Introduction

Incorporation of green chemistry techniques and methodologies into nanotechnology is of great interest which has gained much attention over the past decade [1]. Furthermore, NPs are widely applied to human contact areas and there is a growing need to develop processes for synthesis that do not use harsh toxic chemicals [2]. The nanoparticles synthesized from chemical and physical methods generally require high temperature, pressure, expensive equipment, toxic chemicals, and reagents and most importantly capping agents for the stabilization of nanoparticles; thus, these methods are toxic to environment and nonecofriendly [3]. With their antioxidant or reducing properties they are usually responsible for the reduction of metal compounds into their respective nanoparticles [4]. The conventional methods for the production of NPs are expensive, toxic, and non-environment friendly. To overcome these problems, researchers have found the precise green routes like the naturally occurring sources and their products that can be used for the synthesis of NPs [5].

Therefore, green/biological synthesis of NPs is a possible alternative to chemical and physical methods [6]. Biological methods of synthesis have thus paved way for the “greener synthesis” of nanoparticles and these have proven to be better methods due to slower kinetics [7]. Recently, green methods using plant extracts have been developed as an alternative for common chemical and physical methods to synthesize noble metal NPs. Due to the presence of reducing agents like alkaloids, polyphenols, and flavonoids which are major phytocomponents of the plant extracts, and stabilizing agents such as polysaccharides and proteins, stable metal NPs can be easily synthesized using the plant extracts. Green synthesis provides advancement over chemical and physical method as it is cost effective, environment friendly, easily scaled up for large
scale synthesis [8]. Green synthesis of nanoparticles has attracted considerable attention in recent years. Several metal nanoparticles such as Cobalt (Co), Copper (Cu), Zinc (Zn), Iron (Fe), Silver (Ag), Lead (Pb), Manganese (Mn), Magnesium (Mg), Palladium (Pd), Gold (Au) are used in green synthesis. Among the several noble metal nanoparticles, AgNPs have attracted special attention due to their unique properties including appropriate electrical conductivity, chemical stability, catalytic and antimicrobial activities. Because of high surface to volume ratio, silver in nanoscale has demonstrated completely different properties from bulk particles made from the same material.

Therefore, synthesis of AgNPs is an emerging area and interesting subject. In green synthesis, a solvent (usually water) is chosen and employed in step one. A non-toxic reducing and stabilizer agents are utilized in steps two and three, respectively. In this method, solvents, reducing, and stabilizers agents are selected from natural non-toxic and eco-friendly substances without any adverse effects on the environment. Figure shows the main steps in the green synthesis of metal nanoparticles.

Steps involved in the biosynthesis of nanoparticles [4]:

(Figure 1)

Methodology
1. About 180 articles were collected from various databases including Google Scholars, ScienceDirect, Sci-Hub, PubMed, ResearchGate and studied.
2. From 180 articles, 100 articles were collected for green synthesis of antimicrobial study.
3. Finally, 20 plants were reviewed comprehensively.

Result and Discussion
(Tables 1 & 2)

Many research papers reported the synthesis of silver nanoparticles using plant extracts such as Croton sparsiflorus (Ban tulasi) [1]; Chlorophytum borivilianum (Musli) [5]; Musa paradisiaca (Banana) [6]; Aloe vera [7]; Enteromorpha flexuosa (Green alga) [8]; salvinia molesta (Giant salvinia or exotic weed) [9]; Cissus quadrangularis (Veldt grape) [10]; Ficus benghalensis (Banyan) [11]; Azadirachta indica (Neem) [11]; Cocos nucifera (Coconut) [12]; Pithophora oedogonia (Green alga) [13]; Aegle marmelos (Bael) [14]; Dalbergia spinosa [15]; Lythrum salicaria (Purple loosestrife) [16]; Euphorbia confinalis (Spurge) [17]; Withania somnifera (Ashwagandha) [18]; Justicia adhatoda L. (Vasaka) [19]; Chrysanthemum indicum (Chandramallika) [20]; Taraxacum officinale (Dandelion) [21]; Phoenix dactylifera (Date palm) [22].
| Plants name & Family                  | Parts used/Extract | Microorganisms                                           | Phytochemical compounds                                                                 | Metal used | Size(nm) and shape          | Ref. |
|--------------------------------------|--------------------|----------------------------------------------------------|-----------------------------------------------------------------------------------------|------------|-----------------------------|------|
| Croton sparsiflorus (Ban tulasi); Euphorbiaceae | Root               | Staphylococcus aureus (19.62 mm), Klebsiella pneumonia (10.14 mm), Pseudomonas aeruginosa (9.12 mm) | glycosides, saponins, tannins, flavonoids, terpenoids, alkaloids, croatparine, phenolics, N-methyl-croarie, and N, O-dimethyl croatparine | Ag         | 36.51±4.249nm; spherical     | 1    |
| Chlorophyllum borivilianum (Musil); Asparagusaceae | Root               | Pseudomonas aeruginosa (15mm), Proteus mirabilis (15mm), Coagulase-positive Staphylococcus (13mm), Enterococcus faecalis (13mm) | saponins, flavones, terpenoids, glycoside                                               | Ag         | 30-50nm; spherical           | 5    |
| Musa paradisica (Banan); Musaceae     | Peel               | B. Subtilis (12mm), Sauerus (16mm), Pseudomonas aeruginosa (20mm), Escherichia coli (17mm)                | lignin, hemicellulose, cellulose and pectins                                              | Ag         | 23.7nm; spherical & crystalline | 6    |
| Aloe vera; Asphodelaceae              | Leaf               | Staphylococcus aureus (0.014 mm), Escherichia coli (0.007mm)                                           | Lignin, flavonoids, hemicellulose, pectin, polyphenols, citric acid, ascorbic acid, and acetic acid | Ag         | 23nm; Spherical              | 7    |
| Enteromorpha flexuosa (Green alga); Ulvaceae | Seaweed            | B. Subtilis (18±0.8mm), B. pulmislis(19±1.2mm), E. Faecalis(12±0.9mm), S. aureus(14±0.7mm), S. Epidemidiis(20±1.5mm), E. coli(13±0.9mm), K. Pneumoniae(10±0.4mm), C. Albicans(14±0.8mm), S. cerevisiae(16±0.6mm) | carbohydrates, alkaloids, steroids, phenols, saponins and flavonoids                      | Ag         | 2–32mm; Circular             | 8    |
| salvinia molest (Gi ant salvia or exotic weed); Salviniae | Leaf               | Escherichia coli (21mm) and Staphylococcus aureus(16mm)                                               | phenol derivatives, proteins, reducing sugars, flavonoids, and enzymes                    | Ag         | 12.46nm; Spherical           | 9    |
| Cissus quadrangularis (Veldt grape); Vitaceae | Stem               | Klebsiella planticolo (13mm), Bacillus subtilis (11mm)                                                | alcohols, carboxylic acids, phenols, amines and amides                                    | Ag         | 37–44nm; rod, spherical & triangle | 10   |
| Ficus benghalensis (Banyan); Moraceae | Bark               | E. coli (13mm), P. aeruginosa (14mm) and V. Cholera (14.1mm) and B. subtilis (1.8mm)                     | leucopelargonidin-3-0-α-L rhamnoside, beta glucoside, leucocyninin-3-0-α-D galactosyl celllobiose, glucoside, pentatrichoptar-5-one and beta sitosteryl-α-D-glucose | Ag         | 40nm                        | 11   |
| Axadirachta indica (Neem); Meliaceae  | Bark               | E. coli (13mm), P. aeruginosa (14mm) and V. Cholera (14.1mm) and B. subtilis (1.8mm)                     | Nimbin, Nimbinin, Deacetyl nimbin, Nimbinen, 6-Deacetyl nimbinen, Nimbandiol, polysaccharides G1A, G1B, G2A, and G3A, NB-2 peptidogulcan | Ag         | 50nm                        | 11   |
| Cocos nucifera (Coconut); Arecaceae   | Leaf               | Klebsiella pneumonia (24mm), Plesiomonas shigellloides (21 mm), Vibrio algolyticus (19 mm) and Salmonella porotyphi (16 mm), P. aeruginosa (14 mm), Vibrio harveyi (14 mm), Bacillus subtilis (14 mm), E. coli (12 mm) | Tannin, alkaloids, carbohydrates, terpenoids, saponins, phenolic compounds and reducing sugar | Ag         | 22mm; Spherical              | 12   |
| Pithophora oedogonia (Mont.) Wittrock (Green alga); Pithophoraceae | Green algae       | E. coli, Pseudomonas aeruginosa (17.2 mm), E. coli (16.8 mm), Vibrio cholera, Shigella flexneri, Bacillus subtilis, Staphylococcus aureus, and Micrococcus luteus | Carbohydrates, steroids, saponins, tannins, and protein                                  | Ag         | 34.03nm; cubic & hexagonal    | 13   |
| Aegle marmelos (Bael); Rutaceae       | Leaf & fruit       | B. Cereus (19.25 ± 0.19mm), P. aeruginosa (16.50 ± 0.30mm), S. dysenteriae (15.90 ± 0.35mm), E. Coli (15.15 ± 0.62mm), S. Typhi (14.50 ± 0.70mm), Y. Pestis (14.65 ± 0.38mm), S. Aureus (15.22 ± 0.52mm) | carbohydrates, steroids, soluble starch, tannins, terpenoids, flavonoids, saponin, and alkaloid | Ag         | 159.76 nm to 181.36 nm; Crystaline & spherical | 14   |

Table 1: Green synthesis of silver nanoparticles using plants extracts.
| Plants name                        | Microorganisms                             | Antimicrobial potential                      | Ref. |
|-----------------------------------|--------------------------------------------|----------------------------------------------|------|
| Dalbergia spinosa; Fabaceae       | Leaf | *Bacillus subtilis* (23mm), *Pseudomonas aeruginosa* (19mm), *Staphylococcus aureus* (21mm) and *E. coli* (28mm) | flavonoids, isoflavonoids, neoflavonoids, steroids, terpenoids | Ag 18±4nm; spherical | 15 |
| Lythrum salicaria (Purple loosestrife); Lythraceae | Aerial | *S. aureus* (17.62 ± 0.205mm) and *E. coli* (14.54 ± 0.234mm) | phenolics, terpenoids, flavones, and polysaccharides | Ag 45±0.65nm; spherical | 16 |
| Euphorbia confinalis (Spurge); Euphorbiaceae | Stems | *E. coli* (11 mm) and *S. aureus* (13 mm) | oils, keto steroids, glycosides, coumestrol, indirubin, isatin, phenolic compounds, flavonoids, and terpenoids | Ag 12nm-18nm; spherical | 17 |
| Withania somnifera (Ashwagandha); Solanaceae | Leaves, fruits, and roots | *P. vulgaris, E. coli*, and *A. tumefaciens*, *Candida albicans*, *Proteus vulgaris* | Withanolide, Catechin, p-coumaric acid, Luteolin-7-glucoside | Ag 70 & 110nm; spherical | 18 |
| Justicia adhatoda (Vasaka); Acanthaceae | Leaf | *Pseudomonas aeruginosa* (7-9 mm) | vasicine, vasicinone, vasicinol, vasicinone, essential oil, maionitone, deoxyvasicinone, vasicol, glucoside sitosterol, kaempferol alkaloids | Ag 20 mm; spherical | 19 |
| Chrysanthemum indicum (Chandramalli); Sapotaceae | Flower | *Staphylococcus aureus* (8.33±0.57mm), *E. coli* (13.00±0.90mm), *Klebsiella pneumonia* (19.10±0.50mm), *Pseudomonas aeruginosa* (99.60±0.51mm) | Tannins, flavonoids, proteins, glycosides reducing sugars | Ag 37.7±71.99nm; spherical and hexagonal | 20 |
| Taraxacum officinale (Dandelion); Asteraceae | Flower | *Enterococcus faecalis* (10-0.50mm), *Pseudomonas aeruginosa* (11-0.76mm) | Flavonoids, phenols, proteins, terpenoids, alkaloids | Ag 545nm±5nm; crystalline and spherical | 21 |
| Phoenix dactylifera (Date palm); Arecales | Seed | 24mm) at highest concentrations (500μg/ml), (11 mm) at lowest concentrations (7.8μg/ml) against Methicillin-resistant *S. aureus* | phenolics, flavonoids, polyphenols, aldehydes, carboxylic acids, saponin, anthraquinone, terpenoids, proteins | Ag 14–30mm; spherical | 22 |

Table 2: Comparative study between plant extracts & nanoparticles using plant extracts.
The nanoparticles were engineered via reduction of silver nitrate (AgNO₃) solution with aqueous root extract of C. borivilianum at 50 °C. The root extract of Chlorophytm borivilianum as capping agent with an average diameter of 30-50nm. The formation of NPs is analyzed by UV-Vis spectroscopy, distinctive phases and morphology are confirmed by using XRD, SEM, TEM, and FTIR is used to identify the biomolecules which are responsible for reduction and stabilization of NPs. These biologically synthesized AgNPs were found to highly toxic against some clinically pathogenic bacteria such as coagulase positive Staphylococcus sp., Enterococcus faecalis, Pseudomonas species, and Proteus mirabilis with reference to commercially available antibiotics [5]. The biosynthesized silver nanoparticles using banana peel extract were characterized by UV-Vis spectrophotometer, XRD, DLS, TEM, and FTIR; they are crystalline, uniform, spherical and monodispersed nanoparticles with average particle size of 23.7 nm. Synthesized silver nanoparticles revealed good antimicrobial activity against B. subtilis, S. aureus, and E. coli [6]. The phytochemical compounds like Lignin, hemicellulose, pectin, flavonoids, polyphenols, ascorbic acid, citric acid, and acetic acid of Aloe vera (family: Asphodelaceae) as reducing agent showed 23nm size nps with spherical shape [7].

Circular shape of AgNPs within the range of 2-32nm were produced by using the seaweed extract of Enteromorpha flexuosa plant and showed more antibacterial activity than plant extract against B. subtilis, B. pumulis, E. faecalis, S. aureus, S. epidermidis, E. coli, K. pneumoniae, C. albicans, S. cerevisiae. The reduced silver nanoparticles were characterized by UV–vis spectrophotometer, EDS, XRD and TEM [8], FESEM, EDX, HRTEM, AFM and XRD analysis showed that most of AgNPs of salvinia molesta extracts were spherical in shape with average size distribution of 12.46 nm having face centered cubic (fcc) crystal lattice. Antibacterial studies reviled the better efficacy of AgNPs against Gram negative bacteria as compared to Gram positive bacteria [9]. Cissus quadrangularis stem extracts showed mostly spherical and some rod and triangle shapes with sizes ranging from 37 to 44 nm, which were characterized by SEM. FTIR shows that the functional groups are carboxyl, amine, and phenolic compounds of stem extract which are involved in the reduction of silver ions. Thus, synthesized silver nanoparticles show more antibacterial activity against Klebsiella planticola and Bacillus subtilis, which was analyzed by disc diffusion method [10].

Ag-Nps were synthesized by using phytochemical compounds (eucopelargonidin-3-0-α-L rhamnoside, leucocynidin-3-0-α-D galactosyl celllobioside, glucoside, beta glucoside, pentatriacontan-5-one and beta sitosterol-α-D-glucose) of Ficus benghalensis (family: Moraceae) with size 40nm and analyzed by UV-spectrophotometer, DLS, Fe-SEM, AFM and ATR-FTIR [11]. Various phytochemicals like nimbín, nimbinin, deactetyl nimbín, nimbine, 6-deactetyl nimbine, nimbandiol, polysaccharides G1A, G1B, G2A, and G3A, and NB-2 peptidoglucon were synthesized from the bark extract of Azadirachta indica and used in the synthesis of Ag-Nps with 50nm size and showed antimicrobial activity against B. subtilis, E. coli, P. aeruginosa and V. cholerae [11]. The synthesized silver nanoparticles showed maximum activity by using leaf extract of coconut tree against K. pneumoniae, P. shigelloides, V. Alginolyticus, P. shigelloides, K. pneumoniae, Salmonella paratyphi, P. aeruginosa, Vibrio harveyi, Bacillus subtilis, E. coli, B. cereus, S. aureus, E. coli, E. coli, P. aeruginosa, and NB-2 peptidoglucan were synthesized from the bark extract of Azadirachta indica and used in the synthesis of Ag-Nps with 50nm size and showed antimicrobial activity against B. subtilis, E. coli, P. aeruginosa and V. cholerae [11]. The synthesized silver nanoparticles showed maximum activity by using leaf extract of coconut tree against K. pneumoniae, P. shigelloides, V. Alginolyticus.

| Family            | Species                  | Diameter (nm) | Shape          |
|-------------------|--------------------------|---------------|----------------|
| Cocos nucifera    | Vibrio alginolyticus     | 12            | 19             |
|                   | P. shigelloides          | 9             | 21             |
|                   | K. pneumoniae            | 12            | 24             |
|                   | Salmonella paratyphi     | 15            | 16             |
|                   | P. aeruginosa            | 10            | 14             |
|                   | Vibrio harveyi           | 13            | 14             |
|                   | Bacillus subtilis        | 12            | 14             |
|                   | E. coli                  | 10            | 12             |
| Phoenix dactylifera| Methicillin-resistant Staphylococcus aureus (MRSA) | 9              | 11             |
| Aegle marmelos    | E. coli                  | 9.0 ± 0.15    | 15.15±0.62     |
|                   | S. typhi                 | 9.16 ± 0.54   | 15.22±0.52     |
|                   | B. cereus                | 10.15±0.62    | 19.25±0.19     |
| Dalbergia spinosa | S. aureus                | 17            | 21             |
|                   | E. coli                  | 19            | 28             |
|                   | B. subtilis              | 16            | 23             |
|                   | P. aeruginosa            | 14            | 19             |
| Euphorbia confinalis| Staphylococcus aureus   | 2             | 13             |
|                   | Escherichia coli         | 2             | 11             |
| Taraxacum officinale| E. Faecalis             | 10±0.50       | 12±0.27        |
|                   | P. aeruginosa            | 11±0.76       | 14±0.90        |

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Salmonella paratyphi and Bacillus subtilis and produced 22nm size with spherical shape nanoparticles. The synthesized nanoparticles were characterized by UV-visible spectroscopy, FTIR, and TEM analysis [12].

Pithophora oedogonia (Mont.) Wittrock extract as a reducing agent can effectively produced 34.03nm cubical and hexagonal shape silver nanoparticles. Characterization of synthesized silver nanoparticles was carried out by UV-vis spectroscopy, FTIR, DLS and SEM equipped with EDS [12]. Phytochemical analysis of methanolic extract of *Aegle marmelos* revealed the presence of tannins, saponins, steroids, alkaloids, flavonoids, and glycosides. Agar well diffusion method was used for determining antimicrobial activity of AgNPs. AgNPs synthesized using *Aegle marmelos* methanolic extract, characterized by UV-Visible spectroscopy, atomic force microscopy, dynamic light scattering, and X-ray diffraction showed size ranged between 159 and 181 nm. Evaluation of the antimicrobial potential of green synthesized AgNPs recorded the highest inhibitory activity against *B. cereus* [19.25 ± 0.19 mm] followed by *P. aeruginosa* [16.50 ± 0.30 mm] and *S. dysentriae* [14.35 ± 0.20 mm] [14]. Phytochemical compounds like flavonoids, isoflavonoids, neoflavonoids, steroids, terpenoids of leaf extract of Dalbergia spinosa used in the synthesis of Ag-NPs [18 ± 4nm; spherical] and showed more activity against Bacillus subtilis, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Escherichia coli* than plant extract [15].

*Lythrum salicaria* extract was used as a reducing agent as well as a capping agent. Formation of the spherical AgNPs ranging between 45 and 65 nm was proved by UV-Vis spectroscopy, transmission electron microscopy (TEM), and dynamic light scattering (DLS). Biomaterials supported AgNPs were characterized and compared for their morphological, thermal, release, and antimicrobial properties [16]. The stem extract of *Euphorbia confinalis* from Euphorbiaceae family showed the formation of nanoparticles of spherical shape with a size of 12-18nm. The synthesized silver nanoparticles showed maximum activity against *E. coli*, *S. aureus* and analyzed by UV-Vis, SEM, TEM, and FTIR [17]. The phytochemical compounds catechin, p-coumaric acid, luteolin-7-glucoside, and a nonidentified withanolide derivative present in the *Withania somnifera* (Ashwagandha) aqueous leaf extract showed the formation of nanoparticles of spherical shaped with a size of 70 & 110nm [18]. AgNPs were synthesized by reduction of AgNO₃ solution using extract of *Vasaka* as capping agent and observed the spherical shaped nanoparticles and the average particle size is 20 nm in the range of 5-50 nm.

The biosynthesized silver nanoparticles were characterized by UV-Vis spectroscopy and TEM analysis. The antibacterial activity of these nanoparticles against *Pseudomonas aeruginosa* was measured by disc diffusion method, agar cup assay and serial dilution turbidity measurement assay [19]. The phytochemical screening of *Chrysanthemum indicum* revealed the presence of flavonoids, terpenoids, and glycosides, suggesting that these compounds act as reducing and stabilizing agents. The spherical and hexagonal Ag-NPs were also synthesized by using *Chrysanthemum indicum* flower extract with an average particle size from 37.71-71.99nm and characterized by using UV-Vis spectroscopy, XRD, TEM, and EDX. The antimicrobial effect of the synthesized AgNPs revealed a significant effect against the bacteria *Klebsiella pneumonia*, *Escherichia coli*, and *Pseudomonas aeruginosa* [20]. The biosynthesis of silver nanoparticles using *Taraxacum officinale* floral extract showed the formation of nanoparticles of spherical shape with a size of 545nm ± 5nm) upon addition of 1 mM silver nitrate. AgNPs synthesized from floral extract of *T. officinale* showed good antibacterial activity against selected pathogens such as *Enterococcus faecalis* and *Pseudomonas aeruginosa* by disc diffision assay [21].

The spherical-shaped AgNPs were synthesized by using Phoenix dactylifera seed extract as stabilizing agent and characteristics of particles was studied by using UV-Vis spectroscopy, SEM, HR/TEM, and DLS. The antibacterial activities were found to be increased with the increasing concentration of AgNPs. The zone of inhibition was greater (24mm) at highest concentrations (500μg/ml) of AgNPs, while smaller (11mm) at lowest concentrations (7.8μg/ml) [22]. The silver nanoparticles (AgNPs) synthesized using hot water olive leaf extracts as reducing and stabilizing agent is evaluated for antibacterial activity against drug resistant bacterial isolates. The silver nanoparticles were with an average size of 20-25 nm and mostly spherical.

**Conclusion**

In summary, it is concluded that during the last decade many efforts have been made for the development of green synthesis. Green synthesis gives headway over chemical and physical methods as it is cost-effective, eco-accommodating and effectively scaled up for large-scale synthesis. Production of NPs using extracts from natural substances is emerging as an important area in nanotechnology. Plants are having broad range of phytochemicals like alkaloids, terpenoids, phenols, flavonoids, tannins and quinines etc. which can mediate the synthesis of nanoparticles. It was shown that a variety of plant extracts have been used to efficiently synthesize metal nanoparticles for green synthesis, but the metal nanoparticles produced by plants are more stable and bioactive in comparison with those produced by plant extracts. The findings of this study suggest that the nps synthesized by plant extracts exhibited good antimicrobial activity against bacterial pathogens which indicates the immense potential as effective antimicrobial agents that can be used in various modern medicines. Natural sources have the potential to reduce silver ions into AgNPs.

It is understood that the variety of natural compounds that are present in plant extracts can act as both reducing and stabilizing agents for synthesis of AgNPs. Plants mediated AgNPs are stable.
due to the presence of natural capping agents such as proteins which prevent the particles from aggregation. Green synthesis of AgNPs using plant extracts has several advantages such as eco-friendliness, biocompatibility and cost-effectiveness. It is concluded that due to these unique properties, AgNPs will have a key role in many of the nanotechnology-based processes.

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