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Synthesis of Nanoparticles from Plant Extracts

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Abstract: The nanoparticles were common in nature due to various events occurring in the environment among them human activities were of prime importance that result production of reactive oxygen species (ROS) showing negative impact in biological systems. The progress in time evidenced development in technology that revealed the ability metals of nanoscale to perform specific functions better than the bulk form of metals. The Nobel metals like silver, gold, platinum, palladium, copper, zinc, and iron were used in synthesis of particles of nano size. These particles were used in applied forms in various fields. The extensive potential applications of these particles made the biological synthesis by using algae, actinomycetes, bacteria, fungi and plants. In the plant based synthesis several extracts (leaves, bark, stem, shoots, seeds, latex, secondary metabolites, roots, twigs, peel, fruit, seedlings, essential oils, tissue cultures, gum) were proved to generate particles. The objective of this review was to report phytosynthesis of metal nanoparticles and their fields of applications.

1. Introduction

The particles of size less than 100 nm diameter were not uncommon on the planet earth as these were found in nature due to photochemical volcanic activity, combustion and food cooking and vehicle exhausts but in 1974, Prof. Norio Taniguchi, was first to introduce the multidisciplinary discipline covering research and technology from physics, chemistry and biology commonly nanotechnology. The synthesis of nanoparticles has introduced nanotechnology during the last two decades that produced novel compounds applied in various fields. The pure metals in nanoparticle form are applied in the field of diagnostics, antimicrobial agents, drug delivery, textiles (clothing), electronics, bio-sensing, food industry, paints, cosmetics, medical devices and treatment of several acute and chronic diseases-malaria, hepatitis, cancer and AIDS (Table 1). The nanoparticles were common in nature due to various events occurring in the environment among them human activities were of prime importance that result production of reactive oxygen species (ROS) showing negative impact in biological systems. The progress in time evidenced development in technology that revealed the ability metals of nanoscale to perform specific functions better than the bulk form of metals. The Nobel metals like silver, gold, platinum, palladium, copper, zinc, and iron were used in synthesis of particles of nano size. The nanoparticle properties such as size, shape, composition, crystalline nature and structure determine their applications (Table 2). The nanoparticles (NPs) are metal atom clusters of range 1-100 nm, highly promising due to their wide range of applications in commercial products. The metal nanoparticles are synthesized by physical, chemical and biological approaches. The biological synthesis of nanoparticles involves algae, actinomycetes, bacteria, fungi and plants (Table.3).

Table 1: Different types of Metal nanoparticles and their fields of applications

Metal Nanoparticle	Applications
Aluminum, Cesium, Cobalt, Copper, Gold, Magnetite, Nickel, Palladium, Platinum, Silicon, Silver, Zinc	Industries: (Electronics, Food & feed, Space, Chemical, Textile, Fertilizers, Pesticides), Agriculture, Biomedical, Cosmetics, Diagnostics, Drug delivery, Energy science, Environment, Healthcare, Light emitters, Mechanics, Medical devices, Nonlinear optical devices, Paints & coatings, Pharmacological, Photo-electrochemical, Phytomining, Phytoremediation, Sensors & tracers, Single electron transistors, Waste water treatment

2. Plant and plant extracts

Plants are known to be an important component of different ecosystems. From the ancient times to modern days, plants serve numerous sources to mankind (Table 4). The twenty-first century witnessed vast improvement in the technology to sophisticate the lifestyle. The advent of techniques such as plant biotechnology, tissue culture and transgenesis improved the applied value of plants. The plant systems are reported as reliable green, ecofriendly approach for metal nanoparticle synthesis.

Table 2: Approaches for purification and characterization of metal nanoparticles

Purification	Centrifugation, ultracentrifugation, chromatography (Ion-Exchange, HPLC), Electrophoresis
Characterization	**Spectroscopy**: UV-visible, Inductively-coupled plasma mass spectra (ICP-MS), Fourier-transform infrared (FT-IR), Raman **Microscopy**: Scanning electron (SEM), Transmission electron (TEM), Atomic force (AFM)

Table 3: Approaches in Metal nanoparticles synthesis

Non-Biological	**Top to Bottom**	Mechanical/Ball milling, Diffusion flame, chemical etching, Thermal/ Laser ablation, Sputtering, Microwave, Ultra films, Plasma arching, Molecular beam epistaxis, Lithography
Non-Biological	**Bottom to Top**	**Chemical/electrochemical**: Precipitation, Vapor deposition, Atomic/molecular condensation, sol-gel process, Spray pyrolysis, Laser pyrolysis, Aerosol pyrolysis,
Biological	**Bottom to Top**	**Green synthesis**: **Microscopic**: Bacteria, Actinomycetes, Fungi, **Macroscopic**: Algae, Sea weeds, Plant Extracts (Leaves, Bark, Stem, Shoots, Seeds, Latex, Secondary metabolites, Roots, Twigs, peel, fruit, seedlings, essential oils, Tissue cultures, Gum)

Table 4: Phytochemicals reported from different plant sources and their benefits

Phytochemicals	Alkaloids, amino acids, flavonoids, terpenoids, organic acids, polysaccharides, saponins, tannins, vitamins, polyphenols, proteins, steroids
Benefits	Analgesic, antipyretic, antinociceptive, antioxidant, anti-proliferative, cytotoxic, melanogenesis inhibitory activity, chemo sensitizer, anti-inflammatory, vasorelaxant, blood anticoagulant, antiplatelet, neuroprotective, hypoglycemic, hypolipidemic, anxiolytic, sedative, AchE inhibitory, insulin sensitivity, antihypertensive, diuretic, wound healing, hepatoprotective, induce apoptosis, antihyperglycemic, antispasmodic, free radical scavenging, immunomodulatory, antianaphylactic, antidiarrhoeic, haemostatic, antiangiogenic, antidepressive, antidiabetic, antimicrobial (antibacterial, antiviral, antifungal), antiplasmodial, anticancer

Leaf extracts:

The leaves of plants like *Mentha*, *Ocimum*, *and Eucalyptus* were reported for the synthesis of gold nanoparticles. The particles were spherical in shape, 3-16 nm, *Ocimum* leaf provided finer particles compared with other plant leaves used [1]. The polymorphic gold nanoparticles synthesis was reported from *Citrus limon*, *Murraya koenigii* Linn. leaves, and *Canna indica* (red), *Quisqualis indica* pink flowers. The gold nanoparticles were polymorphic, stable, size 30–130 nm in non-agglomerated form [2]. *Lonicera japonica* plant leaf extract was investigated for the synthesis of silver and gold nanoparticles. The particles were different in size and shape; silver nanoparticles were 36–72 nm in size and their shape was spherical to plate-like poly-shaped, while gold nanoparticles synthesized were poly-shaped nanoplates of 40–92 nm in size. The molecules involved in the synthesis and capping of silver and gold nanoparticles were reported as carbohydrates, polyphenols, and protein [3]. *Cycas* leaf was reported for the synthesis of silver nanoparticles. The particles were spherical with 2–6 nm [4]. The gold nanotriangles were synthesized with the leaf extract of the lemon grass (*Cymbopogan flexuosus*). The cancerous and non-cancerous cells were exposed to the gold nanotriangles to test dose dependent viability in these cells. The gold nanotriangles were internalized inside the cells and compartmentalized into the cytoplasm and reported as biocompatible and promising candidates for delivery of drug, genes or growth factors inside the cells [5].

The synthesis of silver nanoparticles (AgNPs) was reported with the leaf extract of *Murraya koenigii* (Indian curry leaf tree). The AgNPs along with antibiotics were tested for antibacterial activity against three human pathogenic bacteria (*Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*). The bactericidal activity of the standard antibiotics was significantly increased in the presence of AgNPs against pathogenic bacteria [6]. The synthesis of gold nanoparticles was reported with Bael (*Aegle marmelos*) leaves and the particles were spherical in shape with a size of 4–10 nm [7]. The silver nanoparticles were synthesized by using *Paederia foetida* L. leaf extract. The synthesized nanoparticles were spherical in shape with size range of 4–15 nm. The nanoparticles were in cubical shape and showed antibacterial activity against different gram classes of bacteria [8]. The plant leaf extract of *Azadirachta indica* was used for synthesis of silver nanoparticles in different concentrations and reaction pH. The sizes of nanoparticles were in the range between 10 to 63 nm. The sizes of nanoparticles were attributed to the concentration of leaf extract and pH of the reaction [9].

The single-pot process was used for synthesis of silver nanoparticles from carob leaf extract (*Ceratonia siliqua*). The nanoparticles at different concentrations of $AgNO_3$ resulted in spherical particles with diameter of 5 to 40 nm. The AgNPs showed an effective antibacterial activity against pathogenic *Escherichia coli* [10]. The silver nanoparticles (AgNPs) synthesis with leaf extract of *Manilkara zapota* was reported. The AgNPs were with spherical, oval in shape and size of 70–140 nm, showed acaricidal activity against *Rhipicephalus* (*Boophilus*) *microplus* [11]. The leaf extracts of *Euphorbia prostrata* Ait. was used in synthesis of silver nanoparticles (NPs). These AgNPs were tested against the adult cattle tick (*Haemaphysalis bispinosa* Neumann) and the haematophagous fly (*Hippobosca maculata* Leach). The AgNPs were rod shape (25–80 nm). The toxicity tests were showed effects on *Daphnia magna* and *Ceriodaphnia dubia*, and the animal model test against *Bos indicus* was reported [12].

The silver nanoparticles were synthesized using leaf extract of *Acalypha indica*. These nanoparticles showed effective antibacterial activity against water borne pathogens (*Escherichia coli* and *Vibrio cholera*) [13]. The leaf extracts of *Magnolia kobus* and *Diopyros kaki* were used in the synthesis of gold nanoparticles. The mixture of plate (triangles, pentagons, and hexagons) and spherical structures (size, 5–300 nm) were found at lower temperatures and smaller spherical shapes were obtained at higher temperatures [14]. Neem (*Azadirachta indica*) leaf broth was used for the synthesis of silver and gold nanoparticles and bimetallic Au/Ag nanoparticles. The leaf extract showed rapid formation of stable silver and gold nanoparticles at high concentrations that exhibiting flat, plate like morphology [15].

The synthesis of Ag nanoparticles (AgNPs) using *Lippia citriodora* leaves aqueous extract showed spherical crystalline AgNPs (size of 15–30 nm). The particles formation was proportional to the effect of reducing agent concentration [16]. The aqueous extract of *Ocimum sanctum* leaf is used for the synthesis of gold and silver nanoparticles. The silver nanoparticles size was 10–20 nm [17]. *Murraya Koenigii* leaf extract was used to produce silver and gold nanoparticles. The silver nanoparticles were of size 10 nm, spherical and gold nanoparticles were of size 20 nm [18]. The aqueous $AgNO_3$ and *Mangifera indica* leaf extract reported to produce triangular, hexagonal and nearly spherical nanoparticles with size of 20 nm [19]. The leaf extract of *Hibiscus rosa sinensis* was used in synthesis of gold and silver nanoparticles of various shapes. The size and shape of Au nanoparticles varied with the ratio of metal salt and extract in the reaction medium. The Au nanoparticles were bound to amine groups and the Ag nanoparticles to carboxylate ion groups [20].

The silver and gold nanoparticles from aqueous leaf extract of *Chenopodium album* were reported [21]. The synthesis of gold nanoparticles with the leaf extract of *Coleus amboinicus* Lour was reported. The leaf extract resulted in the synthesis of spherical, truncated triangle, triangle, hexagonal and decahedral nanoparticles, size of gold nanoparticles ranged from 4.6 to 55.1 nm [22, 23]. The synthesis of silver nanoparticles with leaf extract of *Hibiscus cannabinus*. The ascorbic acid present in leaf extract was used as reducing agent. The nanoparticle showed antimicrobial activity against *Escherichia coli*, *Proteus mirabilis* and *Shigella flexneri* [24]. The aqueous extract of fresh leaves of *Prosopis juliflora* was used in the synthesis of silver (Ag) nanoparticles. The nanoparticles were antimicrobial along with sewage [25]. Five plant leaf extracts (*Malva parviflora, Beta vulgaris subsp. Vulgaris, Anethum graveolens, Allium kurrat and Capsicum frutescens*) were screened for synthesis of silver nanoparticles. The Ag nanoparticles by *M. parviflora* produced were 19–25 nm in diameter [26]. The synthesis of silver nanoparticles (AgNPs) with aqueous extract of Lakshmi tulasi (*Ocimum sanctum*) leaf was a reducing and stabilizing agent. The particles were crystalline and triangle in shape with size of 42 nm [27]. The synthesis of silver nanoparticles (AgNPs) using *Annona squamosa* leaf extract and its cytotoxicity against MCF-7 cells was reported. The AgNPs were spherical in shape with 20 to 100 nm [28]. The efficacy of silver nanoparticles (AgNPs) biosynthesis from leaf extract of *Vitex negundo* L. as an antitumor agent using human colon cancer cell line HCT15 was reported [29]. The synthesis of antimicrobial silver nanoparticles (AgNPs) using leaf extract of *Mukia scabrella* was reported. The biosynthesized AgNPs exhibited significant antimicrobial activity against nosocomial pathogens-*Acinetobacter* sp., *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* [30].

Syzygium cumini leaf extract (LE) and seed extract (SE) were used in the synthesis of silver nanoparticles. The size of SNP was found to be directly correlated with the amount of polyphenols as well as surfactants [31]. The copper nanoparticles were biologically synthesized by using *Magnolia kobus* leaf extract as reducing agent and their antibacterial activity was evaluated against *Escherichia coli* [32]. The synthesis of silver nanoparticles with *Ocimum tenuiflorum* leaf extract was reported. The nanoparticles were found to exhibit high antibacterial activity against *Escherichia coli*, *Cornyebacterium*, *Bacillus subtilis* [33]. The synthesis of silver nanoparticles (AgNPs) from room dried leaves of *Vinca rosea*. The nanoparticles obtained from leaf extracts were of size 27-30 nm [34].

Essential oils:

The synthesis of gold nanoparticles with essential oils extracted from the fresh leaves of *Anacardium occidentale* was reported. The NPs synthesized at room temperature were hexagonal in shape while at higher temperature were mixture of anisotropic particles [35].

Peel extracts, Gum extracts:

The biosynthesis of silver nanoparticles (AgNPs) from *Citrus sinensis* peel extract was reported. The synthesized AgNPs were effective antibacterial agent against *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* [36]. The aqueous extracts from the peels of Citrus fruits (orange, grapefruit, tangelo, lemon and lime) were used for the synthesis of AgNPs using microwave technology; the synthesis was successful for the orange peel extract [37].

The silver nanoparticles were synthesized by using gum acacia, the antimicrobial activity of silver nanoparticles against *E. coli* and *M. luteus* was found to possess inhibiting properties [38]. The silver nanoparticles with the aqueous extract of gum olibanum (*Boswellia serrata*) were reported. The shape was spherical for nanoparticles, with size of 7.5 ± 3.8 nm, the produced silver nanoparticles exhibited substantial antibacterial activity on both the Gram classes of bacteria [39]. The synthesis of Ag, Au and Pt nanoparticles was reported by using gum kondagogu (*Cochlospermum gossypium*). The synthesized silver nanoparticles had significant antibacterial action on both the Gram classes of bacteria [40, 41].

Seed extracts:

The synthesis of silver nanoparticles through seeds of the plant *Elaeocarpus granitrus* Roxb. (Rudraksha) was reported. The nanoparticles were involved for development of bionanocomposite with chitosan matrix and antimicrobial assay was done [42]. The synthesis of silver nanoparticles was reported using aqueous seed extract of *Jatropha curcas*. The stable silver nanoparticles at different concentration of $AgNO_3$ were spherical in shape with diameter ranging from 15 to 50 nm [43]. The synthesis of silver nanoparticles with aqueous seed extract of *Macrotyloma uniflorum* was reported, the nanoparticles were with anisotropic morphology, with size 12 nm [44]. The gold nanoparticles with aqueous extract of fenugreek (*Trigonella foenum-graecum*) were reported. The particles were reducing, protecting agents and size from 15 to 25 nm [45]. The synthesis of silver nanoparticles (AgNPs) from *Artocarpus heterophyllus* Lam. seed powder extract (ASPE) as a reducing agent was reported. The AgNPs obtained showed highly potent antibacterial activity toward Gram-positive (*Bacillus cereus*, *B. subtilis* and *Staphyloccocus aureus*) and Gram-negative (*Pseudomonas aeruginosa*) microorganisms [46]. The synthesis of gold nanoparticles (Au NPs) with seed aqueous extract of *Abelmoschus esculentus* and its antifungal activity against *Puccinia graminis tritci*, *Aspergillus flavus*, *Aspergillus niger* and *Candida albicans* [47].

Secondary metabolites:

The plant broth of *Phyllanthus amarus* containing secondary metabolites was used for the formation of silver nanoparticles (AgNPs) [48]. The coconut water was used for synthesis of gold nanoparticles through microwave irradiation. The nanoparticles were tested for cytotoxicity on two human cancer cell lines, HeLa (human cervical cancer) and MCF-7 (human breast cancer). The nanoparticles found to be nontoxic [49]. The silver nanoparticles were synthesized with mesocarp layer extract of *Cocos nucifera* and extracts of *Annona squamosa* and compared for anti-larvicidal activity for mosquitoes. These nanoparticles were reported as effective anti-larvicidal agents against *Anopheles stephensi* and *C. quinquefasciatus* [50].

Table 5: Metal nanoparticles synthesized with different plants and their significance

Plant part	Plant	Metal	Significance	Reference
Leaves	*Mentha, Ocimum, Eucalyptus*	Gold	Metabolites	[1]
Leaves Flowers	*Citrus limon, Murraya koenigii Canna indica, Quisqualis indica*	Gold	Phytochemicals	[2]
Leaf extract	*Lonicera japonica*	Silver, Gold	Carbohydrate, polyphenols, protein	[3]
Leaf	*Cycas*	Silver	polyphenols, glutathiones, metallothioneins, ascorbates	[4]
Leaf extract	*Cymbopogan flexuosus*	Gold	cytotoxicity and cellular internalization studies	[5]
Leaf extract	*Murraya Koenigii*	Gold	Biomolecules	[6]
Leaves	*Aegle marmelos*	Gold		[7]
Leaf extract	*Paederia foetida L.*	Silver	Antibacterial activity	[8]
Leaf	*Azadirachta indica*	Silver, Gold	Reduction rate was faster than fungi	[9]
Leaf extract	*Ceratonia siliqua*	Silver	Antibacterial activity	[10]
Leaf extract	*Manilkara zapota*	Silver	Acaricidal activity	[11]
Leaf extract	*Euphorbia prostrata* Ait.	Silver	Antiparasitic activity	[12]
Leaf extract	*Acalypha indica*	Silver	Antibacterial activity	[13]
Leaf extract	*Magnolia Kobus, Diopyros kaki,*	Gold	Effect of temperature, leaf broth concentrations	[14]
Leaf extract	*Azadirachta indica*	Silver	Characterization with various techniques	[15]
Leaf extract	*Lippia citriodora*	Silver	Isoverbascoside compound	[16]
Leaf extract	*Ocimum sanctum*	Silver, Gold	Biomolecules	[17, 27, 74]
Leaf extract	*Murraya koenigii*	Silver	Bactericidal activity	[18]
Leaf extract	*Mangifera Indica*	Silver	Green method provides faster synthesis	[19]
Leaf extract	*Hibiscus rosa sinensis*	Silver, Gold	pH, concentration of salt	[20]
Leaf extract	*Chenopodium album*	Silver, Gold	Leaf extract quantities, metal concentrations, contact time, reaction temperature and pH	[21]
Leaf extract	*Coleus amboinicus*	Silver, Gold	aromatic amines, amide (II) groups, secondary alcohols	[22, 23]
Leaf extract	*Hibiscus cannabinus*	Silver	antimicrobial activity	[24]
Leaf extract	*Prosopis juliflora*	Silver	antimicrobial activity	[25]
Leaf extract	*Malva parviflora, Beta vulgaris, Anethum graveolens, Allium kurrat, Capsicum frutescens*	Silver	Proteins	[26]
Leaf extract	*Annona squamosa*	Silver	cytotoxicity against human breast cancer cell	[28]

Leaf extract	*Vitex negundo*	Silver	Anti-proliferative effects	[29]
Leaf extract	*Mukia scabrella*	Silver	antimicrobial activity against MDR-GNB nosocomial pathogens	[30]
Leaf extract	*Syzygium cumini*	Silver	polyphenols	[31]
Leaf extract	*Magnolia kobus*	Copper	antibacterial activity	[32]
Leaf extract	*Ocimum tenuiflorum*	Silver	antibacterial activity	[33]
Leaf extract	*Vinca rosea*	Silver	antimicrobial activity	[34]
Essential oils	*Anacardium occidentale*	Gold	quantity of oil	[35]
Peel extract	*Citrus sinensis*	Silver	antibacterial activity	[36]
Peel extract	Citrus fruits (orange, grape fruit, tangelo, lemon, lime)	Silver	one-step microwave assisted synthesis	[37]
Gum	*Acacia*	Silver	antimicrobial activity	[38]
Gum	*Boswellia serrata*	Silver	antibacterial activity	[39]
Gum	*Cochlospermum gossypium*	Silver, Gold, Platinum	antibacterial activity	[40,41]
Seed	*Elaeocarpus granitrus*	Silver	antimicrobial activity	[42]
Seed	*Jatropha curcas*	Silver		[43]
Seed	*Macrotyloma uniflorum*	Silver		[44]
Seed	*Trigonella foenum-graecum*	Gold		[45]
Seed	*Artocarpus heterophyllus*	Silver	antibacterial activity	[46]
Seed	*Abelmoschus esculentus*	Gold	Antifungal activity	[47]
Secondary metabolites	*Phyllanthus amarus*	Silver		[48]
coconut water	*Cocos nucifera*	Gold	Cytotoxicity on two human cancer cell lines	[49]
Coir	*Cocos nucifera*	Silver	larvicidal: *Anopheles stephensi* and *C. quinquefasciatus*	[50]
Stem extract	*Breynia rhamnoides*	Gold, silver	Phenolic glycosides, reducing sugars	[51]
Fruit	*Tribulus terrestris*	Silver	Antibacterial activity	[52]
Latex	*Jatropha curcas*	Silver		[53]
Latex	*Euphorbia milii*	Silver		[54]
Tissue culture-derived callus and leaf	*Sesuvium portulacastrum*	Silver	Antimicrobial activity	[55]
Dried stem, root	*Ocimum sanctum*	Silver		[56]
Rose petals	*Rosa hybrida*	Gold		[57]
Bark extract	*Cinnamon zeylanicum*	Silver	Antimicrobial activity	[58]
Living plant	*Arachis hypogaea*	Gold		[59]
Polyphenols	*Angelica, Hypericum, Hamamelis*	Gold	biological and medical applications	[60]
Areca Extract	*Areca catechu*	Silver	cytotoxicity against tumor cells	[61]
Plant extract	*Mentha piperita*	Silver, Gold	Antibacterial activity	[62]
Plant extract	*Artemisia nilagirica*	Silver	Antimicrobial activity	[63]
Plant extract	*Eclipta prostrata*	Silver	Larvicidal: *Culex quinquefasciatus Anopheles subpictus*	[64]
Plant extract	*Iresine herbstii*	Silver	antibacterial, antioxidant, cytotoxic	[65]
Stem extract	*Cissus quadrangularis*	Silver	adult hematophagous fly, cattle tick larvae	[66]
Plant extract	*Terminalia chebula*	Gold	Antimicrobial activity	[67, 68]
Bulb extract	*Allium sativum*	Silver	antibacterial activity	[69]
Rhizome extract	*Zingiber officinale*	Gold	applications in drug delivery, gene delivery, biosensors	[70]

Bark extract	*Alstonia scholaris*	Silver	Antimicrobial activity	[71]
Leaves Peel	*Ocimum tenuiflorum, Solanum tricobatum, Syzygium cumini, Centella asiatica, Citrus sinensis*	Silver	Antimicrobial activity	[72]
Leaves	*Stevia rebaudiana*	Gold	leaves in powder form	[73]
Petal extract	*Crocus sativus*	Silver	Antimicrobial activity	[75]
Leaf extract	*Pterocarpus santalinus*	Silver	antibacterial activity	[76]
Roots, shoots	*Sinapis alba, Lepidium sativum*	Platinum	Phytoremediation	[77]
Leaf extract	*Musa balbisiana* (banana), *Azadirachta indica* (neem), *Ocimum tenuiflorum* (black tulsi)	Silver	antibacterial activity and toxicity	[78]
Fruit hull	*Quercus infectoria*	Silver	Cytotoxicity effects-human breast cancer cells	[79]
Flower	*Tagetes erecta*	Silver	Antimicrobial activity	[80]
Leaf extract	*Butea monosperma*	Silver	anti-algal properties	[81]
hypericin-rich shoot culture	*Hypericum hookerianum*	Silver	antibacterial activity	[82]
Leaf extract	*Viburnum lantana*	Silver	Antimicrobial activity	[83]
Flower extract	*Aloe vera*	Copper		[84]
Polyphenols	*Psidium guajava*	Silver	Cytotoxicity, Antimicrobial	[85]

Stem extracts, Fruit extracts:

The stem extract of *Breynia rhamnoides* was used for synthesis of gold and silver nanoparticles was reported [51].

Tribulus terrestris L. fruit bodies were used for synthesis of silver nanoparticles. The nanoparticles were spherical shaped with 16-28 nm of size. The nanoparticles showed antibacterial property against multi-drug resistant bacteria such as *Streptococcus pyogens*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Bacillus subtilis* and *Staphylococcus aureus* [52].

Latex extracts, Tissue culture extracts:

The latex of *Jatropha curcas* was used in silver nanoparticles synthesis. The particles radius was 10–20 nm and stabilized by the cyclic peptides [53]. The latex of *Euphorbia milii* was used in silver nanoparticles synthesis. The silver nanoparticles sizes were of 10–50 nm [54].

The extracts from tissue culture-derived callus and leaf of the salt marsh plant (*Sesuvium portulacastrum* L.) used in the synthesis of silver nanoparticles. The callus extract was able to produce antimicrobial silver nanoparticles than leaf extract. The silver nanoparticles synthesized were spherical in shape with size 5 to 20 nm. The silver nanoparticles inhibited clinical test strains of bacteria and fungi. The antibacterial activity was distinct than antifungal activity [55].

Dried stem and root extracts, Petal extracts, Bark extracts, Seedling extracts:

The stem and root of *Ocimum sanctum* was used in synthesis of silver nanoparticles (AgNPs). The silver nanoparticles obtained from roots and stem were of sizes 10 ± 2 and 5 ± 1.5 nm, respectively [56].

The synthesis of gold nanoparticles with petals of rose (*Rosa hybrida*) resulted in cubic structure of particles with 10 nm in size [57].

The bark extract and powder of *Cinnamon zeylanicum* was used in synthesis of silver (Ag) nanoparticles and the particles showed antimicrobial activity [58].

The synthesis of gold nanoparticles (GNPs) with peanut *Arachis hypogaea* L. seedlings was reported. The intercellular nanoparticles were of oval shape and size ranged from 5 to 50 nm [59].

Plant extracts:

The synthesis of gold nanoparticles (GNPs) by reducing chloroauric acid ($HAuCl_4$) with plant extracts (*Angelica*, *Hypericum*, and *Hamamelis*) was reported. The GNPs obtained showed biological and medical applications [60]. The synthesis of silver nanoparticles (AgNPs) with aqueous extract of *Areca catechu* and its impact on a mice model was reported. The AgNPs showed higher level of cytotoxicity in Dalton's ascites lymphoma (DAL) tumor cells [61]. The synthesis of silver and gold nanoparticles with the plant extract from *Mentha piperita* was reported. The particles showed that the leaf extract of menthol was bioreductant for the synthesis of silver and gold nanoparticles. The nanoparticles were active against human pathogenic isolates-*Staphylococcus aureus* and *Escherichia coli* [62].

The synthesis of silver nanoparticles (AgNPs) from *Artemisia nilagirica* (Asteraceae) was reported. The AgNPs showed microbial susceptibility and was different for each microorganism [63]. The silver nanoparticles (AgNPs) with aqueous extract from *Eclipta prostrata* was investigated against fourth instar larvae of filariasis vector (*Culex quinquefasciatus* say) and malaria vector (*Anopheles subpictus* Grassi). The particles showed mosquito larvicidal activity against vectors [64]. The silver nanoparticles with *Iresine herbstii* were reported for antibacterial, antioxidant and cytotoxic activities [65]. The aqueous extract of stem from *Cissus quandrangularis* was reported for the synthesis of silver nanoparticles. The anti-parasitic activities against the adult-*Hippobosca maculate* (hematophagous fly) and larva-*Rhipicephalus microphilus* (cattle tick) were reported [66]. The synthesis of gold nanoparticles with aqueous extracts of *Terminalia chebula* as reducing and stabilizing agent was reported. The morphology of the particles contains anisotropic, with size 6 to 60 nm. The hydrolysable tannins present in the extract of *T. chebula* were responsible for reduction and stabilization of nanoparticles. The gold nanoparticles showed antimicrobial activity against *S. aureus* compared to *E. coli* [67, 68]. The silver nanoparticles with aqueous garlic (*Allium sativum*) extract were reported. The synthesized silver nanoparticles exhibited antibacterial potential against both tested gram positive and gram negative bacteria [69]. The synthesis of gold nanoparticles with *Zingiber officinale* extracts which acts both as reducing and stabilizing agent was reported. The particles were highly stable at physiological condition compared to citrate capped nanoparticles [70].

3. Conclusions

There are physical/chemical methods to synthesize metal nanoparticles. These methods have limitations of applied value that pose hazards to ecosystem. The objective of review was to report on phytosynthesis of metal nanoparticle by using different plant extracts and their significance in different fields (Table 5). In the plant based synthesis several extracts (leaves, bark, stem, shoots, seeds, latex, secondary metabolites, roots, twigs, peel, fruit, seedlings, essential oils, tissue cultures, gum) were proved to generate particles. These metal nanoparticles were applied for disease diagnosis to treatment and antimicrobial to anti-cancer activities. Therefore it is concluded that plants and their extractives are important in synthesis of nanoparticles as ecofriendly approach.

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