International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Unveiling Biological Synthesis of Metal Nanoparticles, their Characterization and Scopes: A Review

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Abstract
Due to their distinct physico-chemical characteristics and prospective uses in a variety of disciplines, nanoparticles (NPs) have attracted a lot of attention recently, including plant science. Green synthesis methods, which utilize environment friendly and sustainable approaches, have shown to be an effective approach to fabricate NPs for plant-related applications. This paper seeks to give a general overview of the green synthesis methods used to create nanoparticles and their uses. We discuss the advantages of green synthesis, including reduced environmental impact and enhanced biocompatibility. Furthermore, it highlights the properties, characterization, synthesis of nanoparticles and potential roles of green synthesized nanoparticles in agricultural, antitumor, oxidative, larvicidal and microbial activity.

Key words: Plants, Metal nanoparticles, Biogenic reduction, Nanotechnology,Biological applications

1. Introduction

Nanotechnology is an area of research and development that is concerned with 'effects' on structure at the scale of atoms and molecules, usually speaking, in materials and electronics. The most active research field into material science and the nanoparticles (NPs) creation is the field of nanotechnology. Taking into mind specific parameters, such as size, shape, and structure, nanoparticles exhibit increased qualities (Jahn, 1999; Slawson*et al.*, 1992; Nalwa, 1999). NPs are broadly dividedinto two types- one type is organic NPs and the other type is inorganic NPs. Among these types the inorganic nanoparticles incorporate mostly semi-conductor nanoparticles such as ZnS or ZnO, magnetic nanoparticles, for example- Ni, Co and Fe and also metallic nanoparticles such as Au, Cu, Ag, Al while organic nanoparticles incorporate nanoparticles containing carbon, for example- quantum dots along with nanotubes containing carbon. As they offer exceptional qualities with helpful inflexibility, gold and silver nanoparticles are gaining popularity (Vadlapudi&Kaladhar, 2014). Compared to larger molecules with the same chemical constitution, the silver nanoparticles have a considerable surface zone that results in biological reactivity, catalytic activity, and atomic bearing (Xu et al., 2006). Nanoparticles have different physical properties including strength, colour, magnetic and thermodynamic properties in the exploration and development field. These include biological, optical, electrical, and thermal characteristics, as well as strong electrical conductivity. They're also suitable for a variety of objectives because of their peculiar properties such as optic detectors, health-care related products, antibacterial agents, in diagnostics, in dietary supplements, in food industry, medical-device coatings, in delivery of medicines, in synthetic products, in household products and also in cosmetics, in the pharmaceutical industry, orthopaedics and eventually in enhancing the ability to destroy tumor by the use of chemotherapy drugs. (Chernousova&Epple, 2013). Synthesis of nanoparticles involved two approaches. The chemical approach and approach including green-synthesis is called as bottom-up and physical methodology is included in approach designated as top-down.

The process of milling generates small atoms from the corresponding bulk material in top-down approaches. In bottom-up approaches, the work of nanoparticles starts from atomic degree. There are several different ways to create nanoparticles, including physical, chemical, and natural methods. For NPs creation, physical manufacturing and chemical manufacturing process are not favored over biological synthesis processes. In the biosynthesis processes that result in the creation of NPs, fungal species, bacterial strains, algae and extracts of plants serve as intermediates. Natural approaches are less damaging to the environment than conventional ones (Hulkoti&Taranath, 2017). AgNPs that are prepared by biological methods exhibit good yield, solubility, and stability (Gurunathan*et al.*, 2015). The metal ions are bio-reduced into their most basic state in the size range of 1–100 nm is a key component in the green synthesis of nanoparticles. Among the several ways to create nanoparticles synthetically, biological methods seem to be easy, quick, and safe. Green synthesis techniques have an advantage over traditional methodologies because of the involvement of chemical agents whose effects on the environment are detrimental in nature. Different nanoparticles, including those of zinc oxide, silver, gold, palladium, and iron, have efficiently been created by green synthesis. Phytocompounds such as polysols, terpenes along with polyphenols that are found in extracts of plant are the substances in charge of bio-reducing metallic ions. The reduction of nanoparticles with the use of phytocompounds have extraordinary antibacterial, antioxidant, and catalytic characteristics, which are inferred from the nanoparticles as a result of this process. Numerous NPs applications have made use of these qualities, including industry concerned with delivery or supply of drugs, food industry, cosmetics and also the pharmaceutical industry. To fully utilize any nanomaterial for human interest, in nanomedicines, or in the healthcare sector, there are various safety concerns. Before use, the prepared nanoparticles must be characterized (Lin *et al.*, 2014; Pleus*et al.*, 2012). Before determining a substance's toxicity or level of biocompatibility, identifying the distinguishing characteristics of NPs, for example-aggregation of NPs, size, surface area to be considered, solubility, shape of NPs is essential (Murdock *et al*., 2008).

2. Characteristics of Nanoparticles

Nanoparticles have a variety of features that make them useful in different scientific and technological domains. Following is a list of some of them.

2.1 Optical and Electronic Characteristics

The interdependence between electrical and optical characteristics is extensive. NPs of noble metal elements have optical features which are mainly dependent on size and exhibit potent band that is not found in the heavy metal's spectra. The Ultraviolet-Visible excitation band, often referred to as LSPR, is produced when the frequency of the photons remains unchanged. The inter-particle spacing along with range and form of NPs play an important role in wavelength of spectra. Apart from this, the LSPR spectra peak wavelength is affected by the presence of adsorbates, solvents and the presence of substrates that is present in the original medium (Eustis & El- Sayed, 2006).

2.2 Magnetic Properties of nanoparticles

The investigators from several disciplines have shown their interest in various fields, including data storage, MRI, two types of catalysis - homogenous along with heterogeneous catalysis, magnetic fluids, the clean-up of the environment identical to decontamination of water, bio-medicine have expressed interest in magnetic nanoparticles. According to studies, NPs perform best at sizes between 10 and 20 nm, which is below the critical value (Reiss &Hütten, 2005). The magnetic characteristics of NPs were successfully managed at a corresponding low scale (Faivre&Bennet, 2016; Priyadarshana, 2015; Reiss &Hütten, 2005; Zhu, 1994). The magnetic property of NPs results from the random electronic dispersion. These characteristics depend on various synthetic techniques. (Qi, 2016) (Wu *etal*., 2008).

2.3 Adhesion, Friction and Movement of NPs

The role of friction and the role of adhesion in colloidal stabilization, drug transport, micro/nano device design, lubrication, and nanofabrication is quite important. The two thirds power of the circumference was used to calculate the substrate's frictional forces in relation to the particles' frictional forces. The adhesion behaviour may be affected and by the change in exterior energy caused by distortion of the particles, the surface's chemical makeup and at last by how terminal groups are arranged on the surfaces of particles. Theactivity of NPs in the media is influenced by a variety of factors, including gravitational (buoyancy), surface, viscous inflow, and brownian movement forces. After colliding in a liquid, adsorbed NPs on a surface which is solid were considerably more easily removed than those formed on dry surfaces (Xu *et al*., 2005).

2.4 Thermal Conductivity of NPs

Thermal conductivities of NPs consisting of metal is greater than those of solid-state fluids. Even oxides like alumina (Al_2O_3) have a better heat conductivity than water. Therefore, it is anticipated that the particle suspension in a liquid will exhibit significantly improved thermal conductivity in comparison to those of conventional heat transfer fluids. In liquids like water, ethylene glycol, or oils, solid particles are dispersed to create nanofluids. Incorporating particles with a large overall surface area is preferred since heat transfer occurs at their surface. The stability suspension is further enhanced by the huge total surface area (Lee *et al.*, 1999). Recent research has shown that fluids made of copper oxide nanoparticles (CuO NPs) in water or ethylene exhibit advanced thermal conductivity (Cao, 2002).

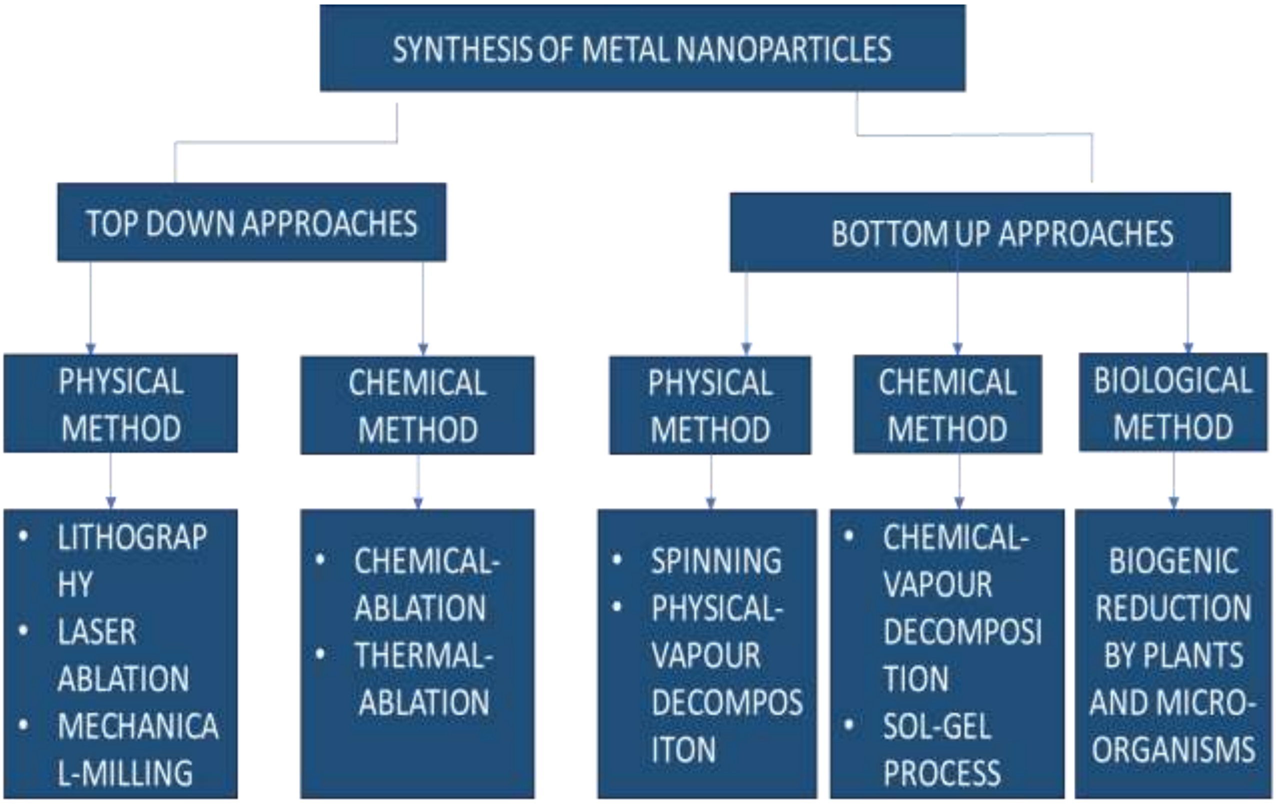

Fig. 1 Top-down and Bottom-up Approaches for Synthesis of Nanoparticles.

3. Synthesis ofnanoparticles –

The process of NP synthesis involves two approaches- top down and bottom-up synthesis of NPs.

3.1 Top- down synthesis

The method involves destructive synthesis. In this process, larger molecules having big sizeget decomposed into molecules having small size.NPs are created by converting tiny molecules. The examples of this method are as follows- Lithography, Mechanical milling, Laser ablation, Chemical and thermal ablation (Iravani*et al.*, 2011).The mechanical milling is a technique for transferring K.E. (Kinetic energy) from the grinding medium to the substance that is being reduced. This technique is utilized for making various metal alloys.In laser ablation method, varying solvent is used for NPs synthesis (Amendola et al., 2009).The chemical and physical process are quite costly and it requires harmful, toxic and hazardous chemicals. So, these methods are less effective.

3.2 Bottom-up synthesis

In this method, constructive approach is followed. It involves NPs formation from simpler to complex substances. This method includes spinning, physical vapour decomposition, chemical vapour decomposition, sol-gel process and biogenic reduction of NPs. In sol-gel process sol is transformed into gel. It is a simple process and most used process (Ramesh, 2013). In chemical vapour decomposition method, pure and regular-shaped NPs are formed. This method is disadvantageous because it needs complex apparatus and the by-products are toxic in nature (Adachi *et al.*, 2003).In spinning method, first of all fusion of molecules takes place. After this step precipitation step takes place followed by collection and drying step. This process is quite simple and cost-effective. The technique used for NPs formation in industries is pyrolysis. In this technique, the preparatory material is ignited using flame. The preparatory material could be either a liquid or a vapor. To obtain the NPs the precursor is introduced into furnace under quite high pressure (Kammler*et al.*, 2001).It also involves biogenic reduction of NPs.

4. Biological Synthesis of Nanoparticles

Nanoparticles can be produced by a variety of methods - physical, chemical or biological routes. However, while nanoparticles are created physically or chemically, it is toxic and create harmful problems and environmental dangers. Due to these factors, green nanotechnology was considered a novel way to make nanoparticles leading to its demand. Among all these three methods green NPs synthesis is seen as an easier, less expensive, and environmentally benign approach. Recently, it has grown significantly in relevance. The living organisms, for examples- plants or their various parts, fungi or bacteria play a key role in the manufacture of nanoparticles called as green nanotechnology. This process involves various biotechnological approaches. The NPs formed by this technology are harmless to the environment and free of any hazardous substances.

4.1 Plant Mediated Nanoparticles Synthesis

The creation of clean and ecologically acceptable nanoparticles using the widely acknowledged "green chemistry" idea, which encompasses bacterial species, fungal species and plant extract, etc., is referred to as "green synthesis"(Pal *et al.*, 2019). It is thought that biosynthesis of nanoparticles utilizing the aforementioned organisms is a more environment friendly method of producing nanoparticles with novel properties (Mohanpuria*et al.*, 2008).

As they require less upkeep and are more economical, plants are referred as the natural equivalent of chemical factories. Because even at extremely low concentrations certain metals are hazardous, in the detoxification of heavy metals plants serve a crucial part, which could help in solving the problem of environmental pollution (Shahid *et al*., 2017). The use of plant extract in the synthesis of nanoparticles is favourable in comparison to other biological synthesis methods, such as those involving microbes, which necessitate laborious procedures for the microbial culture preservation (Taranath and Hulkoti 2014). Due to the abundance of phytochemicals that are present in plants, various plant parts, including fruit, leaves, stems, and roots, are widely utilized for the green synthesis of NPs. The plant-assisted NPs formation is quite advantageous because the kinetics of this process is significantly higher compared to other methods of biological origin and also practically at par with those of chemical nanoparticles creation (Iravani, 2011). The plant parts that must be employed in the synthesis of nanoparticles are carefully cleaned before being squeezed, filtered, and mixed with the appropriate solutions for the type of NP synthesis. Fe, Ag and AuNPs have been created by the use of a green method of synthesis (Singh *et al*., 2018). Terpenoids and polyphenols, two phytocompounds found in plant extract, are responsible for the bio reduction of metallic ions. (Ovais*et al*., 2018).

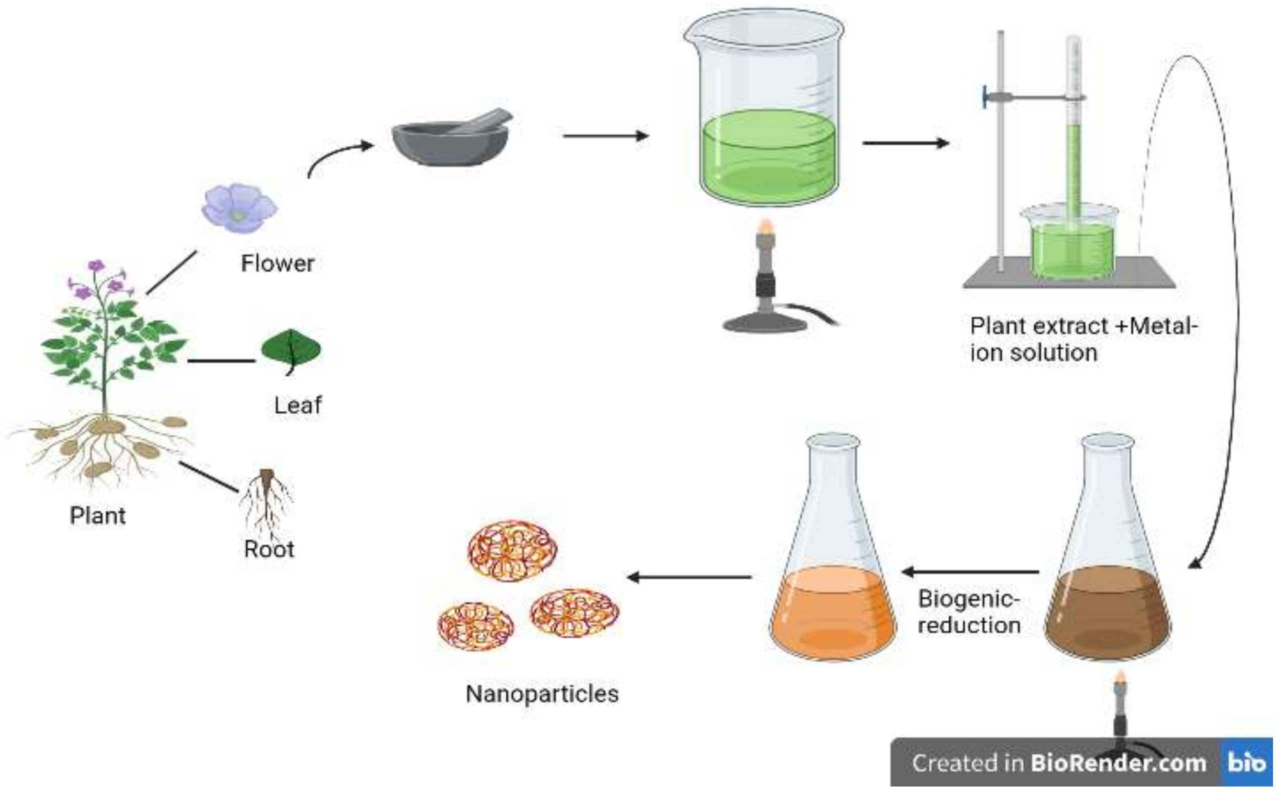

Fig.2 – Synthesis of nanoparticles using extract of plants

Assembling silver nanoparticles using plants has grown in popularity lately because of its quick, environment benign, non-pathogenic, and economical protocol. The simplest and least expensive method to create silver nanoparticles is to reduce and stabilize silver ions using a mixture of biomolecules that are already present in plant extracts (Roy & Das, 2015). The fundamental use of employing extracts made from plants for the manufacture of NPs is that they are non-toxic, readily available, containing a wide range of plant-metabolites and they are also safe that are quite beneficial in the reduction of Ag ions & are synthesized more quickly compared to various microorganisms. The primary mechanism taken into account for this procedure is plant-assisted reduction because phytochemicals are present in the extract (Sondi*et al.*, 2004).

Table 1- Green synthesis of NPs by extracts of plant parts.

Plant	**Parts of plant**	**Size of NPs(nm)**	**Type of NPs**	**Shape of NPs**	**Application of NPs**	**References**
P. bengalensis	Leaves	10-50	Au	Triangular	Degradation of methylene blue	Paul *et al.*, 2015
Lantana camara	Flower	4-12	Au	Spherical	Anti-oxidant activity	Kumar *et al.*, 2016 b
Vetiveriazizanioides	Roots	10-35	Au	Spherical	Antifungal activity	Swain *et al.*, 2016
Parkiaroxburghii	Leaf	5-25	Au,	Spherical	Antibacterial,	Paul *et al.*,

			Ag		Photocatalytic activity	2016
Calliandrahaemacephala	Leaf	70	Ag	Spherical	Hydrogen-peroxide sensing ability	Raja *et al.*, 2017
Couroupitaguianensis	Leaf	10-12	Ag	Spherical	Control of mosquito	Vimala *etal.*, 2015 b
Capparis spinosa	Leaf	5-30	Ag	Spherical	Anti-bacterial activity	*Benakashani et al., 2016*
Camelliasilensis	Leaves	5-8	Pd	Spherical	Suzuki-Miyaura coupling	Lebaschi*et al.*, 2017
Rosacanina	Fruit extract	10-33	Pd	Spherical	Suzuki-Miyaura coupling	Veisi*et al.*, 2016
Malvasylvestris	Leaf	5-30	CuO	Monoclinic	Antibacterial activity	Kuppusamy *et al.*, 2016
Eichhornia crassipes	Leaf	20–80	Fe	Spherical	-	Wei *et al.*, 2017
Eucalyptus	Leaf	20–80	Fe	Poly-dispersed	Removal of Chromium (VI) and Copper (II)	Weng *et al.*, 2016
Eucalyptus	Leaf	20–80	Fe	Spheroidal	Role in eutrophic wastewater	Wang *et al.*, 2014b
Psoraleacorylifolia	Seeds	39	α-Fe2O3	Spherical, Rod-like and Uneven	Cancer cells	Nagajyothi*et al.*, 2016
Catharanthusroseus	Leaves	38	Pd	Spherical	Clean-up of textile wastewater	Kalaiselvi*et al.*, 2015
Crotonsparsiflorus	Leaves	22-52	Ag	Spherical	Effective against *B. subtilis, S. aureus, E. coli*	Kathiravan*et al.*, 2015
Dioscoreabatatas	Rhizome	-	Ag	Spherical	Antimicrobial activity *against C. albicans and S. cerevisiae*	Nagajyothi and Lee 2011
Sorghum	bran powder	50	Fe, Ag	-	Environmental remediation and treatment of hazardous waste	Njagi*et al.*, 2011
Gloriosasuperba	Leaves	36	Ru	-	Effective against gram+ve than gram -ve bacteria	Gopinath *et al.*, 2014
Dodonaeaviscosa	Leaf	12-20	Ag	Irregular	Anticancer	Anandan*et*

	extract				Antibacterial andproperty	*al.*, 2019
Meliaazedarach	Leaf extract	18-30	Ag	Spherical	Antifungal property	Jebril*et al.*, 2020
Prunusserrulata	Fruit extract	65	Au	Spherical, Hexagonal	In-vitro anti-inflammatory activity	Singh *et al.*, 2018
Cucurbitapepo L.	Leaves	10-15	Au	Spherical	Plant-ageing	Gonnelli*et al.*, 2018
Plantagomajor	Leaf extract	4.6-30.6	Fe	Spherical	Catalyst for azo-dye decoloration	Lohrasbi*et al.*, 2019
Calotropisprocera	Leaf extract	32	Fe	Orthorhombic	Antifungal capability against *Alternariaalternata*	Ali *et al.*, 2020

4.2 Nanoparticles generation by bacteria

As bacteria have the ability to create various inorganic materials either intra cellularly or extra cellularly, they are thought to be the main source of biological factories for the manufacture of nanoparticles from metals. The biocidal abilities of silver are widely recognized. However, certain bacteria are silver-resistant (Paulkumar*et al.*, 2013) Additionally, they concentrate silver on their cell well to a significant level of twenty-five percent of their dry weight in biomass, stating their application to industry (Pooley,1982). Earliest validation of bacteria synthesizing Ag nanoparticles was demonstrated utilizing strain of '*Pseudomonas stutzeri* AG259' (Prabhu S &Poulose EK, 2012).

4.3 Synthesis OF NPs by using fungi

Various species of fungi are employed to create metallic nanoparticles because they have bacterial-like tolerance, the ability to bioaccumulate metals and high binding capacity. Numerous fungi, including *Fusarium* species and species of *Colletotrichum*and *Phaenerochaete*have been utilized for nanoparticles creation (Vigneshwaran*et al.*, 2003) (Shankar *et al.*, 2003) (Mukherjee *et al.*, 2002). The production of nanoparticles from fungi is preferred to other microorganisms because it grows faster, is easier to work with and generate in a lab setting in comparison to bacteria. In bioreactors or different reaction chambers, fungal mycelial mesh can withstand a variety of circumstances, including flow pressure and agitation.

At the beginning, *Verticillium* (a fungus) was used to synthesize Ag NPs that had a 25–12 nm radius. This was the first metal nanoparticles creation using fungus mediated methods. (Mukherjee *et al.*, 2001). The form and range of the intracellular gold NPs altering corresponding to the pH variations in the medium when *Verticilliumluteoalbum* was utilised in the experiment (Gericki& Pinches, 2006). The extract of *Volvariellavolvacea* (saprophytic fungus) was used in extracellular biological creation of nanoparticles, resulted in the formation of Ag, Au and also Au-Ag nanoparticles (Philip, 2009).

4.4 Algae mediated nanoparticles generation

According to numerous research, algae are frequently used in the creation of nanoparticles. Protein-mediated Au nanoparticle production, which produces particles with an average size of about 5 nm, has been carried out using the blue-green algae *Spirulina platensis*. These were tested for antibacterial efficacy over the bacteria *Bacillus subtilis* and *Staphylococcus aureus* as well. (Suganya*et al.*, 2015). It has been demonstrated that *Sargassumwightii* , commonly known as brown sea-weed has been shown to generate durable, uniformly dispersed Au nanoparticles with sizes between 8 and 12 nm as verified by TEM, XRD and UV–visible spectroscopy (Singaravelu*et al.*, 2007). In a similar manner, Ag NPs were also created using species of *Sargassum* and its capacity to fight germs was tested. (Govindaraju*et al.*, 2009). Nanoparticles of gold, EPS-gold, and silica with the help of diatoms like *Naviculaatomus* and *Diadesmis* gallica, Au bio nano composites have been created (Schrofel*et al.*, 2011).

Table 2- Biological synthesis of NPs by various micro-organisms.

Micro-organism	**Type**	**Size(nm)**	**Nanoparticle type**	**Shape of NPs**	**Applications**	**References**
Bacillus cereus	Bacteria	4-5	Silver	Spherical	Catalysis, Microelectronics	Ganesh Babu and Gunasekaran, 2009
Bhargavaeaindica	Bacteria	30-100	Silver and gold	Flower and anisotropic	Anti-microbial activity	Singh *et al.*, 2015a, 2015b
Pseudomonas deceptionensis	Bacteria	10-30	Silver	Spherical	Antibiofilm and antimicrobial activity	Jo *et al.*, 2016
Weissellaoryzae	Bacteria	10-30	Silver	Spherical	Antibiofilm and antimicrobial activity	Singh *et al.*, 2016
Aspergillustamarii	Fungus	3.5	Silver	Spherical	-	Devi and Joshi, 2015
Fusariumoxysporum	Fungus	5-15	Silver	Spherical	-	Zhao *et al.*, 2018
Pencilliumochrochloron	Fungus	7.7	Silver	Spherical	-	Devi and Joshi, 2015
ActinomycetesStreptomycetes sp.	Actinomycetes	5	Silver	Spherical	Acaricidal	Karthik *et al.*, 2014
Candida utilis NCIM 3469	Yeast	20-80	Silver	Spherical	Antibacterial	Waghmare *et al.*, 2015
Yarrowialipolytica	Yeast	15	Silver	Spherica	Antibiofilm	Apte*et al.*,

				l		2013
Sargassummuticum	Algae	18	Iron	Cubic	Biomedical	Mahdavi *et al.*, 2013
Bifurcaria bifurcate	Algae	5-45	Copper	Spherical, Elongated	Medical, environmental, Pharmaceutical	Abboud*et al.*, 2014
Chlorella vulgaris	Algae	2-10	Gold	Spherical	Capping agent and medical field	Annamalai and Nallamuthu, 2015
Lemaneafluviatilis	Algae	5-15	Gold	Cubic	Radical scavenging activity, antioxidant activity	Sharma *et al.*, 2014
Sargassummuticum	Algae	30-57	Zinc	Hexagonal	Biomedical and pharmaceutical	Azizi *et al.*, 2014

5. Techniques Used for Nanoparticles Characterization

Following their creation, nanoparticles' structural characteristics, including size, shape, uniformity along with morphology of surface, are assessed using a variety of techniques. The widely used techniques for NPs characterization for determination of form and size-range of NPs in an aqueous suspension are XDR, SEM, FTIR, TEM, DLS, EDX analysis, Ultraviolet-visible spectroscopy etc (Rajesh *et al*..2009). The wavelengths between 300 to 800 nm are used in order to characterize nanoparticles with sizes between 2 and 100 nm, (Feldheim and Foss, 2002). SEM and TEM are carried out to characterize the range of nanoparticles and also the morphology (Schaffer *et al.*, 2009). Green synthetic carbon nanotubes were completely encircled by polyaniline layers in the study of SEM and TEM (Nguyen and Shim, 2015). Spherical shaped agglomerated TiO2 particles with a size between 10 and 30 nm are visible in the TEM investigation. Likewise, crystalline shape is indicated by the ‘selected area electron diffraction’ (Dhandapani *et al.*, 2012). XRD provides data on the size, phase identification, and translational symmetry of metal-based nanoparticles (Sun *et al.*, 2000). The penetration of X-rays and the observed diffraction pattern is compared with respect to standard measures for structure-related information (Arumugama*et al.*, 2015). Lead nanoparticles' crystalline pattern was validated by an XRD analysis, and the Scherer equation was used to calculate the average particle size (Elango and Roopan, 2015). FTIR spectroscopy identifies the types of functional groups or we can say the kind of metabolites that are found on the NPs surface and could be in charge of stabilizing and reducing nanoparticles. (Sankar *et al*. 2014). FTIR spectrum of Ag nanoparticles synthesized by plant *Solanumtuberosum* displayed peaks at 1648, 1535, 1450 and 1019 cm by utilizing leaf extract (Govindaraju*et al.*, 2010).

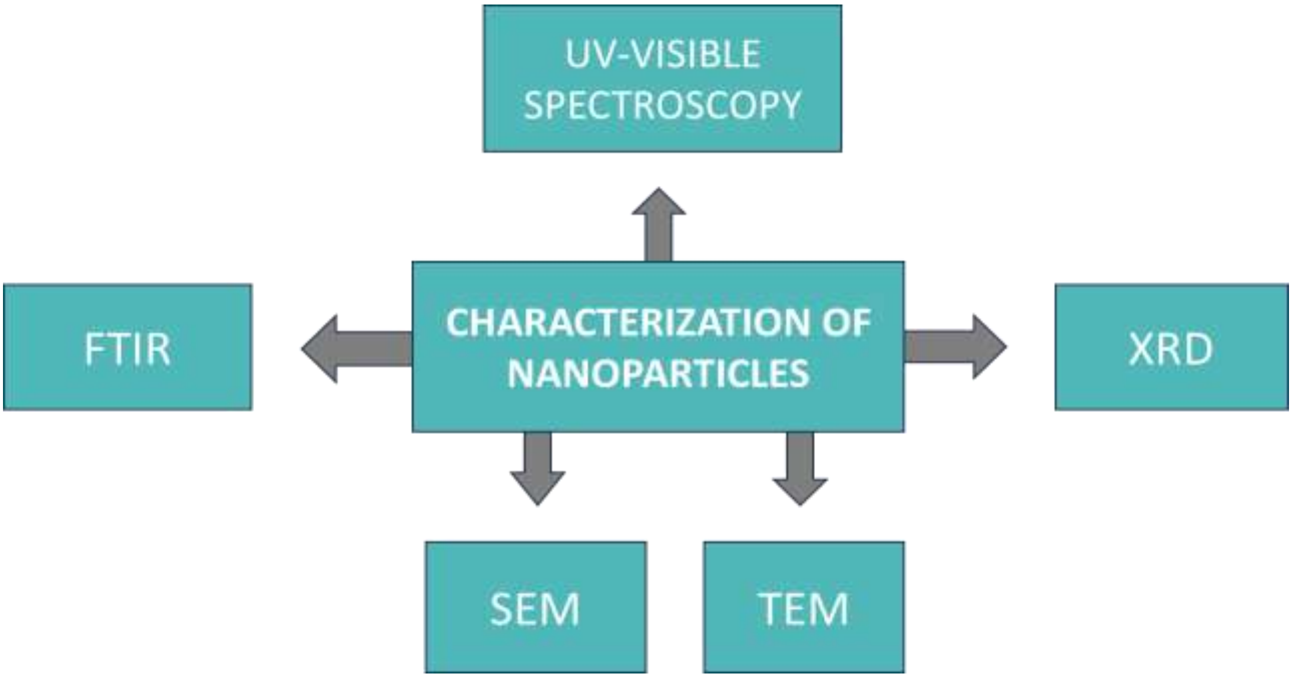

Fig. 3 Basic Techniques used for characterization of nanoparticles.

6. Factors Impacting Nanoparticles' Green Synthesis

The nanoparticles production and stabilization produced by biological organisms are influenced by a variety of variables, including reaction time or duration, pressure, temperature and pH of reaction solution. The following are some of the variables that affect the creation of biogenic nanoparticles:

6.1 Duration

The quality and shape of nanoparticles are significantly influenced by the length of incubation time for reaction (Darroudi*et al.*, 2011). The effects of time fluctuations on the properties of synthesized nanoparticles are similar to those of other parameters, such as light exposure, synthesis process, and storage conditions (Mudunkotuwa*et al.*, 2012). Long period incubation of nanoparticle may promote shrinkage and aggregation, which could reduce the potential of the nanoparticles. (Baer, 2011).

6.2 pH of Reaction medium

The production of nanoparticles is significantly influenced by the pH of the reaction media (Gericke & Pinches, 2006). The NPs form and size show great variance depending on the concentration of H+ ion. Additionally, the observation was that the larger nanoparticles are formed at lower pH levels of acidity than at higher pH levels. (Dubey *et al.*, 2010).

6.3 Role of temperature

By directly influencing range and structure of the resultantNPs, creation of metallic nanoparticles depends considerably on temperature. Reduced temperatures for reaction were demonstrated to form nanotriangles, whereas at higher temperatures, more spherical nanoparticles were produced (Raju *et al.*, 2011).

6.4 Effect of Pressure

Additionally, as it influences size and form of the synthesised NPs, pressure plays a crucial role in metallic NPs formation (Abhilash *et al.*, 2012). As per various studies, the phytochemical agents that results in the reductive process of NPs occured more quickly than usual when ambient pressure conditions were present (Tran and Le, 2013).

7. Nanoparticlesapplicationsinvariousfields

7.1 Agricultural uses of NPs

Zinc oxide nanoparticles from lemon fruit against the soft rot bacterium pathogen illustrate the extensive agricultural interest in these particles by having an anti-phytopathogenic effect against bacteria. the soft rot-causing *Dickeyadadantii*(Hossain *et al*., 2019), and ZnO NPs made with Eucalyptus globule extract have fungicidal efficacy against the majority of pathogens in apple orchards (Ahmad *et al*., 2020). When compared to zinc oxide nanoparticles, the titanium oxide nanoparticles made from lemon fruit have antibacterial action against *D. daantii*(Hossain *et al*., 2019). The deleterious effects of salinity stress on wheat plants were greatly reduced by silver nanoparticles made from wheat extract by altering the quantity of abscisic acid, defence mechanisms, and ion homeostasis, which included both enzymatic and non-enzymatic antioxidants (Wahid *et al*., 2020). Less toxic and capable of triggering the antioxidant response in flax seedlings, zinc-oxide nanoparticles displayed these properties. (Zaeem *et al*., 2020).

7.2 Nanoparticles activity against tumor

The apoptotic dysregulation results in sudden death of organ is associated with a number of clinical conditions. Additionally, irregular cell survival brought on by faulty apoptosis may result in the creation of lumps (Zörniga*etal*., 2001). Cancerous cells typically exhibit altered apoptosis, and they have the ability to circumvent the normal apoptotic process. The frequency of programmed cell death was substantially enhanced by the silver nanoparticles that were created using extract of *Achilleabiebersteinii*. It was demonstrated that the silver nanoparticles made from *Achilleabiebersteinii* can be used as an anti-tumor agent since they prevented cell proliferation and did so in a time-dependent manner (Zörniga*et al*., 2001).

7.3Insecticidal activity of nanoparticles against larva

A particularly anthropophilic species, *Ae. aegypti* has been able to spread throughout the tropical regions of the world and survive in human settlements (Cook & Zumla, 2012). The mosquito becomes infectious when the pathogen is produced in its saliva, and it spreads the disease each time it feeds on the blood of a host (Sardar *et al*., 2015). Since this insect spreads viral diseases, there is apparently no vaccination against them that is commercially accessible. The larvicides derived from plants contain a variety of chemical components that combine to effectively target various biological pathways, which prevents their targets from developing resistance to them. (Benelli *et al.*, 2017).

The creation of silver nanoparticles made from plant extracts as capping, stabilising as well as reducing agents is an alluring substitute for larvicides (Priyadarshini *et al.*, 2012). The propensity of silver nanoparticles made from plants to evade through invertebrate exoskeletons and enter insect cells, where they attach to macromolecules like proteins and DNA and change its structure and functioning, is a physiological cause for the high toxicity of these particles (Arjunan*et al.*, 2012).

7.4Antimicrobial activity

The Artemisia species are aromatic and therapeutic plants that have a long history of usage in traditional cuisine (Obolsky*et al*., 2011). They have been diligently used in varied purposes, such as-common cold, chills, coughs, stomach-ache, purgative effect; cataplasm, inhalation, insects-pest repellent (Graven *et al*., 1992); a vermifuge, as an antispasmodic and antiseptic in the treatment of severe illnesses and for liver inflammation (Weyerstahl*et al*., 1997). Numerous active compounds found in Artemisia species, including phenolic composites and essential oils, have strong properties against bacteria and also fungi. The hydrophilic outer barrier that may prevent the passage of hydrophobic combinations into the target bacterial cell membrane has been linked to Gram-negative bacteria's resistance to plant extract and essential oils (Barreda*et al*., 2015). The antioxidant and antibacterial properties of several biomolecules, including phenolics and terpenoid, are essential for the incorporation with nanoparticles (Ouerghemmi*et al*., 2017). Its antibacterial efficacy against gram+ve and gram-ve strains, as well as its antifungal activity against fungi such as *Aspergillusniger*, *Candida albicans* are due to the presence of increased coumarins. Additionally, it showed useful antioxidant activity. (Tataringa*et al*., 2019).

7.5 Antioxidant Activity

Anti-Oxidants are those chemical substances which aid in preventing oxidation. Free radicals cannot harm tissues because antioxidants can withstand them. They are regularly employed to guard against cerebrovascular disorders (Bandyopadhyay *et al*., 2007). The prime pathogenic factor for cardiovascular diseases is the oxidative stress which takes place at cellular level. It happens as a result of the toxins produced by free radicals that are generated by smooth muscle and endothelial cells. Phenolic chemicals, which have a propensity to scavenge free radicals, demonstrated the majority of the antioxidant capabilities. Through chelating the metal ions, phenolic chemicals improve the body's natural antioxidant system and prevent the production of free radicals (Fearon and Faux, 2009).

8. Conclusion

The green production of nanoparticle for use in plant applications offers tremendous potential for sustainable agriculture and environmental management. An eco-friendly alternative to traditional synthesis techniques that frequently use dangerous chemicals is the creation of nanoparticles from plant extracts and other natural sources. Green-synthesized nanoparticles possess unique properties and functionalities that can be harnessed to enhance plant growth and antimicrobial, antioxidant and larvicidal properties. Through physicochemical characterization, we can gain insights into the composition, stability and also the dimension and form of green-synthesized nanoparticles. This information is crucial for understanding their behaviour and interactions within plant systems. While significant progress has been made, future research should focus on standardizing synthesis protocols, optimizing nanoparticle properties for specific applications evaluating the extended fate of nanoparticles and their potential ecotoxicity, understanding plant-nanoparticle interactions at a molecular level, tailoring nanoparticles for application-specific needs, addressing regulatory and societal concerns, and promoting collaboration and knowledge sharing among stakeholders. Agriculture and environmental cleanup could be revolutionised with continuing work in the field of green synthesis of nanoparticles for plant uses. The development of safe, sustainable, and effective nanoparticle-based solutions will contribute to improving crop productivity, reducing environmental impact, and ensuring food security in a rapidly changing world. By embracing these advancements, we can pave the way for a greener and more sustainable future for plants, ecosystems, and human well-being.

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