shams, S. et al. (2019) studied gold and iron nanoparticles synthesized from *Citrus sinensis* fruit extract, which acted as both a stabilizing and reducing agent. Characterization was carried out using SEM, FTIR, and XRD. UV-Vis analysis showed absorption peaks at 290 nm and 520 nm. SEM revealed a spherical-like morphology. The photocatalytic activity of the nanoparticles was tested against methylene blue dye. Antioxidant activity was evaluated using free radical scavenging analysis, and antibacterial activity was assessed using the agar well diffusion method [132].

Oruç, Z. et al. (2019) studied bimetallic iron-zinc nanoparticles synthesized using *Citrus lemon* leaf extract. Various techniques were used for characterization. EDX analysis provided both qualitative and quantitative elemental composition. XRD confirmed the crystal structure and morphology. These nanoparticles were effectively used in catalyzing the decolorization of toxic azo dyes [133]. Tarangini, K. et al. (2022) synthesized iron nanoparticles using *Aegle marmelos* leaf extract, which is rich in polyphenols, particularly tannins, acting as reducing agents. UV-Vis spectroscopy showed a maximum spectral absorption at 470 nm. FESEM analysis indicated a particle size of 34 ± 7 nm.

These iron nanoparticles were further applied in the degradation of methylene blue dye [134].

Table No. 5 of Plant extract Fe -NP's

Fe	*Aegle marmelos*	leaf	spherical	< 50nm	Photocatalytic	Jassal, V. et al. (2016)
Fe	*Zanthoxylum rhetsa*	fruit	sheet like	12.2±0.8 nm	catalyst	Saikia, I. et al (2017)
Fe	*Glycosmis mauritiana*	Leaf	Spherical	below 100 nm	antimicrobial	Amutha, S. et al. (2018)
Fe	*Zanthoxylum armatum*	Leaf	Spherical	17 nm	-----	Ramesh, A. V. et al. (2018)
Fe, Au	*Citrus sinensis*	fruit	Spherical	-----	Photocatalytic, Antioxidant ,antibacterial	Shams, S. et al. (2019)
Fe Zn	*citrus lemon*	Leaf	spherical	126nm	Dye decolourisation	Oruç, Z. et al. (2019)
Fe	*Aegle Marmelos*	Leaf	spherical	34 ± 7 nm	methylene blue degradation	Tarangini, K.et al. (2022)

VI. Green synthesis of Nickel nanoparticles:

Angel Ezhilarasi, A. et al. (2018) conducted an in-depth analysis using *Aegle marmelos* plant extract for the synthesis of nickel oxide nanoparticles (NiO NPs). Several analytical methods were employed for characterization. XRD analysis confirmed that the nickel oxide nanoparticles were crystalline. NiO exhibited strong emission peaks at 363 nm and 412 nm. HRSEM analysis revealed both spherical and cubical morphologies. HRTEM analysis showed particle diameters ranging from 8 to 10 nm. Vibrating Sample Magnetometry (VSM) was used to study the magnetization behavior. The anticancer activity was evaluated using A549 cell lines. Antibacterial activity was tested against both Gram-positive and Gram-negative microorganisms. Additional studies were conducted on the photocatalytic degradation properties of the nanoparticles [135].

Lakshmi et al. (2021) synthesized nickel selenide ($NiSe_2$) nanoparticles using a green method involving *Citrus lemon* leaf extract. The final materials were comprehensively characterized using antimicrobial assays, powder XRD, electron microscopy, and EDX analysis. The antibacterial activity of the $NiSe_2$ nanoparticles was evaluated against *E. coli*, *P. aeruginosa*, *S. oralis*, *S. aureus*, and *Propionibacterium acnes* using the agar well diffusion technique [136]. Jothi, G. et al. (2022) synthesized nickel nanoparticles using fresh *Aegle marmelos* leaf extract. The $Ni(NO_3)_2$ nanoparticles were prepared via a precipitation method. FTIR spectra were used to identify functional groups involved in synthesis. UV-Vis analysis revealed an absorption peak at 383.85 nm, and SEM analysis showed spherical morphology [137].

Kumar, S. et al. (2023) synthesized $NiCo_2O_4$ nanostructures using *Citrus lemon* extract. Various analytical techniques were used to characterize the morphology, surface defects, crystalline phases, and elemental composition of the $NiCo_2O_4$ nanostructures. SEM revealed a nanorod-like structure, while TEM indicated particle sizes ranging from 20 to 80 nm. The synthesized nickel nanoparticles were further explored for application as supercapacitor materials [138].

Table No. 6 of Plant extract Ni -NP's

Ni	*Aegle Marmelos*	Leaf	Cubic and spherical	8 to 10 nm	anti-cancer, antibacterial, photocatalytic	Angel Ezhilarasi, A. et al (2018)
Ni	*citrus lemon*	leaves	agglomeration	1 nm to 100 nm	antimicrobial	Lakshmi et al (2021)
Ni	*Aegle Marmelos*	leaf	spherical	----	------	Jothi, G. et al. (2022)
Ni	*citrus lemon*	juice	Nano-rod	20-80 nm.	capacitor	Kumar, S. et al (2023)

VII. Cadmium nanoparticles: green production and their uses:

Kanude, K. et al. (2017) used *Murraya koenigii* leaf extract to synthesize cadmium nanoparticles, which were thoroughly characterized using XRD, SEM, FTIR, TEM, and UV-visible spectroscopy. The antibacterial properties of *Murraya koenigii* were tested against four different bacterial strains. SEM analysis indicated particle sizes of approximately 20 nm, while

TEM revealed a cubic morphology. An absorption peak was observed at 480 nm in the UV-visible spectrum [139]. Pandey, S. C. et al. (2020) synthesized cadmium nanoparticles using *Murraya koenigii* plant extract. The synthesized nanoparticles were characterized using photoluminescence spectroscopy, UVvisible spectroscopy, zeta potential analysis, XRD, FTIR, HR-TEM, XPS, and DLS. TEM analysis showed that the nanoparticles were circular in shape, with sizes ranging from 2 to 8 nm. The FTIR spectra displayed characteristic peaks confirming the functional groups involved. These nanoparticles were further used for water analysis applications [140].

D. Adinarayana et al. (2023) synthesized CdS nanoparticles (CdS-NPs) using leaf extract derived from *Murraya paniculata*. The synthesized CdS-NPs were characterized using XRD and FTIR. FTIR spectra were recorded in the range of 400 to 4000 cm^{-1}. The antibacterial activity of the nanoparticles was evaluated against *S. typhimurium*, *S. flexneri*, *Clostridium perfringens*, and *E. faecalis*. Anticancer activity was assessed using MCF-7 human breast cancer cells, and the nanoparticles also demonstrated antifungal properties [141].

Table No. 7 of Plant extract Cd -NP's

Cd	*Murraya Koenigii*	Leaf	cubic	20 nm	antibacterial	Kanude, K. et al (2017)
Cd	*murraya koenigii*	Leaf	spherical	2-8 nm	water analysis	Pandey, S. C. et al (2020)
Cd	*Murraya paniculata*	Leaf	-----	-----	Antibacterial , anti-cancer, antifungal	D. Adinarayana et al. (2023)

VIII. Applications for environmentally friendly titanium nanoparticles production

Farook, M. et al. (2017) explored the synthesis of titanium nanoparticles using *Citrus limon* (lemon) leaf extract, with a focus on eco-friendliness. FESEM-EDS, FTIR, and SEM were employed for characterization. The nanoparticles were evaluated for their antibacterial properties against *E. coli* and *P. aeruginosa* using the Muller Hinton agar method. The FTIR spectrum of *Citrus limon* powder revealed various peaks ranging from 527 to 3436 cm^{-1}, showing the reducing agents from the plant. SEM imaging of *Citrus limon* leaf broth at 15,000× magnification was also provided [142].

Rosi, H. et al. (2018) used *Glycosmis cochinchinensis* leaf extract to synthesize titanium nanoparticles. SEM showed a spherical morphology, while TEM revealed a size of 40 ± 5 nm. One of the UV peaks was observed at 430 nm. The crystalline structure of the nanoparticles was confirmed by X-ray diffraction. FTIR spectra of the titanium dioxide nanoparticles exhibited a broad band between 380 and 3000 cm^{-1}. Bactericidal activity was tested against *E. coli* and *P. aeruginosa*, as well as gram-positive and gram-negative microorganisms like *S. saprophyticus* and *B. subtilis* [143].

Iqbal, H. et al. (2021) synthesized titanium oxide nanoparticles using *Zanthoxylum armatum* plant extract for medicinal applications. Various analytical tools were used to characterize the nanoparticles. Anticancer activity was assessed ex vivo (in 4T1 mammary carcinoma cells) as well as in 4T1-induced breast carcinoma in BALB/c mice [144].

Nabi, G. et al. (2022) synthesized titanium nanoparticles from *Citrus limon* peel extract. The nanoparticles were characterized using XRD, EDX, TEM, SEM, and UV–Vis spectroscopy. TEM revealed a circular shape with sizes ranging from 80 to 140 nm, and an absorption peak was observed at 400 nm. Photocatalytic activity was investigated using a photocatalytic reactor with a neon mercury flash lamp [145].

Ouerghi, O. et al. (2022) assessed the green and straightforward synthesis of titanium dioxide nanoparticles from *Citrus limon*. Several analytical techniques were used to characterize the prepared samples, including XRD, infrared spectroscopy, SEM, Raman spectroscopy, and XPS.

SEM showed a round morphology. The antibacterial effectiveness of the green-synthesized TiO_2 nanoparticles was evaluated on model bacterial strains, such as *E. coli* [146].

Table No. 8 of Plant extract Ti-NP’s

Ti	*Citrus limon*	leaf	various	-----	antibacterial	Farook, M. et al (2017)
Ti	*Glycosmis cochinchinensis*	Leaf	spherical	40 ±5 nm	bactericidal	Rosi, H.et al. (2018)
Ti	*Zanthoxylum armatum*	leaf	---	----	Anticancer	Iqbal, H. et al (2021)
Ti	*lemon*	peel	spherical	80 to 140 nm	photocatalytic	Nabi, G. et al. (2022)
Ti	*citrus lemon*	fruit	spherical	---	antibacterial	Ouerghi, O. et al. (2022)

IX. Green synthesis of magnesium, calcium, selenium, and zirconium nanoparticles and its applications

Sivanesan, K. et al. (2017) synthesized manganese nanoparticles using *Aegle marmelos* fruit extract. The 355 nm peak observed in UV-Vis spectroscopy confirmed the formation of nanoparticles. FTIR peaks ranged from 400–4000 cm^{-1}. The antioxidant activity of manganese nanoparticles was assessed based on free radical scavenging activity using the DPPH assay. Antibiofilm activity was tested against microorganisms [147].

Manjula, R. et al. (2020) synthesized magnesium oxide nanoparticles from fresh extract of *Gardenia resinifera*. The nanoparticles were characterized using UV-Vis spectroscopy, PSA, FT-IR, XRD, SEM-EDAX, and HR-TEM analysis. TEM and SEM revealed a circular shape with particle sizes ranging from 17 to 35 nm. The absorption peak was observed at 362 nm. The antibacterial activity of the nanoparticles was tested using the agar well diffusion method [148].

Leizou, K. E. et al. (2022) synthesized magnesium nanoparticles from *Murraya koenigii* leaves. Characterization was carried out, and the particles were analyzed. SEM revealed a circular shape with particle sizes ranging from 10 to 100 nm. EDX confirmed the elemental composition of the material [149].

Vijaya, S. et al. (2017) synthesized carbon nanoparticles from the *Murraya* plant and characterized them using UV-Vis, SEM, TEM, EDAX, and FTIR. XRD showed the translucent nature of the nanoparticles. The morphology of the synthesized CNPs was honeycomb-like and well dispersed. EDAX confirmed the elemental composition of the carbon nanoparticles [150]. Bano, S. et al. (2020) synthesized calcium nanoparticles at different temperatures using leaf extract from *Murraya koenigii*. Characterization was done using SEM, XRD, EDX, IR, and UV-Vis spectroscopy. The absorption peak observed in UV-Vis spectroscopy ranged from 400–500 nm at different temperatures (200°C, 300°C, and 500°C). SEM showed spherical-like structures. Photoluminescence studies showed two peaks, one around 375 nm and the other at 400 nm, which may correspond to band-edge emission. XRD studies confirmed the cubic phase of CaO [151]. Ismail, M. et al. (2022) synthesized calcium oxide nanoparticles using *Murraya koenigii* plant extract. The nanoparticles were analyzed using UV-Vis, FTIR, SEM, TEM, and other techniques. UV-Vis spectroscopy showed an absorption peak at 345 nm. FTIR showed sharp peaks at 871.82 cm^{-1}, 711.73 cm^{-1}, and 1394.54 cm^{-1}. XRD confirmed the crystallinity and nanosize of the CaO nanoparticles. SEM showed an average particle size of approximately 9.9 nm. EDX revealed that the total percentage of calcium was about 24.54%. Photocatalytic activity for dye degradation was tested using methyl blue and methyl red [152].

Alvi, G. B. et al. (2021) carried out the green synthesis of selenium nanoparticles using *Citrus limon* extract. UV-Vis spectrophotometry showed maximum absorption peaks in the range of 400–600 nm. FTIR showed a range of 1000–3500 cm^{-1}. The size of the synthesized Se-NPs was measured using a Zetasizer. Antimicrobial activity of the Se-NPs synthesized from various fruit extracts was evaluated using the agar well diffusion method against bacterial microbes [153].

Rajaa H. Salih et al. (2021) synthesized zirconium nanoparticles from *Citrus limon* and lemon peel extract through a biogenic synthesis route. UV-Vis absorbance spectra of lemon peel nanoparticles and lemon juice nanoparticles showed peaks at 457 and 478 nm for peel nanoparticles, while lemon juice nanoparticles showed peaks at 217 and 270 nm. Antioxidant activity was assessed using a
DPPH assay. Anticancer activity was evaluated using MCF-7 (human breast cancer) cell lines [154].

Table No. 9 of Plant extract Mg, C, Ca, Se, Zr -NP's

Mg	*Aegle marmelos*	fruit	crystals	23.7nm	Antioxidant, Antibiofilm	Sivanesan, K. et al. (2017)
Mg	*Gardenia resinifera*	leaf	spherical	17–35 nm	antibacterial	Manjula, R. et al. (2020)
Mg	*Murraya Koenigi*	leaf	circular	10 to 100 nm	---	Leizou, K. E. et al. (2022)

C	*Murraya koenigii*	leaf	honeycomb	29.67nm	------	vijaya, S. et al. (2017)
Ca	*Murraya koenigii*	leaf	spherical	--	----	Bano, S. et al (2020)
Ca	*Murraya koenigii*	leaf	spherical	9.9 nm	photocatalytic	Ismail, M. et al. (2022)
Se	*citrus lemon, Citrus paradise*	fruit	----	------	Antimicrobial	Alvi, G. B. et al. (2021)
Zr	*citrus lemon and lemon*	peel	Agglomerated	6-35nm	Antioxidant, Anticancer	Rajaa H. Salih et al. (2021)

Conclusion:

Nanoparticles are used in several industries, including those related to food, medicine, micro-wiring, electronics, and energy harvesting, among others. Physical, synthetic, and natural processes are involved in the synthesis of nanoparticles. Green synthesis methods are emerging as more efficient and effective compared to other methods. The green synthesis technique is environmentally friendly, non-toxic, and cost-efficient. This study primarily focuses on metal oxide nanoparticles and plant-based synthetic metals, summarizing relevant information on their synthesis, characterization, and applications. These nanoparticles are used to analyse antibacterial, antiviral, antimicrobial, anti-diabetic, antioxidant, anticancer, photocatalytic properties, and metal toxicity properties. This study strongly recommends the green synthesis approach for developing nanomaterials with beneficial responses both in the environment and in the biomedical field. In the future, we aim to bridge the knowledge gap by synthesizing various green nanomaterials for use in diverse fields such as medicine, the environment, agriculture, and disease prevention.

Acknowledgements

Author wish to acknowledge Head of department, Guide and Principal of research institute for valuable support.

Funding

There is no any financial assistance provided.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations Conflict of interest

The authors declare no conflict of interest.

Consent for publication

All authors have approved the contents of this paper.

Author contributions

Sumangal Subhash Kale was involved in conceptualization, investigation, data curation, writing original draft, writing review, editing, and visualization. Ajay Nikum, Yogesh Pawar, Udaysinha Patil, Dadasao Shinde and Vijay Gurav took part in suggestion and correction of the original draft and editing. Ghanasham Sathe contributed to conceptualization, writing review, editing, supervision and guidance.

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