SciMedCentral
International Journal of Plant Biology & Research

Review Article

Plant Mediated Green Synthesis of Silver Nanoparticles-A Review

Swarup Roy* and Tapan Kumar Das

Department of Biochemistry and Biophysics, University of Kalyani, Kalyani – 741235, West Bengal, India

***Corresponding author**

Swarup Roy, Department of Biochemistry and Biophysics, University of Kalyani, Kalyani – 741235, West Bengal, India. Telephone: Office: (033) 25828750, 2582 8378 (Ext. 385), 919046546632 (M); Fax: +91-33-25828282; Email: swaruproy@klyuniv.ac.in , swaruproy2013@gmail.com

Submitted: 28 April 2015

Accepted: 27 August 2015

Published: 29 August 2015

ISSN: 2333-6668

Keywords

- Biosynthesis
- Nanotechnology
- Silver nanoparticles
- Plants

Abstract

Developing an environment friendly process for synthesis of nanoparticles is a significant step in the field of nanotechnology. Nanotechnology involves the tailoring of materials at the atomic level to attain unique properties, which can be suitably manipulated for the desired applications. Among the all metallic nanoparticles silver nanoparticles draw more attention due to its unique physical, chemical and biological properties. Green protocol of synthesizing nanoparticles has emerged as an alternative to overcome the limitation of conventional methods. Plant and microorganisms are majorly applied for green synthesis of metallic nanoparticles. Using plants towards synthesis of nanoparticles are emerging and also beneficial compared to microbes with the presence of broad variability of bio-molecules in plants which can act as capping/stabilizing and reducing agents and so increases the rate of reduction and stabilization of synthesized nanoparticles. Among all organisms plants seem to be the best candidates for biosynthesis of silver nanoparticles and they are suitable for large-scale biosynthesis. Nanoparticles produced by plants are more stable and the rate of synthesis is faster than in the case of microorganisms. This review focuses on the green synthesis of silver nanoparticles using various plant sources.

INTRODUCTION

Nanotechnology is a field of science which deals with production, manipulation and use of materials ranging in nanometers. With the advancement of technologies and improved scientific knowledge a way for research and development in the field of herbal and medicinal plant biology towards intersection of nanotechnology has been observed. One such interference is applying plants source in the green synthesis of nanoparticles.

Nanoparticles can be easily synthesized using various methods by various approaches available for the synthesis of silver nanoparticles include chemical [1], electrochemical [2], radiation [3], photochemical methods [4] and Langmuir-Blodgett [5,6] and biological techniques [7]. But most of the chemical methods used for the synthesis of nanoparticles involve the use of toxic, hazardous chemicals that create biological risks and sometime these chemical processes are not ecofriendly. This enhances the growing need to develop environmentally friendly processes through green synthesis and other biological approaches. Sometimes the synthesis of nanoparticles using various plants materials and their extracts can be beneficial over other biological synthesis processes which involve the very complex procedures of maintaining microbial cultures [8,9].

A lot of literature has been reported till to date on biological synthesis of silver nanoparticles using microorganisms including bacteria, fungi and plants; because of their antioxidant or reducing properties typically responsible for the reduction of metal compounds in their respective nanoparticles. Although; among the various biological methods of silver nanoparticle synthesis, microbe mediated synthesis is not very suitable for industrial feasibility because of requirements of highly aseptic conditions and their maintenance. So, the use of plant extracts for this purpose is potentially advantageous over microorganisms due to the ease of improvement, the less biohazard and elaborate process of maintaining cell cultures [10]. It is one of the best platforms for synthesis of nanoparticles as it is free from toxic chemicals as well as providing natural capping agents for the stabilization of silver nanoparticles. Now, plant mediated synthesis of metal nanoparticles is receiving lots of attention due to its simplicity, speedy synthesis of nanoparticles of attractive and diverse morphologies and elimination of detailed maintenance of cell cultures and eco-friendliness. The reason for selecting plant for biosynthesis is because they contain important reducing agents like Citric acid, Ascorbic acids, flavonoids, reductases etc., dehydrogenases and extracellular electron shuttlers that may play an important role in biosynthesis of metal nano particles [11].

The nanoparticles used so far, the metallic nanoparticles considered as the most promising as they contain remarkable antimicrobial properties due to their large surface area to volume ratio, which is of interest for researchers due to the growing microbial resistance against metal ions, antibiotics and the development of resistant strains [12]. In nanotechnology, silver nanoparticles are the most promising one. It is observed that silver nanoparticles do not affect living cells, so not able to provoke microbial resistance. It is believed that silver nanoparticles can attach to the cell wall and disturb cell-wall permeability and cellular respiration [13].

Silver is well-known since ancient time due to its medicinal value and for its preservative properties. Silver is one of the basic elements that make up our planet. It is efficient antimicrobial agent compared to other salts due to their extremely large surface area, which provides better contact with microorganisms. Silver nanoparticles have many applications (Figure 1); spectrally selective coatings for solar energy absorption and intercalation material for electrical batteries, as catalysts in chemical reactions, for bio-labelling etc. Silver containing particles also used in textile fabrics, as food additives, and in package and plastics to eliminate microorganisms. Because of such a wide range of applications, various methods concerning the fabrication of silver nanoparticles, as well as various silver-based compounds containing metallic silver (Ag^o) have been developed [14]. Silver nanoparticles used in environmental-friendly antimicrobial nano paint [15], antimicrobial nature of silver ions plays a prominent role in food packaging systems [16]. Silver nanoparticles have antibacterial properties mediated by silver ions [17], it used as preservative in food and various food related products [18]. Silver nanoparticles are reported to show better wound healing capacity, better cosmetic appearance and scar less healing when tested using an animal model [19].

The present review article draws attention to the current knowledge regarding the potential of plant materials for biosynthesis of silver nanoparticles and presents a database that future researchers can be based on the green synthesis of silver nanoparticles using plants.

Biosynthesis of silver nanoparticle by using plant materials

Green synthesis of nanoparticles has been an emerging research area now a day. The advancement of green syntheses over chemical and physical methods is: environment friendly, cost effective and easily scaled up for large scale syntheses of nanoparticles, furthermore there is no need to use high temperature, pressure, energy and toxic chemicals.

The use of plants for the production of silver nanoparticles has received lots of attention due to its rapid, eco-friendly, non-pathogenic, economical protocol and providing a single step technique for the green synthesis processes [20]. The reduction and stabilization of silver ions by combination of biomolecules such as proteins, amino acids, enzymes, polysaccharides, alkaloids, tannins, phenolics, saponins, terpinoids and vitamins which are already established in the plant extracts having medicinal values and are environmental benign, yet chemically complex structures [21]. A large number of plants are already

Figure 1 Various applications of silver nanoparticles.

reported to facilitate silver nanoparticles synthesis and some of them are mentioned in this review (Table 1). The different parts of plant such as stem, root, fruit, seed, callus, peel, leaves and flower are used to synthesis of metallic nanoparticles in various shapes and sizes by biological approaches.

The general protocol for the nanoparticle synthesis involves the following steps- the collection of the part of plant/plant materials of interest from the available sites followed by washing thoroughly twice/thrice with distil water to remove both epiphytes and necrotic plants; followed with washing with sterile distilled water to remove associated debris if any. Thereafter, clean and fresh plant sources are dried for 10-15 days in dark and then powdered using domestic blender. Now, for the plant broth preparation, ~10 g of the dried powder is boiled with 100 mL of deionized distilled water. The resulting solution is then filtered thoroughly until no insoluble material appeared in the broth. Soon after, filtrate is collected and to this filtrate (Raw/diluted) at a 1 mM final concentration $AgNO_3$ solution need to be added. Then, after addition the mixture is sometime shaken in a shaking incubator and very soon color of the mixture changes due to the reduction of pure Ag^+ ions to Ag^o and the resulted sample need to be monitor at regular intervals in UV-visible spectra of the solution to identify the characteristic absorption properties of nanoparticles, this gives an indication of formation of nanoparticles [22]. Thereafter, the synthesized nanoparticles need to be characterized by using various techniques. At last after confirmation of formation of nanoparticles for its application it needs to be purified and separated from the plant extract (Figure 2).

Flavonone and terpenoid components of leaf broth are being predicted to stabilize the formation of nanoparticles in comparison to high molecular weight proteins of fungal biomass [23]. The polyol components and the water soluble heterocyclic components are mainly responsible for reduction of silver ions (Ag^+) as well as stabilization of nanoparticles. Information regarding the activity of reductases in nanoparticles fabrication is well illustrated [24]. Differences in morphology of nanoparticles synthesized, is one possible reason for variation in optical properties [25]. It is well known that silver nanoparticles exhibit brownish color in aqueous solution due to excitation of surface plasmon vibrations in silver nanoparticles [26].

Among the list of plant materials mentioned in Table 1 and

Table 1: Green synthesis of silver nanoparticles using plant.

Sl. No.	Name of Plant	Size of nanoparticles	References
1.	*Allium cepa*	33.6 nm	Saxena et al. [27]
2.	*Allium sativum* L.	4 .4 ± 1.5 nm	White II et al. [28]
3.	*Achyranthus aspera* L.	20-30 nm	Daniel et al. [29]
4.	*Andrographis paniculata* Nees.	28 nm	Sulochana et al. [30]
5.	*Astragalus gummifer* Labill	13.1 ± 1.0 nm	Kora et al. [31]
6.	*Asiatic Pennywort*	18-21 nm	Saikia et al. [32]
7.	*Azadirachta indica* L.	< 30 nm	Velusamy et al. [33]
8.	*Andrographis paniculata*	40-60 nm	Sinhaa & Paul [34]
9.	*Bryophyllum*	18-21 nm	Saikia et al. [32]
10.	*Carica papaya* L.	15 nm	Jain et al. [35]
11.	*Centella asiatica* L.	-	Palaniselvam et al. [36]
12.	*Chenopodium album* L.	12 nm	Dwivedi and Gopal [37]
13.	*Coleus aromaticus* Lour.	40-50 nm	Vanaja and Annadurai [38]
14.	*Citrullus colocynthis* L.	31 nm	Satyavani et al. [39]
15.	*Capsicum annuum* L.	30-70 nm	Li et al. [40]
16.	*Citrus limon*	10-30 nm	Mohapatra et al. [41]
17.	*Clerodendrum Inerme*	-	Farooqui et al. [42]
18.	*Datura metel* L.	16-40 nm	Kesharwani et al. [43]
19.	*Desmodium triflorum* (L) DC.	5–20 nm	Ahmed et al. [44]
20.	*Dioscorea bulbifera* L.	8-20 nm	Ghosh et al. [45]
21.	*Dioscorea oppositifolia* L.	14 nm	Maheswari et al. [46]
22.	*Elettaria cardamomom* (L) Maton.	-	GnanaJobitha et al. [47]
23.	*Euphorbia hirta* (L)	40-50 nm	Elumalai et al. [48]
24.	*Emblica officinalis*	10-70 nm	Ramesh et al. [49]
25.	*Glycyrrhiza Glabra* L.	20 nm	Dinesh et al. [50]
26.	*Hibiscus cannabinus* L.	9 nm	Bindhu and Umadevi [51]
27.	*Hydrilla verticilata* (L.f.) Royle.	65.55 nm	Sable et al. [52]
28.	*Lantana camara* L.	12.55 nm	Sivakumar et al. [53]
29.	*Leonuri herba* L.	9.9-13.0 nm	A-Rang Im et al. [54]
30.	*Mentha piperita* L.	90 nm	Ali et al. [55]
31.	*Morinda pubescens* L.	25-50 nm	Mary and Inbathamizh [56]
32.	*Ocimum sanctum* L.	10 nm	Ahmad et al. [57]
33.	*Ocimum sanctum* L.	-	Brahmachari et al. [58]
34.	*Ocimum sanctum* L.	4-30 nm	Ramteke et al. [59]
35.	*Parthenium hysterophorus* L.	10 nm	Ashok Kumar [60]
36.	*Parthenium hysterophorous* L	40-160 nm	Sarkar et al. [61]
37.	*Parthenium hysterophorus* L	30-80 nm	Parashar et al. [62]
38.	*Psidium guajava* L.	2–10 nm	Lokina et al. [63]
39.	*Pedilanthus tithymaloides* (L) Poit.	15-30 nm	Sundarayadivelan et al. [64]
40.	*Piper betle* L.	3-37 nm	Mallikarjuna et al. [65]
41.	*Plumeria rubra* L.	32-220 nm	Patil et al. [66]
42.	*Sesuvium portulacastrum* L.	5-20 nm	Nabikhan et al. [67]
43.	*Solanum xanthocarpum* L.	10 nm	Amin et al. [68]
44.	*Swietenia mahogany* (L) Jacq.	-	Mondala et al. [69]
45.	*Saururus chinensis*	38 nm	Nagajyoti et al. [70]
46.	*Syzygium cumini* L	93 nm	Banerjee & Narendhirakannan [71]
47.	*Trianthema decandra* L.	10-50 nm	Geethalakshmi and Sarada [72]
48.	*Tagetes erecta*	10-90 nm	Padalia et al. [73]
49.	*Viburnum lantana*	20–80 nm	Shafaghat [74]
50.	*Zingiber officinale* Rosc.	10 nm	Singh et al. [75]
51.	*Paederia foetida* L.	4-15 nm	Mollick et al.[76]
52.	*Cucumis sativus*	8-10 nm	Roy et al. [77]
53.	*Morinda tinctoria*	79-96 nm	Vanaja et al. [78]
54.	*Aloe vera*	15.2 ± 4.2 nm	Chandran et al. [79]

55.	*Jatropha curcas*	10-20 nm	Bar et al. [80]
56.	*Cinnamomum camphora*	10-20 nm	Huang et al. [81]
57.	*Medicago sativa*	2-20 nm	Gardea-Torresdey et al. [82]
58.	*Azadirachta indica*	50 nm	Shankar et al. [83]
59.	*Cinnamon zeylanicum*	50-100 nm	Sathishkumar et al. [84]
60.	*Coriandrum sativum*	26 nm	Sathyavathi et al. [85]
61.	*Holarrhena antidysenterica*	2-70 nm	Yadav and Rai [86]
62.	*Opuntia ficus-indica*	-	Gade et al. [87]
63.	*Ocimum sanctum*	50-200 nm	Gudadhe et al. [88]
64.	*Carica papaya*	60-80 nm	Mude et al. [89]
65.	*Euphorbia hirta*	31 nm	Mano Priya et al. [90]
66.	*Nerium indicum*	29 nm	Mano Priya et al. [90]
67.	*Plectranthus barbatus*	20 nm	Manikandan et al. [91]
68.	*Aerva lanata.*	18.62 nm	Joseph and Mathew [92]
69.	*Myristica fragrans*	7-20 nm	Sharma et al. [93]
70.	*Solanum trilobatum*	12.50-41.90 nm	Ramar et al. [94]
71.	*Piper pedicellatum*	5-40 nm	Tamuly et al. [95]
72.	*Ocimum sanctum*	4–30 nm	Singhal et al. [96]

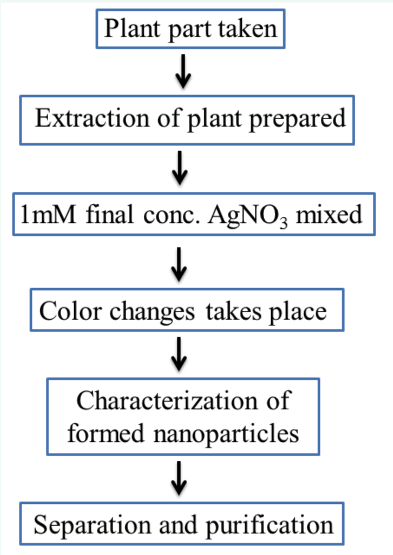

Figure 2 Biosynthesis of silver nanoparticles using plant extract.

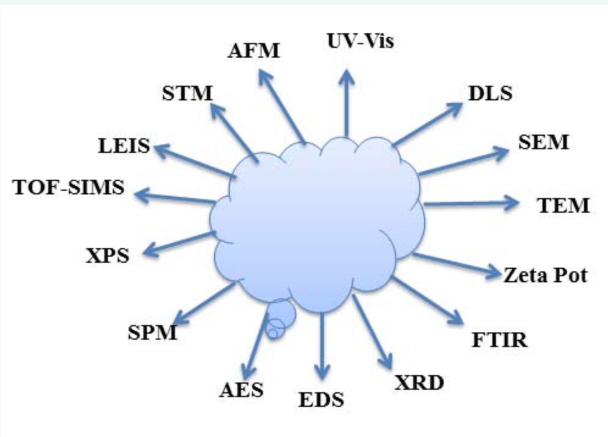

Figure 3 Various characterization techniques of nanoparticles.

few of them are discussed briefly in the present review.

Singhal et al. described biosynthesis and antimicrobial activity of silver nanoparticles using *Ocimum sanctum*. They showed that *O. sanctum* leaf extract can reduce silver ions into silver nanoparticles within 8 min of reaction time. Biosynthesized silver nanoparticles are in the size range of 4–30 nm and possessed antimicrobial activity. They showed silver nanoparticles were exhibit more antimicrobial activity on gram-negative microorganism than gram-positive ones and also showed synthesized silver nanoparticles have stronger activity than silver nitrate and standard antibiotic ciprofloxacin.

Jain et al. reported green synthesis of silver nanoparticles using *Carica papaya* L and studied antimicrobial activity of the synthesized nanoparticles against multi-drug resistant human pathogen. The synthesized silver nanoparticles were found to be cubic particles with average particle size of 15 nm. They showed that biologically synthesized nanoparticles were found to be highly toxic against different multi drug resistant human pathogens.

Farooqui et al. described green synthesis of silver nanoparticles using extracts of a medicinal leaf *Clerodendrum Inerme*. They synthesized nanoparticles from three different leaf conditions- fresh leaves, sun-dried leaves, and hot-air oven dried leaves and silver nanoparticles synthesized using fresh leaves gives the smallest sizes. They showed that the *Clerodendrum inerme* plant which is grown as an ornamental plant in many gardens in India and other parts of the world can be beneficially used for biosynthesis of silver nanoparticles.

Banerjee et al. synthesized silver nanoparticles using *Syzygium cumini* seed extract as reducing agent and also studied the antioxidant activity of the synthesized nanoparticles. The average size of silver nanoparticles was 93 nm. They showed green synthesized silver nanoparticles using *Syzygium cumini* seed have greater antioxidant activity compare to seed extract of *Syzygium cumini*.

Velusamy et al. reported green synthesis of silver nanoparticles using *Azadirachta indica* and also studied the antimicrobial activity. The synthesized silver nanoparticles were monodispersed and spherical particles with an average size < 30 nm. They showed that, the synthesized silver nanoparticles showed potent antibacterial activity. What is more, the antibacterial activity of the synthesized nanoparticles was confirmed by degradation of test bacterial DNA. Their results showed that the gum mediated synthesized silver nanoparticles could be used as a promising antibacterial agent against clinical pathogens.

Saxena et al. described biosynthesis of silver nanoparticles using *Allium cepa* and also studied the antibacterial activity of the synthesized nanoparticles. The synthesized silver nanoparticles were 33.6 nm in averages mean size and showed antibacterial activity against *E.coli* and *Salmonella typhimurium*. The bactericidal property of nanoparticles was examined by measuring the growth curve of bacteria in presence of 50 μg/ml concentration of silver nanoparticles and the results was found to be very effective.

Gade et al. showed *Opuntia ficus-indica* mediated synthesis of colloidal silver nanoparticles and studied the antibacterial activity as well as the mechanism involved in the synthesis process. Their report established that silver nanoparticles in combination with commercially available antibiotics showed a remarkable antibacterial activity and the maximum activity was demonstrated by Ampicillin followed by Streptomycin and Vancomycin. They also suggested two-step proposed mechanism of bio-reduction and formation of an intermediate complex leading to formation of capped biogenic silver nanoparticles.

Sarkar et al. reported synthesis of silver nanoparticles of varying sizes using *parthenium* leaf extract at a higher temperature of 100 °C as well as at room temperature. They showed the variation of particle size with the reaction temperature and reaction time. The synthesized colloidal silver nanoparticles were photo-luminescent. The size of the silver nanoparticles synthesized after 2 minutes of chemical reaction at a higher temperature of 100 °C lie within 40-160 nm and the average size of the nanoparticles was ~ 110 nm.

Ramesh et al. described plant mediated green synthesis of silver nanoparticles and its antibacterial activity using *Emblica officinalis* fruit extract. The synthesized silver nanoparticles are in the size of around 70 nm. They showed silver nanoparticles possess significant antimicrobial activity against gram-negative bacteria, *E. coli* and *K. pneumonia* and gram-positive bacteria, *S. aureus* and *B. subtilis*.

Mohapatra et al. reported *Citrus limon* extract mediated synthesis of silver nanoparticles. The biosynthesized silver nanoparticles are of in the size range of 10-30 nm. They showed that addition of NaOH is a key factor for rapid biosynthesis of stable aqueous dispersions of high concentration of silver nanoparticles. So, the alkaline environment is favorable for the biosynthesis of silver nanoparticles using *Citrus limon*.

Sinha and Paul synthesized silver nanoparticles using aqueous extract of *Andrographis paniculata* and they also studied the antibacterial activity against various bacterial strain. The size of the synthesized silver nanoparticles was in between 40 and 60 nm. They showed the antibacterial activity of the synthesized nanoparticles is very promising against *Pseudomonas aeruginosa* among the bacteria tested.

Saikia et al. described the green synthesis of silver nanoparticles using *Asiatic Pennywort* and *Bryophyllum* leaf extracts as reducing and capping agents. Their synthesized silver nanoparticles have average sizes 18-21 nm. They also described the size dependent antimicrobial activities of silver nanoparticles against gram negative bacteria *Pseudomonas Fluorescens* and gram positive bacteria *Staphylococcus epidermidis*. They showed that silver nanoparticles obtained from *Asiatic pennywort* was more effective on gram positive bacteria while silver nanoparticles obtained from *Bryophyllum* was more effective on gram negative bacteria.

Sathishkumar et al. reported biosynthesis of nanoparticles and also studied the antibacterial activity using the bark extract and powder of *Cinnamon zeylanicum*. The average size of the nanoparticles ranged between 31 and 40 nm. They showed that pH played a major role in size control of the particles and also bark extract are more effective silver nanoparticles producer than the powder. The nanoparticles synthesized showed an EC50 value of 11±1.72 mg/L against *Escherichia coli* BL-21 strain. So, the bark extract is good source of biosynthesis of silver nanoparticles and synthesized nanoparticles can be used as a potential antimicrobial agent.

Vanaja et al. synthesized silver nanoparticles using *Morinda tinctoria* leaf extract and studied the photocatalytic activity of synthesized nanoparticles. The synthesized nanoparticle is spherical shape with the size ranges from 79-96 nm. They evaluated the photo catalytic activity of green synthesized silver nanoparticles using methylene blue dye and results indicate silver nanoparticles exhibits excellent photo catalytic activity.

Mollick et al. synthesized silver nanoparticles using *Paederia foetida L.* leaf extract as a reducing cum stabilizing agent and also studied the antimicrobial activity of the synthesized nanoparticles against various bacteria. Their synthesized silver nanoparticles were spherical in shape with size range of 4–15 nm. The synthesized nanoparticles showed significant antibacterial reactivity on both the gram classes of bacteria.

Ali Shafaghat reported green synthesis of silver nanoparticles using methanol extract of *Viburnum lantana* leaves and also analyzed the biological activity of synthesized silver nanoparticles against various bacteria. They showed silver nanoparticles are in 20–80 nm size range. The antibacterial efficacy against some bacteria confirmed that the silver nanoparticles are capable of rendering antibacterial efficacy and strengthen the medicinal value of plants.

Roy et al. described biosynthesis of silver nanoparticles using fruit extract of cucumber (*Cucumis sativus*) and they also analyzed the photo catalytic and antibacterial activity of synthesized nanoparticles. The biologically synthesized silver nanoparticles were found to have spherical shape with average diameter nearly 8-10 nm. The Photo catalytic study suggests the efficiency of these biosynthesized nanoparticles in degrading organic dyes methylene blue under solar radiation. In addition, the result of antibacterial assay (tested against- *Staphylococcus aureus, Klebsiella pneumoniae* and *Escherichia coli*) showed that these nanoparticles possess effective bactericidal property.

Priya et al. reported plant mediated synthesis of silver nanoparticles using *Euphorbia hirta* and *Nerium indicum* and examined the antimicrobial activity of nanoparticles against various bacteria. Antimicrobial activity of synthesized nanoparticles tested against six different bacteria such as *E. coli, S. pyrogens, S. auereus, B. Subtilis, S. typhi and Citrobacter* sp. They showed the synthesized nanoparticles were highly effective in their activity against *S. pyrogens, B. Subtilis, S. typhi and Citrobacter* sp. than antibiotics.

Satyavani et al reported biosynthesis of silver nanoparticles using stem derived callus extracts of bitter apple (*Citrullus colocynthis* L.) and analyzed the antimicrobial activity of the prepared nanoparticles. The shape of the nanoparticles synthesized by stem derived callus extract was spherical and was found to be in the range of 75 nm. The silver nanoparticles exhibited a tremendous antibacterial activity against various strain and among those it showed the maximum activity against biofilm bacteria *E.coli*.

Characterization techniques of nanoparticle

After green synthesis of nanoparticles, characterization is an important step to identify the nanoparticles by their shape, size, surface area and dispersity [97]. To characterize nanomaterials various techniques [98-105] are employed which are shown below (Figure 3)-

1) UV-visible spectrophotometer- UV-Vis spectrophotometer allows identification, characterization and analysis of metallic nanoparticles. In general 200-800 nm light wavelength is used for the characterization of size range 2-100 nm [98].

2) Dynamic light scattering (DLS) - The dynamic light scattering (DLS) is used to characterize the surface charge and the size distribution and quality of nanoparticles. It is also very useful to know the polydispersity index of the prepared nanoparticles [97].

3) Scanning electron microscopy (SEM), and Transmission electron microscopy (TEM) - Electron microscopy is a common method for surface and morphological characterization. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) are used for the morphological characterization at the nanometer to micrometer scale [101]. SEM can provide morphological information on the submicron scale and elemental information at the micron scale, but TEM has a much higher resolution compared with the SEM. So, to know the surface morphology of the prepared nanoparticle sample same is used and TEM is useful to know the exact size and shape of nanoparticles.

4) Zeta potential measurement- Zeta potential is used to know the stability of prepared nanomaterial, more the value of zeta potential more stabilized sample.

5) Fourier transforms infrared spectroscopy (FTIR)- Characterization of nanoparticle using FTIR is very useful for the surface chemistry because the organic functional groups can be determined which are attached to the surface of nanoparticles [102].

6) X-ray diffraction (XRD) - XRD is used to examine the overall oxidation state of the particles as a function of time, i.e. phase identification and characterization of the crystal structure of the nanoparticles [103].

7) Energy dispersive spectroscopy (EDS) - To know the elemental composition of metal nanoparticles EDS is used, which gives the elemental knowledge of sample [104].

8) Auger electron spectroscopy (AES), scanning probe electron microscopy (SPM), X-ray photoelectron spectroscopy (XPS), time of flight secondary ion mass spectrometry (TOF-SIMS)- AES, XPS, TOFSIMS, scanning probe microscopy (SPM) techniques are important for the primary surface analysis of nanoparticles. AES and XPS are used to determine the presence, composition and thickness of coating on nanoparticles, surface enrichment and depletion at particle surfaces. Sometimes XPS is used to determine particle sizes when conditions are not appropriate for analysis by other methods. TOF-SIMS is useful for obtaining molecular information about surface layers, functional groups which are added to the surface.

9) Low energy ion scattering (LEIS)- In LEIS process the amount of energy lost by the ion during this scattering process due to a low energy ion beam can be determined. This scattering process is used to determine the identity of the elements present in the outermost surface of the material under analysis. Recently it is found that it is useful due to its high sensitivity to the outermost atomic layers of a sample [105].

10) Scanning tunneling microscopy (STM), Atomic force microscopy (AFM) - AFM and STM provide surface characterization at the atomic scale.

All these techniques are very useful to know the complete characterization details of synthesized nanoparticles.

CONCLUSION

Synthesis of silver nanoparticles using plant extracts is beneficial as it is an economical, energy efficient, low cost and supplemented to that it protecting human health and environment leading to lesser waste and safer products. Green synthesized silver nanoparticles have significant aspects of nanotechnology through unmatched applications and synthesis of nanoparticles using plants can be beneficial over other biological entities which can overcome the time consuming process of employing microbes and maintaining their culture which can lose their potential during biosynthesis of nanoparticles. Thus the present review showed the importance of plant mediated synthesis of silver nanoparticles by conferring the various literatures reported recently. With the vast plant diversity much more plant species are in way to be exploited and reported in future era towards rapid green synthesis of metallic nanoparticles.

ACKNOWLEDGEMENT

Swarup Roy is thankful to the Department of Science and Technology (DST) of India, for a DST INSPIRE fellowship (IF 110421).

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this review article.

REFERENCES

1. Sun Y, Yin Y, Mayers BT, Herricks T, Xia Y. Uniform form silver nanowires synthesis by reducing AgNO3 with ethylene glycol in presence of seeds and and poly(vinyl pyrrolidone). Chem Mater. 2002; 14: 4736–4745.
2. Yin B, Ma H, Wang S, Chen S. Electrochemical synthesis of silver nanoparticles under protection of poly (N-vinylpyrrolidone). J Phys Chem B. 2003; 107: 8898–8904.
3. Dimitrijevic NM, Bartels DM, Jonah CD, Takahashi K, Rajh T. Radiolytically induced formation and optical absorption spectra of colloidal silver nanoparticles in supercritical ethane. J Phys Chem B 2001; 105: 954–959.
4. Callegari A, Tonti D, Chergui M. Photochemically grown silver nanoparticles with wavelength-controlled size and shape. Nano Lett. 2003; 3: 1565–1568.
5. Zhang L, Shen Y, Xie A, Li S, Jin B, Zhang Q. One-step synthesis of monodisperse silver nanoparticles beneath vitamin E Langmuir monolayers. J Phys Chem B. 2006; 110: 6615-6620.
6. Swami A, Selvakannan PR, Pasricha R, Sastry M. One-step synthesis of ordered two dimensional assemblies of silver nanoparticles by the spontaneous reduction of silver ions by pentadecylphenol Langmuir monolayers. J Phys Chem B. 2004; 108: 19269–19275.
7. Naik RR, Stringer SJ, Agarwal G, Jones SE, Stone MO. Biomimetic synthesis and patterning of silver nanoparticles. Nat Mater. 2002; 1: 169-172.
8. Sastry M, Ahmad A, Islam NI, Kumar R. Biosynthesis of metal nanoparticles using fungi and actinomycetes. Current Sci. 2003; 85: 162-170.
9. Sastry M, Ahmad A, Khan MI, Kumar R. Microbial nanoparticle production in Nanobiotechnology. Nanobiotechnology 2003; 85:163-169.
10. Kalishwaralal K, Deepak V, Ram Kumar Pandian S, Kottaisamy M, BarathmaniKanth S, Kartikeyan B, et al. Biosynthesis of silver and gold nanoparticles using Brevibacterium casei. Colloids Surf B Biointerfaces. 2010; 77: 257-262.
11. Pandey S, Oza G, Mewada A, Sharon M. Green Synthesis of Highly Stable Gold Nanoparticles using, Momordica charantia as Nano fabricator. Archives of Applied Science Research. 2012; 4: 1135-1141.
12. Khalil KA, Fouad H, Elsarnagawy T, Almajhdi FN. Preparation and Characterization of Electrospun PLGA/silver Composite Nanofibers for Biomedical Applications. Int. J. Electrochem. Sci. 2013; 8: 3483-3493.
13. Singh M, Singh S, Prasad S, Gambhir IS. Nanotechnology in medicine and antibacterial effect of silver nanoparticles. Dig J Nanomater Bios. 2008; 3: 115-122.
14. David E, Elumalai EK, Prasad TNVKV, Venkata Kambala, Nagajyothi PC. Green synthesis of silver nanoparticle us¬ing Euphorbia hirta L and their antifungal activities. Archives of Applied Science Research. 2010; 2: 76-81.
15. Kumar A, Vemula PK, Ajayan PM, John G. Silver-nanoparticle-embedded antimicrobial paints based on vegetable oil. Nat Mater. 2008; 7: 236-241.
16. Kumar R, Howdle S, Münstedt H. Polyamide/silver antimicrobials: effect of filler types on the silver ion release. J Biomed Mater Res B Appl Biomater. 2005; 75: 311-319.
17. Lok CN, Ho CM, Chen R, He QY, Yu WY, Sun H, et al. Proteomic analysis of the mode of antibacterial action of silver nanoparticles. J Proteome Res. 2006; 5: 916-924.
18. Gupta A, Silver S. Silver as a biocide: will resistance become a problem? Nat Biotechnol. 1998; 16: 888.
19. Tian J, Wong KK, Ho CM, Lok CN, Yu WY, Che CM, et al. Topical delivery of silver nanoparticles promotes wound healing. Chem Med Chem. 2007; 2: 129-136.
20. Huang J, Li Q, Sun D, Lu Y, Su Y, Yang X, et al. Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. Nanotechnology. 2007; 18: 105104-105115.
21. Kulkarni N, Muddapur U. Biosynthesis of Metal Nanoparticles: A Review. J. Nanotech. 2014; 1-8.
22. Sahayaraj K, Rajesh S. Bionanoparticles: synthesis and antimicrobial applications, Science against microbial pathogens: communicating current research and technological advances, FORMATEX, A. Méndez-Vilas (Ed.), 2011: 228-244.
23. Shankar SS, Rai A, Ahmad A, Sastry M. Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth. J Colloid Interface Sci. 2004; 275: 496-502.
24. Anil Kumar S, Abyaneh MK, Gosavi SW, Kulkarni SK, Pasricha R, Ahmad A, Khan MI. Nitrate reductase-mediated synthesis of silver nanoparticles from AgNO3. Biotechnol Lett. 2007; 29: 439-445.
25. Xu H, Käll M. Morphology effects on the optical properties of silver nanoparticles. J Nanosci Nanotechnol. 2002; 4: 254-259.
26. Jain D, Kumar Daima S, Kachhwaha S, Kothari SL. Synthesis of plant mediated silver nanoparticles using Pa¬paya Fruit Extract and Evaluation of their Antimicrobial Activities. Dig J Nanomater Bios. 2009; 4: 557-56.
27. Saxena A, Tripathi RM, Singh RP. Biological synthesis of silver nanoparticles by using onion (Allium cepa) extract and their antibacterial activity. Dig J Nanomater Bios. 2010; 5: 427 – 432.
28. Von White G, Kerscher P, Brown RM, Morella JD, McAllister W, Dean D, Kitchens CL. Green Synthesis of Robust, Biocompatible Silver Nanoparticles Using Garlic Extract. J Nanomater. 2012; 2012.
29. Daniel SC, Ayyappan S, Philiphan NJP, Sivakumar M, Menaga G, Sironmani, TA. Green Synthesis and Transfer of Silver Nanoparticles in a Food Chain through Chiranamous Larva to Zebra Fish - A New Approach for Therapeutics. Int J NanoSci Nanotech. 2011; 2: 159-169.
30. Sulochana S, Krishnamoorthy P, Sivaranjani K. Synthesis of silver nanoparticles using leaf extract of Andrographis paniculata. J Pharmacol Toxicol. 2012; 7: 251-258.
31. Kora AJ, Arunachala J. Green fabrication of silver nanoparticles by gum Tragacanth (Astragalus gummifer): A dual functional reductant and stabilizer. J Nanomater. 2012; 2012: 1-8.
32. Saikia D, Gogoi PK, Phukan P, Bhuyan N, Borchetia S, Saikia J. Green synthesis of silver nanoparticles using Asiatic Pennywort and Bryophyllum leaves extract and their antimicrobial activity. Adv. Mater. Lett. 2015; 6: 260-264.
33. Velusamy P, Das J, Pachaiappan R, Vaseeharan B, Pandian K. Greener approach for synthesis of antibacterial silver nanoparticles using aqueous solution of neem gum (Azadirachta indica L.). Industrial Crops and Products. 2015; 66:103–109.
34. Sinha SN, Paul D. Phytosynthesis of Silver Nanoparticles Using Andrographis paniculata Leaf Extract and Evaluation of Their

Antibacterial Activities. Spectroscopy Lett. 2015; 48: 600-604.

35. Palaniselvam K, Velanganni AAJ, Govindan SN, Karthi. Leaf assisted bioreduction of silver ions using leaves of Centella asiatica L. and its bioactivity. E- journal of life scie. 2012; 1: 46-49.

36. Dwivedi AD, Gopal K. Plant-mediated biosynthesis of silver and gold nanoparticles. J Biomed Nanotechnol. 2011; 7: 163-164.

37. Vanaja M, Annadurai G. Coleus aromaticus leaf extract mediated synthesis of silver nanoparticles and its bactericidal activity. Appl Nanosci. 2012; 3: 217-223.

38. Satyavani K, Ramanathan T, Gurudeeban S. Plant mediated synthesis of biomedical silver nanoparticles by using leaf extract of Citrullus colocynthis. J Nanosci Nanotechnol. 2011; 1: 95-101.

39. Li S, Shen Y, Xie A, Yu X, Qiu L, Zhang L, et al. Green synthesis of silver nanoparticles using Capsicum annuum L. extract. Green Chem. 2007; 9: 852–858.

40. Mohapatra B, Kaintura R, Singh J, Kuriakose S, Mohapatra S. Biosynthesis of high concentration, stable aqueous dispersions of silver nanoparticles using Citrus limon extract. Adv. Mater. Lett. 2015; 6: 228-234.

41. Farooqui MA, Chauhan PS, Krishnamoorthy P, Shaik J. Extraction of silver nanoparticles from the leaf extracts of Clerodendrum inerme. Dig J Nanomater Bios. 2010; 5: 43–49.

42. Kesharwani J, Yoon KY, Hwang J, Rai M. Phytofabrication of silver nanoparticles by leaf extract of Datura metel: Hypothetical mechanism involved in synthesis. J Bionanosci. 2009; 3: 39-44.

43. Ahmad N, Sharma S, Singh VN, Shamsi SF, Fatma A, Mehta BR,. Biosynthesis of Silver Nanoparticles from Desmodium triflorum: A Novel Approach Towards Weed Utilization. Biotechnol Res Int. 2011; 2011: 454090.

44. Ghosh S, Patil S, Ahire M, Kitture R, Kale S, Pardesi K, et al. Synthesis of silver nanoparticles using Dioscorea bulbifera tuber extract and evaluation of its synergistic potential in combination with antimicrobial agents. Int J Nanomed. 2012; 7: 483- 496.

45. Maheswari RU, Prabha AL, Nandagopalan V, Anburaja V. Green synthesis of silver nanoparticles by using rhizome extract of Dioscorea oppositifolia L. and their antimicrobial activity against human pathogens. IOSR J Pharma Biol Sci. 2012; 1: 38- 42.

46. Gnanajobitha G, Annadurai G, Kannan C. Green synthesis of silver nanoparticles using Elettaria cardamomom and assessment of its antimicrobial activity. Int J Pharma Sci Res. 2012; 3: 323-330.

47. Elumalai EK, Prasad TNVKV, Hemachandran J, Therasa SV, Thirumalai T, David E. Extracellular synthesis of silver nanoparticles using leaves of Euphorbia hirta and their antibacterial activities. J. Pharm. Sci. & Res. 2010; 2: 549-554.

48. Ramesh PS, Kokila T, Geetha D. Plant mediated green synthesis and antibacterial activity of silver nanoparticles using Emblica Officinalis fruit extract. Spectrochimica Acta A. 2015; 142: 339–343.

49. Dinesh S, Karthikeyan S, Arumugam P. Biosynthesis of silver nanoparticles from Glycyrrhiza glabra root extract. Arch Appl Sci Res. 2012; 4: 178-187.

50. Bindhu MR, Umadevi M. Synthesis of monodispersed silver nanoparticles using Hibiscus cannabinus leaf extract and its antimicrobial activity. Spectrochim Acta A Mol Biomol Spectrosc. 2013; 101: 184-190.

51. Sable N, Gaikwad S, Bonde S, Gade A, Rai MM. Phytofabrication of silver nanoparticles by using aquatic plant Hydrilla verticilata. Nus Biosci. 2012; 4: 45-49.

52. Sivakumar P, Nethradevi C, Renganathan S. Synthesis of silver nanoparticles using Lantana camara fruit extract and its effect on pathogens. Asian J Pharm Clin Res. 2012; 5: 97-101.

53. Im AR, Han L, Kim ER, Kim J, Kim YS, Park Y. Enhanced antibacterial activities of leonuri herba extracts containing silver nanoparticles. Phytother Res. 2012; 26: 1249-1255.

54. MubarakAli D1, Thajuddin N, Jeganathan K, Gunasekaran M. Plant extract mediated synthesis of silver and gold nanoparticles and its antibacterial activity against clinically isolated pathogens. Colloids Surf B Biointerfaces. 2011; 85: 360-365.

55. Mary EJ, Inbathamizh L. Green synthesis and characterization of nano silver using leaf extract of Morinda pubescens. Asian J Pharm Clin Res. 2012; 5: 159-162.

56. Ahmad N, Sharma S, Alam MK, Singh VN, Shamsi SF, Mehta BR, Fatma A. Rapid synthesis of silver nanoparticles using dried medicinal plant of basil. Colloids Surf B Biointerfaces. 2010; 81: 81-86.

57. Brahmachari G, Sarkar S, Ghosh R, Barman S, Mandal NC, Jash SK, et al. Sunlight-induced rapid and efficient biogenic synthesis of silver nanoparticles using aqueous leaf extract of Ocimum sanctum Linn. with enhanced antibacterial activity. Org. Med. Chem. Lett. 2014; 4: 18.

58. Ramteke C, Chakrabarti T, Sarangi BK, Pandey R. Synthesis of silver nanoparticles from the aqueous extract of leaves of Ocimum sanctum for enhanced antibacterial activity. J Chem., 2013; 7.

59. Ashok kumar D. Rapid and green synthesis of silver nanoparticles using the leaf extracts of Parthenium hysterophorus: A novel biological approach. Int Res J Pharma. 2012; 3: 169-173.

60. Sarkar R, Kumbhakar P, Mitra AK. Green synthesis of silver nanoparticles and its optical properties. Dig J Nanomater Bios. 2010; 5: 491 – 496.

61. Parashar V, Parashar R, Sharma B, Pandey AC. Parthenium leaf extract mediated synthesis of silver nanoparticles: a novel approach towards Weed utilization. Dig J Nanomater Bios. 2009; 4: 45–50.

62. Lokina S, Stephen A, Kaviyarasan V, Arulvasu C, Narayanan V. Cytotoxicity and Antimicrobial Studies of Silver Nanoparticles Synthesized Using Psidium guajava L. Extract. Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry 2015; 45: 426-432.

63. Sundaravadivelan C, Nalini M, Siva Prasath, Lingan Kishmu. Biolarvicidal effect of phyto-synthesized silver nanoparticles using Pedilanthus tithymaloides (L.) Poit stem extract against the dengue vector Aedes aegypti L. (Diptera; Culicidae). Asian Pac J Trop Biomed. 2011; 2012: 1-8.

64. Mallikarjuna K, Dillip GR, Narashima G, Sushma NJ, Raju BDP. Phyto-fabrication and characterization of silver nanoparticles from Piper betel broth. Res J Nanosci Nanotech. 2012; 2: 17-23.

65. Patil DC, Patil VS, Borase PH, Salunke KB, Salunkhe BR. Larvicidal activity of silver nanoparticles synthesized using Plumeria rubra plant latex against Aedes aegypti and Anopheles stephensi. Parasitol Res. 2012; 110: 1815-1822.

66. Nabikhan A, Kandasamy K, Raj A, Alikunhi NM. Synthesis of antimicrobial silver nanoparticles by callus and leaf extracts from saltmarsh plant, Sesuvium portulacastrum L. Colloids Surf B Biointerfaces. 2010; 79: 488-493.

67. Amin M, Anwar F, Janjua MRSA, Iqbal MA, Rashid U. Green synthesis of silver nanoparticles through reduction with Solanum xanthocarpum L. berry extract: characterization, antimicrobial and urease inhibitory activities against Helicobacter pylori. Int J Mol Sci. 2012; 13: 9923-9941.

68. Njagi EC, Huang H, Stafford L, Genuino H, Galindo HM, Collins JB, Hoag GE. Biosynthesis of iron and silver nanoparticles at room temperature using aqueous sorghum bran extracts. Langmuir. 2011; 27: 264-271.

69. Mondal S, Roy N, Laskar RA, Sk I, Basu S, Mandal D, Begum NA. Biogenic synthesis of Ag, Au and bimetallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (Swietenia mahogani JACQ.) leaves. Colloids Surf B Biointerfaces. 2011; 82: 497-504.

70. Nagajyoti PC, Prasad TNVKV, Sreekanth TVM, Lee KD. Bio-fabrication of silver nanoparticles using leaf extract of Saururus chinenis. Dig J Nanomater Bios. 2011; 6: 121– 133.

71. Banerjee J, Narendhirakannan RT. Biosynthesis of Silver Nanoparticles from Syzygium Cumini (L.) Seed Extract and Evaluation Of Their In Vitro Antioxidant Activities. Dig J Nanomater Bios. 2011; 6: 961–968.

72. Geethalakshmi R, Sarada D.V.L. Synthesis of plant mediated silver nanoparticles using Trianthema decandra extract and evaluation of their antimicrobial activities. Int J Eng Sci Technol. 2010; 2: 970-975.

73. Padalia H, Moteriya P, Chanda S. Green synthesis of silver nanoparticles from marigold flower and its synergistic antimicrobial potential. Arabian Journal of Chemistry (2014).

74. Shafaghat A. Synthesis and Characterization of Silver Nanoparticles by Phytosynthesis Method and Their Biological Activity. Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry 2015; 45: 381-387.

75. Singh C, Sharma V, Naik KRP, Khandelwal V, Singh H. A green biogenic approach for synthesis of gold and silver nanoparticles using Zingiber officinale. Dig J Nanomater Bios. 2011; 6: 535-542.

76. Mollick MMR, Bhowmick B, Maity D, Mondal D, Bain MK, Bankura K, et al. Green Synthesis of Silver Nanoparticles Using Paederia foetida L. Leaf Extract and Assessment of Their Antimicrobial Activities. International Journal of Green Nanotechnology 2012; 4: 230-239.

77. Roy K, Sarkar CK, Ghosh CK. Single-step novel biosynthesis of silver nanoparticles using Cucumis sativus fruit extract and study of its photcatalytic and antibacterial activity. Dig J Nanomater Bios. 2015; 10: 107–115.

78. Vanaja M, Paulkumar K, Baburaja M, Rajeshkumar S, Gnanajobitha G, Malarkodi C, Sivakavinesan M. Degradation of methylene blue using biologically synthesized silver nanoparticles. Bioinorg Chem Appl. 2014; 2014: 742346.

79. Chandran SP, Chaudhary M, Pasricha R, Ahmad A, Sastry M. Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract. Biotechnol Prog. 2006; 22: 577-583.

80. Bar H, Bhui DK, Sahoo GP, Sarkar P, De SP, Misra A. Green synthesis of silver nanoparticles using latex of Jatropa curcas. Colloids. Surf A: Physico. Eng. Asp. 2009; 339: 134-139.

81. Huang J, Li Q, Sun D, Lu Y, Su Y, Yang X, et al. Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf. Nanotech. 2007; 18: 105104-105115.

82. Gardea-Torresdey JL, Gomez E, Peralta-Videa JR, Parsons JG, Troiani H, Jose-Yacaman M. Alfalfa sprouts: a natural source for the synthesis of silver nanoparticles. Langmuir 2003; 19: 1357–1361.

83. Shankar SS, Rai A, Ahmad A, Sastry M. Rapid synthesis of Au, Ag, and bimetallic Au core-Ag shell nanoparticles using Neem (Azadirachta indica) leaf broth. J Colloid Interface Sci. 2004; 275: 496-502.

84. Sathishkumar M, Sneha K, Won SW, Cho CW, Kim S, Yun YS,. Cinnamon zeylanicum bark extract and powder mediated green synthesis of nano-crystalline silver particles and its bactericidal activity. Colloids Surf B Biointerfaces. 2009; 73: 332-338.

85. Sathyavathi R, Krishna MB, Rao SV, Saritha R, Rao DN. Biosynthesis of silver nanoparticles using Coriandrum sativum leaf extract and their application in nonlinear optics. Adv. Sci. Lett. 2010; 3: 138–143.

86. Yadav A, Rai M. Bioreduction and Mechanistic Aspects Involved in the Synthesis of Silver Nanoparticles Using Holarrhena antidysenterica. Journal of Bionanoscience 2011; 5: 70–73.

87. Gade A, Gaikwad S, Tiwari V, Yadav A, Ingle A, Rai M. Biofabrication of Silver Nanoparticles by Opuntia ficus-indica: In vitro Antibacterial Activity and Study of the Mechanism Involved in the Synthesis. Current Nanoscience, 2010; 6: 370-375.

88. Gudadhe JA, Yadav A, Gade A, Marcato PD, Durán N, Rai M. Preparation of an agar-silver nanoparticles (A-AgNp) film for increasing the shelf-life of fruits. IET Nanobiotechnol. 2014; 8: 190-195.

89. Mude N, Ingle A, Gade A, Rai M. Synthesis of Silver Nanoparticles Using Callus Extract of Carica papaya – A First Report. J. Plant Biochemistry & Biotechnology 2009; 18: 83-86.

90. Priya MM, Selvia BK, Paul JAJ. Green synthesis of silver nanoparticles from the leaf extracts of Euphorbia hirta and Nerium indicum. Dig J Nanomater Bios. 2011; 6: 869 – 877.

91. Manikandan D, Prakash DG, Gandhi NN. A Rapid and Green Route to Synthesis of Silver Nanoparticles from Plectranthus Barbatus (Coleus Forskohlii) Root Extract for Antimicrobial Activity. International Journal of ChemTech Research 2014; 6: 4391-4396.

92. Joseph S, Mathew B. Microwave assisted facile green synthesis of silver and gold nanocatalysts using the leaf extract of Aerva lanata. Spectrochim Acta A Mol Biomol Spectrosc. 2014; 136PC: 1371-1379.

93. Sharma G, Sharma AR, Kurian M, Bhavesh R, Nam JS, Lee SS. Green synthesis of silver nanoparticle using Myristica fragrans (nutmeg) seed extract and its biological activity. Dig J Nanomater Bios. 2014; 9: 325 – 332.

94. Ramar M, Manikandan B, Marimuthu PN, Raman T, Mahalingam A, Subramanian P, et al. Synthesis of silver nanoparticles using Solanum trilobatum fruits extract and its antibacterial, cytotoxic activity against human breast cancer cell line MCF 7. Spectrochimica Acta A 2014; 140: 223–228.

95. Tamuly C, Hazarika M, Bordoloi M, Bhattacharyya PK, Kar R. Biosynthesis of Ag nanoparticles using pedicellamide and its photocatalytic activity: an eco-friendly approach. Spectrochim Acta A Mol Biomol Spectrosc. 2014; 132: 687-691.

96. Singhal G, Bhavesh R, Kasariya K, Sharma AR, Singh RP. Biosynthesis of silver nanoparticles using Ocimum sanctum (Tulsi) leaf extract and screening its antimicrobial activity. J Nanopart Res. 2011; 13: 2981–2988.

97. Jiang J, Oberdorster G, Biswas P. Characterization of size, surface charge and agglomeration state of nanoparticle dispersions for toxicological studies. Nanopart Res. 2009; 11: 77-89.

98. Feldheim DL, Foss CA. Metal nanoparticles: synthesis, characterization and applications. Boca Raton, FL; CRC Press. 2002.

99. Sepeur S. Nanotechnology: technical basics and applications. Hannover: Vincentz. 2008.

100. Shahverdi AR, Shakibaie M, Nazari P. Basic and practical procedures for microbial synthesis of nanoparticles. In: Rai M, Duran N, editors. Metal nanoparticles in microbiology. Berlin: Springer, 2011; 177-97.

101. Schaffer B, Hohenester U, Trugler A, Hofer F. High resolution surface plasmon imaging of gold nanoparticles by energy-filtered transmission electron microscopy. Phys Rev B 2009; 79.

102. Chithrani BD, Ghazani AA, Chan WC. Determining the size and shape dependence of gold nanoparticle uptake into mammalian cells. Nano Lett. 2006; 6: 662-668.

103. Sun S, Murray CB, Weller D, Folks L, Moser A. Monodisperse FePt nanoparticles and ferromagnetic FePt nanocrystal superlattices Science. 2000; 287: 1989-1992.

104. Strasser P1, Koh S, Anniyev T, Greeley J, More K, Yu C, Liu Z. Lattice-strain control of the activity in dealloyed core-shell fuel cell catalysts. Nat Chem. 2010; 2: 454-460.

105. Brongersma HH, Draxler M, Ridder De M, Bauer. Surface composition analysis by low-energy ion scattering. Surface Science Reports 2007; 62: 63–109.

Email: swaruproy@klyuniv.ac.in , swaruproy2013@gmail.com

Cite this article

Roy S, Das TK (2015) Plant Mediated Green Synthesis of Silver Nanoparticles-A Review. Int J Plant Biol Res 3(3): 1044.