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Plants: Emerging as Green Source toward Biosynthesis of Metallic Nanoparticles and its Applications

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ABSTRACT
This review focuses on the green synthesis of silver nanoparticles using various plant sources. Nano biotechnology focus on the use of living organisms plants for engineering nanoparticles and its biomedical, pharmaceutical applications. Plants extracts provide rapid, cost effective and eco-friendly sources for fabrication of metallic nanoparticles. Green biological method of synthesizing nanoparticles has materialized as alternative to overcome the curb of conventional methods such as synthesized by several physical and chemical methods including chemical reduction of ions in aqueous solution with or without stabilizing agent and reduction in inverse micelles or thermal decomposition in organic solvents. Employing plants towards synthesis of nanoparticles has advantageous over non biological methods as with the presence of broad variability of bio-molecules in plants can act as capping and reducing agents and thus increases the rate of reduction and stabilization of nanoparticles. Thus biosynthesized metallic nanoparticles of variable size and shape have broad potential applications in life and science.
Keyword: Biosynthesized Nanoparticles, Green Source, Biofabrication, Ecofriendly, Applications

INTRODUCTION
The nanotechnology has provided an extensive research on nanomaterial, offered other branches of science and creating impact on all forms of life [1]. The term nanotechnology first described by Richard Feynman in 19592. The first scientific description of the properties of nanoparticles was published in 1857 by Michael Faraday in his famous paper entitle "experimental relations of gold (and other metals) to light" [2]. Nanotechnology offered the synthesis, characterization, exploration and application of Nano sized (1-100nm) materials for the development of science. Green nanotechnology developed eco-friendly biological method alternative to physical and chemical methods for the synthesis of nanoparticle. The physical and chemical methods for synthesis nanoparticles requires extensive care and are highly expensive and also chemicals which used are hazardous to environment and may pose health risks [3]. Green chemistry is "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products" [4,5].

Nanoparticles Synthesis
Among metallic nanoparticles got special attention due to wide range of applications in an area such as catalysis, optics, antimicrobial and biomedical applications [6]. The very first report on the synthesis of silver nanoparticles using Alfalfa (*Medico sativa*) has been appeared in 2003 a step toward green nanotechnology [7]. The synthesis of metallic nanoparticles through plant extracts provide advantageous over other biological synthesis processes which involve the very complex procedures of maintaining microbial cultures The various reports showed related studies, such as silver nanoparticles synthesis form leaves extracts of *Camellia sinensis* [8], *Euphorbia hirta* and *Nerium indicum*, [9], *Eucalyptus hybrida* [10], *Lantana camara* [11], five plants leaf extracts [12], stem bark of *Boswellia ovalifoliolata*[13], from latex of *Euphorbia milii* [14] and *Glycyrrhiza glabra* root extract mediated synthesis of silver nanoparticles have been already reported [15]. The fruit extract of papaya used for the fabrication of metallic nanoparticles. In addition the biosynthesized nanoparticles were found to be highly toxic to *Escherichia coli* and *Pseudomonas aeruginosa* bacteria [16]. Platinum nanoparticles were synthesized using leaf extract of *Diopyros kaki*. The synthesized platinum nanoparticles were characterized resulting in 2 to 12nm in size FTIR analysis revealed that the formation of platinum nanopart the biomolecules present in the extract but not an enzyme mediated process4. Biological synthesis of gold nanoparticles using *Nyctanthes arbortristis* ethanolic flow evaluated resulting in synthesis of spherical shaped gold nanoparticles with size 19.8 ± 5.0 nm [17].

Characterization of Biosynthesized nanoparticles
UV-Vis spectrophotometric analysis: The UV-Vis absorption was analyzed after centrifugation followed by redisposing the particles in deionized water. The room temperature synthesized silver nanoparticles using aqueous Sorghum bran extract showed surface Plasmon resonance peak located at 390 nm

[18].The silver nanoparticles has been synthesized by adding aqueous plant extract to silver nitrate solution [19] and the color change is very first signal for the formation of nanoparticles and bioactive compounds present in the aqueous leaf extract *Memecylon edule* is responsible for the reduction of metal ions to respective metal nanoparticles [20]. Furthermore a peak between 400-440 nm obtained on UV-Vis spectroscopy confirmed the reduction of silver nitrate to silver nanoparticles [21]. In this studied it was reported the reduction of silver nitrate to silver nanoparticles by ethanolic extract of whole plant *Bacoa monniera* and characterization absorption peak at 436 nm, interaction of protein with nanoparticles., act as capping agent, 10-30 nm size and face centered cubic morphology of nanoparticles were analyzed by UV-Vis, FTIR, TEM and XRD analysis respectively [22]. Biogenic synthesized silver nanoparticles were characterized using different techniques. For the characterization of silver nanoparticles solution thus obtained, centrifuged and redispersed repeatedly in deionized water and freeze dried pellet were used for XRD, SEM and EDX analysis [23] and the EDX study showed silver nanoparticles reduced by *Catahranthus roseus* have the weight percentage of silver as 20.16% and 16.41% and optical absorption at 3KeV is a typical characteristic of metallic silver [24].
X-ray Diffraction analysis study were used to confirm chemical composition and crystalline nature of synthesized particles materials the freeze dried powder of silver nanoparticles is analyzed using X'Pert Pro X-ray Diffractometer with Cu-Kα radiation (λ=1.540598) followed method as describe by Sing et al., [25]. TEM images showed the formation of bimetallic Au/Ag alloy nanoparticles and resulted that various polyhydroxy limonoids present in the *Mahogany* leaf were responsible for the reduction and stabilization of silver and gold nanoparticles [26]. X-ray diffraction and SEM analysis showed the average particle size of 15 nm as well as revealed their cubic structure. Synthesized nanoparticles were evaluated for antimicrobial activity against multi-drug resistant human pathogens [27].

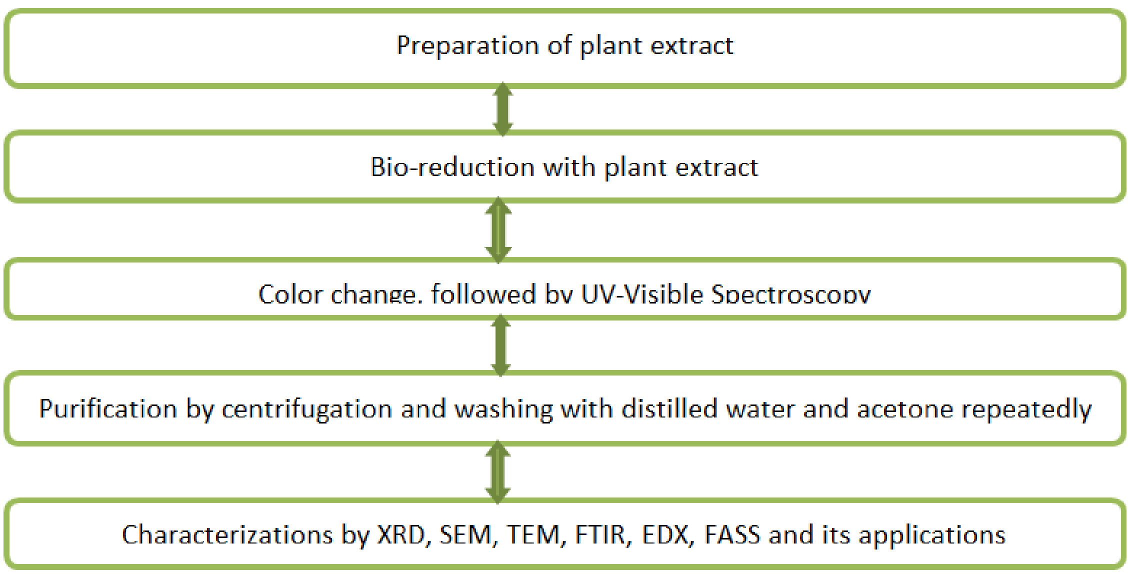

Figure 1: Steps involved in the plant mediated synthesis of nanoparticles.

Table 1: Reviews Reported Bio-based Synthesis of Nanoparticles

Bacteria	**Nanoparticles**	**Average Size**	**Shape**	**References**
Bacillus thurimgiensis	Ag	15 nm	Cubic, hexagonal	Jain et al. [28]
Pseudomonas stutzeri	Ag	200 nm	Spherical	Kllaus et al. [29]
Fungi				
Aspergillus fumigatus	Ag	50 nm	Spherical	Bhainsa et al. [30]
Fusarium oxysporum	Au	20-40nm	Spherical	Ahmad et al. [31]

Pseudomonas aeruginosa	Au	15-30 nm	Spherical	Husseiney et al. [32]
Algae				
Shewanella algae	Au	9-100 nm	Spherical	Ogi et al. [33]
Chlorella vulgaris	Au	9-20 nm	Spherical	Jainping et al. [34]
Plants				
Allium cepa L.	Au	100 nm		Parida et al. [35]
Dioscorea bulbifera L.	Ag	8–20 nm Average 75nm	Spherical	Ghosh et al. [36]
Cinnamomum camphora L.	Pd	3.2to 6.0 nm	Spherical	Xin et al. [37]
Argemone maxicana	Ag	30 nm	Cubic and hexagonal	Sing et al. [38]
Aloe vera	Ag	25 nm	Spherical	Zhang et al. [39]
Euphorbia hirta L	Ag	40-50 nm	Spherical	Elumalai et al. [40]
Lantana camara	Ag	40 nm	Spherical	Thirumurugan et al. [41]
Plants	Biomolecules involve in fabrication of nanoparticles	Nanoparticles size	Shape	References
Zingiber officinale Rosc	alkaloids, flavonoids	Ag /Au 10 nm	Spherical	Singh et al. [42]
Solanum xanthocarpum L.	Phenolics, alkaloids and sugars	Ag 4-18 nm	Spherical	Amin et al. [43]
Glycyrrhiza Glabra L	Flavonoids, terpenoids, thiamine.	Ag 20-30 nm	Spherical	Dinesh et al. [44]
Cinnamomum zeylanicum Blume.	Terpenoids	Pd 15 to 20 nm	Spherical	Sathish kumar et al. [45]
Gardenia jasminoides Ellis.	Geniposide,chlorogeni cacid, crocins	Ag 3-5	Spherical	Jai et al. [46]
Camellia sinensis	Polyphenol	Au 25nm	Spherical	Boruah et al. [47]
Memecylon edule	Terpenoids	Ag ,10–45, Au 50–90 nm	triangular, circular, hexagonal	Elavazhagan and Arunachalam, [48]
Azadirachta indica A. Juss.	Salanin, Nimbin, Azadirone and Azadirachtins	2-100nm		Thirumurugan et al. [49]
Chenopodium album L.	Oxalic acid	Ag, Au 12,10 nm		Dwivedi and Gopal [50]
Jatropha curcas L.	Curcacycline , Curcacycline, Curcain	ZnS 10nm Pb 10-12.5 nm		Hudlikar et al. [51] Joglekar et al. [52]
Mirabilis jalapa L.	Polyol	Au 100nm		Vankar and Bajpai [53]
Mentha piperita L.	Menthol	Ag Au 90, 150 nm		Ali et al. [54]
Sorghum Moench.	Polyphenols	Ag , Fe 10nm,		Njagi et al. [55]

		50nm		

Applications of nanoparticles

In the recent years nanoparticles have attracted unique attention due to their small size as compared to their bulk materials allows their potential applications in various field of technologies such as catalysis, biotechnology, chemical industry, electronics and electro- optical devices [56], and biomedical application [58]. The metal nanoparticles show a specific response to cells [] and entrance to cells and cytotoxicity depend on size and shape of nanoparticles [61]. Anticancer photothermal therapy of gold nanoparticles [62], antiviral activity [63] and antibacterial properties of silver nanoparticles have been demonstrated in various research studies [64].

However green synthesis and enhancing the biological activity f silver nanoparticles has been investigated by using the green plants. The *Citrus limon* mediated synthesis of silver nanoparticles and their enhanced antifungal activity due to synergetic effect of silver nanoparticles and essential oils of citrus against *Fusarium oxysporum* and *Alternaria brassicicola* has been reported [65]. Biosynthesized silver nanoparticles from leaves extract of *Calotropis gigantea* showed inhibition zone 16 mm (±0.25) in diameter, whereas that for the silver nitrate solution was 20 mm in diameter and no zone were observed of leaf extract against bacteria *Vibrio alginolyticus* [66]. For combating bacterial drug resistance problems, biogenic silver nanoparticles could acts as effective and alternative bacteriostatics agents. Silver nanoparticles synthesized with *Sargassum tenerrimum* showed higher antibacterial activity than phytochemical present and effective against both gram positive and gram negative bacteria, zone of inhibition was more than 15 mm in diameter [67]. The biosynthesized silver nanoparticles have also been further evaluated for the control of parasites [68], interaction with HIV-I virus [69]., against water borne pathogens [70] and inhibition of fungal growth [71].

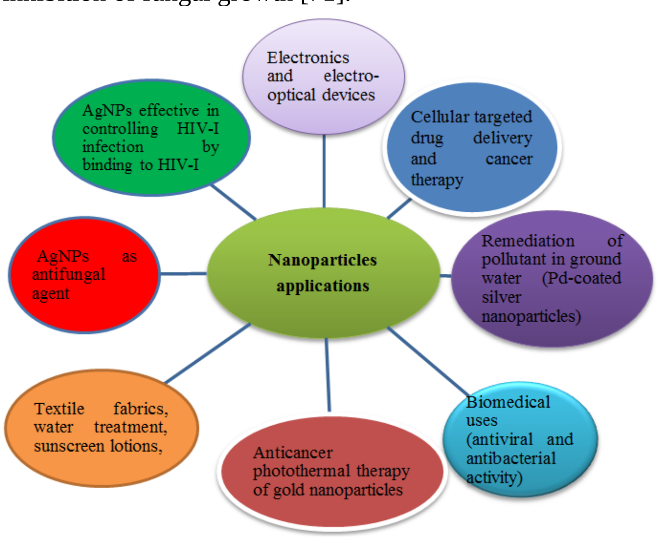

Figure.2: Application of metallic nanoparticles in various fields

CONCLUSION

Biological synthesis of nanoparticles has upsurge in the field of Nano-biotechnology to create novel materials that are ecofriendly, cost effective, stable nanoparticles with a great importance for wider applications in the areas of pharmaceutics, medicine, cancer control and agriculture. During the current scenario nanotechnology motivates progress in all sphere of life, hence biosynthetic route of nanoparticles synthesis will arise as ecofriendly and safer alternative to conventional methods. The various biological resources have been exploited for the production of nanoparticles; the use of plants for the facile robust synthesis of nanoparticles is a marvelous. Thus the present review envisions the importance of plant mediated nanoparticles productions by conferring the various literatures reported by far. With the huge plant diversity much more plant species are in way to be exploited and reported in future era towards rapid and single step protocol with green principle.

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