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Original Article

Green Toolbox for nanoparticles synthesis: A revolutionized framework of bio-compatible material

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Abstract

Green chemistry process for synthesis of nanoparticles has received enormous attention due to ecofriendly nature, economically, easy to access, low energy consumption and high yield of nanoparticles without releasing harmful gases and chemical effluents. Capping of functional biomolecules on the surface of nanoparticles has enhanced extensive applications in catalysis, bio-sensing, nano-fertilizer, and biomedical engineering. The main purpose of this review is to emphasized on biomolecules potentials as reducing, capping and oxidation agent for fabrication of novel nanoparticles. Furthermore, how biomolecules capped nanoparticles are effective in biomedical, environmental and agriculture applications on commercial scale. Finally, this review also provides the base line for young researcher to understand the systematic approach with synthetic and functional identity.

Keywords: Green chemistry, biological identity, nanoprobes, reducing agent, application

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1. The progressive glory of green synthesis

Synthesis of novel nanomaterials with unique structure is always challenging task in the field of nanotechnology (X. Wang et al., 2019). Physical, chemical and biological synthetic routes have own limitation and advantages (Panthi & Park, 2022) that is considered as a potential technology in generating extremely small size nanoparticles. The valuable assets of nanotechnology encompass in the field of chemical sciences, catalysts, medicine; bio imaging, bio sensing, disinfectants, pharmaceutics theranostics, cytotoxicity, agriculture, plant growth(Hasan, Rafique, et al., 2020), nutrition (Hasan, Mehmood, et al., 2021). These nanoparticles are also playing key role in fertilizers, insecticide, pesticides, fungicides, nematocidal pH and soil adjustments, preservation, drug delivery; diagnosis, antimicrobial activities, other involves Nano-warming, bioremediation, mining, biosynthesis, cleaning probing, killing, biocompatibility, risk assignments and etc.

However, it has been observed that Efficiency and effectiveness performance calls upon size, shape, structure at nanometer scale, rational designing and dexterous fabrications of the respective nano-material. Tuning and trimming the morphology and size of nanoparticles at more precise level is attained utilizing different strategies using chemical physical and biological processes, that also provides a relationship between morphology and performances (Sakai-Kato et al., 2020). Hence a more reliable synthetic route for nano-materials needs to be selected and developed that is the most contemporary in all fields that could after an unprecedented and galvanizing insights into the physical and chemical properties of the corresponding fabricating nanomaterial. Diversely arranged synthetic material count the hard template synthesis, soft template synthesis and template-free synthesis fabrication.

On account of fabrication physical method requires high energy, complex instrumental design, and high expenses with a lower yield. However, a simple setup in a chemical method is economical and also provides higher yield (Shenava, 2013). The crucial short coming is the use of toxic and volatile chemical reactants as aromatic amines and thiols proves hazardous and harmful for the environment leading to air pollution(Hussain et al., 2020). Instinctive facts intrigued to develop a sustainable, cost effective and eco-friendly method with high yield. Currently the biogenic synthesis of NPs has great deal of attention because of environmental benignity and ease of its synthesis(Dikshit et al., 2021a). That involves the cellular extracts of the living entities including algae, fungi, bacteria, and plants that employs as green reaction media for the capping and reduction of NPs. Biological extracts in the aqueous media for the synthesis ensures the non-toxic and non-volatile nature of the media(el Messaoudi et al., 2022). Where the biological extract is rich in biomolecules like proteins, carbohydrates, vitamins, polymers and natural surfactants that are the chief stabilizing agents and the dispersity enhancers for the synthesis of NPs by green method. Considering the biological entities, Plants are considered to be the more cheap and economical consisting of several additional metabolites, phytochemicals that give rise to most stable NPs with lesser toxic chemical addition, low potential for global warming, ozone layer depletion and smog formation(Hasan et al., 2018) and reduction of chemical explosion on human health and environment. The researchers are adopting new synthetic pathways by applying green chemistry tools such as green solvent, green catalysis, media preparation and ecofriendly catalyst free reaction and energy efficient synthesis (Byrne et al., 2016; Kumar et al., 2020). Biological resources on the earth are heavy loaded with functional biomolecules in the form of flavonoids(Zulfiqar et al., 2019a), proteins, polysaccharides, lagnins, inorganic materials, fats and nucleic acid plays key role in reducing(Hasan, Zafar, et al., 2020), oxidation(Zafar et al., 2021) and capping of nanoparticles(J. Zhou et al., 2022). The usage of biological route eliminates the risk of toxicity and allow the production of nanoparticle on large scale with less time consumption. In this cost-effective process, researcher has shown the control process to maintain size shape and morphology of nanoparticles by optimizing some important parameters (Jadoun et al., 2021) as shown in Fig 1. These significant factors are listed here. Studies reveled that size and shape of nanoparticles highly associate with physico-chemical assets. And interestingly according to recent research pH plays a very significant role to modulate size and shape of metallic nanoparticles. This is done due to the formation of nucleation centers, which dramatically boost-up by pH (Zulfiqar et al., 2019b). With the increase in pH there will be increase in nucleation center and reduction process of metallic ions proceeds faster as a result size of nanoparticle becomes smaller. High pH also effects the activity of bioactive components present in plant extract, in negative manner(Gour & Jain, 2019).

Researchers, studied the effect of pH on the synthesis of Pt nanoparticles and results reveled that as the pH of the reaction mixture increased from 2 to 10.2, the average size of the nanoparticles was decreased profoundly from 14.4nm to 1.5 nm(Choo et al., 2002). Another study revealed that the pH can control the size range of Ag nanoparticles as the pH set between 8-10 the size was 15nm but when pH range was 2-6 particle size was found larger(Marciniak et al., 2020).

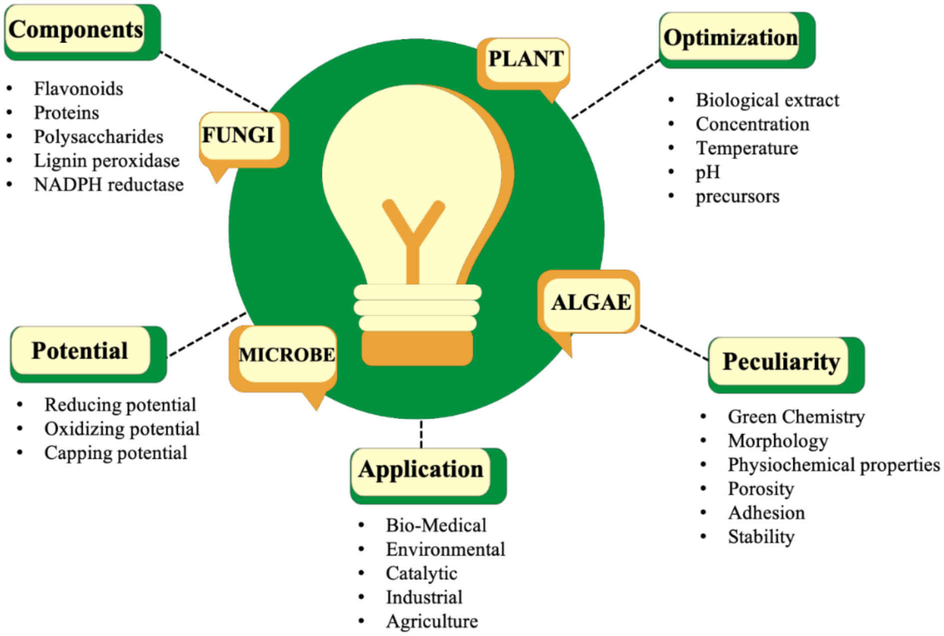

Fig 1. Schematic illustration of green synthesized nanoparticles with optimization, peculiarity and their application

In addition to pH, temperature is another key factor for the modulation of shape and size of nanoparticles. Research revealed that high temperature is favorable for increase production of nanoparticles. In the formation of metallic nanoparticles precursor and extract concentration plays an important role. In earlier reports, Researchers illustrate the fabrication of Ag NPs from *Fagonia cretica.* Results showed that by increasing the time, concentration of precursor and plant extract, the fabrication of NPs increased, and reaction time synthesis of NPs changed (A. Yousaf et al., 2019). Keeping in mind about optimization conditions, a researcher can alter all these parameters to refined the synthesis of NPs according to their need.

Several factors affect the synthesis of NPs including pH of the solution, temperature, concentration of the extracts used, concentration of the precursor salt, pressure, retention time (S. Patil & Chandrasekaran, 2020). Researchers revealed that the shape of the synthesized product under lower pH was less regular and tend to agglomerate. Though, we can fabricate the desired size and shape of NPs under diverse pH conditions. At alkaline to basic pH range the synthesized NPs were in colloidal stage, prevent aggregation and were of small size (Dikshit et al., 2021b).

Usually, high temperature is favorable for nucleation and growth of larger NPs (Shaba et al., 2021). Temperature displays diverse possessions on the size of NPs under adequate and inadequate amount of the precursors because of its remarkably diverse effect on nucleation kinetics constant (k1) and growth kinetics constant (k2). So, by increasing the reaction temperature, rate of reduction increases, metallic ions take part in nuclei formation (Kaabipour & Hemmati, 2021).

Pressure is also an important factor for the synthesis of nanoparticles. it applied to the reaction medium which modulate the shape and size of the manufactured nanoparticles. At ambient pressure reduction of metal ion becomes faster by using biomolecules (Patra & Baek, 2014).

2. Primal Bio-templates

2.1. Plant templated nanomaterials

Over the last few decades, plants have the ability to transform inorganic metal ions into the metal NPs on their surface decorated with various functional molecules to play crucial role in enhancing the biological as well as physico-chemical activities (Jeevanandam et al., 2018). Under this consideration, plants with high reductive and hyper accumulative capacity that have been used to highjack precious metals from them. Harvesting have been done to recover the accumulated metals from plants via sintering and smelting methods. This natural process is referred as Phyto-mining (Yan et al., 2020). Deep investigations confirmed the existence of metal NPs within plant. For example: Andrew & roza bali studied the chemistry of *Brassia Juncea* (BJ) and *Medicago staiva* (MS) and results showed that after 72 hr exposure of aqueous solution of $AgNO_3$ on plant the accumulation of Ag NPs was 12.45 wt.% in BJ plant. However, MS accumulate 13.6 wt.% of Ag NPs after 24 hours exposure of $AgNO_3$ with spherical shape and average size of 50 nm (Peralta-Videa et al., 2016). In another example I.L. Gardea- Torrsedey et al investigated the formation of Au NPs in *Alfalfa* plant result confirmed the synthesis of gold NPs within the plant of the size range of approximate size of 4 nm (Gardea-Torresdey et al., 2002) . In another research scientists investigated the synthesis of Ag NPs in different parts of plants with different size ranges (Siddiqi et al., 2018). But there are certain limitations in this procedure that includes the following flaws. We can't use this procedure on large scale because NPs can't synthesize in bulk amount. Another drawback is that the synthesized NPs have variable size and shape depending on the part of plant where they fabricate. Owing to the natural synthesis of NPs controlled and optimized synthesis can't be possible and this variation hinders their application in those fields where there is a need of tunned and fine NPs. Furthermore, it is difficult to extract and purify the naturally synthesized NPs(Sánchez-López et al., 2020). So, to overcome such limitations invitro approaches have been developed in recent years in which plant extract contain bioactive molecules which are used as a reducing and capping agent for the reduction of metal ions into NPs.

Plant metabolites such as flavonoids, alkaloids, terpenoids, proteins, sugar used for reduction of metal ion into nanoparticles and creates a stable surface configuration. Terpenoids are a class of diversified organic chemicals, derived from five-carbon isoprene units combine to form monoterpenoids and sesquiterpenoids. They exhibit strong potential for the synthesis of Ag NPs (Kuppusamy et al., 2016). Moreover, terpenoids act as the building blocks for other secondary metabolites such as plant hormones, sterols, the phytol tail of chlorophyll, and turpentine (Bag et al., 2019).

According to Murtaza et al, active functional biomolecules in *Withania* showed the reducing potential for synthesis of zinc and iron nanoparticles with best characterization in the form of crystals form results supported by XRD Fig 2(a) spectra of different zinc precursors concentration and plant extract concentration for achieving stable nanoparticles. However, further confirmation was performed by TEM analysis Fig 2(b). Well flowers shaped zinc, rode shaped iron and round shaped silver were synthesized by green method by involving bio-molecules present in the extract which gives the proper shaped and control their functionality. From Fig 2(c) elemental analysis was performed to evaluate the plant-based synthesis of zinc nanoparticles. Iron oxide nanorods were also prepared and characterized and their application was tested against the degradation of dye Fig 2(d). Similarly, plant-based zinc nanoflowers were also assessed for the synthetic, antimicrobial and harvesting efficiency Fig 2(e).

Antifungal activity was evaluated by 12 different fraction extract of methanol and hexane with their mixtures using plant extract of Withania against the *A, niger* by the disc method in **Fig 2(f)**. The active biomolecules in these fractions showed activity against the fungal strains. Flavonoid, another important metabolite for fabricating NPs *via* green route. These are the extensive group of multi class polyphenolic compounds including anthocyanins, iso-flavonoids, flavanols, chalcones, flavones, and flavanones that act as chelating agent (Pandian et al., 2021) The transformation of enol to keto form by the release of hydrogen atom, is the reduction mechanism of flavonoids which is used for the reduction of metal ions into NPs.

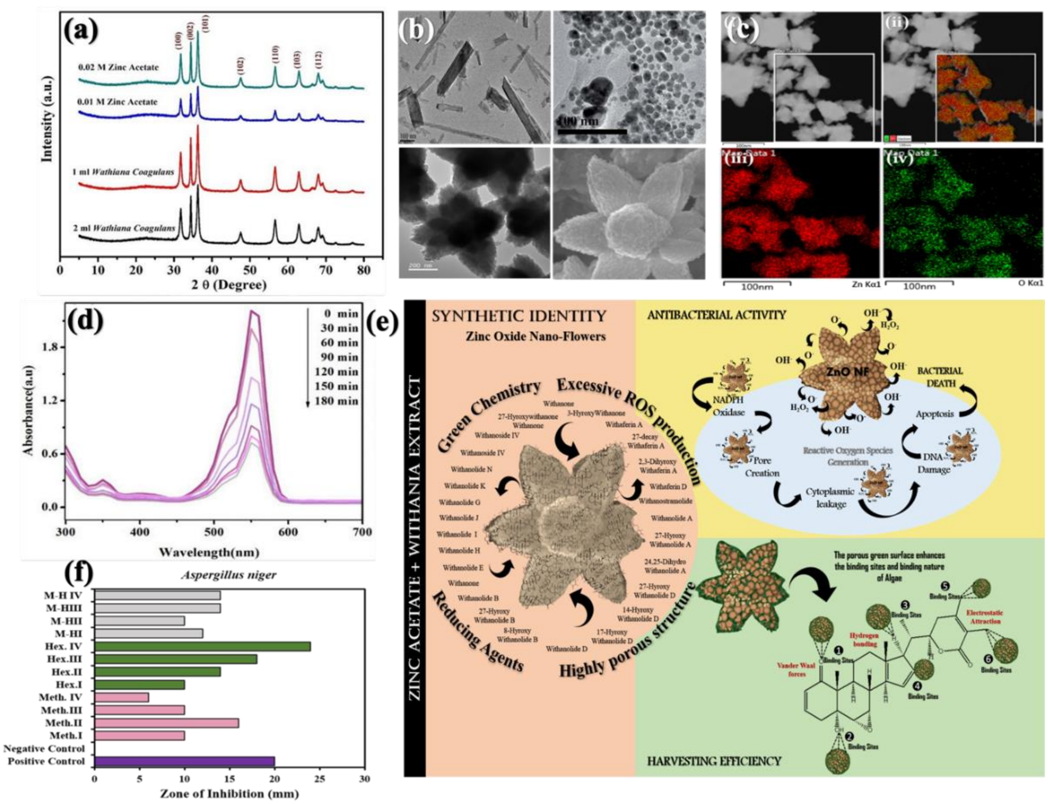

Fig 2. Plant templated nanomaterials **(a-c)** Withania based ZnO nanoflower synthesis and characterization (Hasan, Altaf, et al., 2021)**(d)** degradation of dye *via* iron oxide nanoparticles (Qasim et al., 2020) **(e)** Synthetic identity of zinc NPs with antimicrobial and harvesting efficiency **(f)** Withania fraction analysis against *A, niger* (Hasan, Zafar, et al., 2020)

For instance, researchers studied that in the extract of *Ocimum basilicum*, the interconversion of two flavonoids luteolin and rosmarinic acid, into keto type from enol type assists the transformation of Ag+ ions to Ag NPs (Marslin et al., 2018). Sugar is another important metabolite used in metal reduction and its conversion into nanoparticle. The presence of reducing sugar like glucose and fructose in leaf concoction of *Azadirachta indica* plays a role in reduction of Ag+ ions. In another example, researchers studied the synthesis of Ag and Au NPs which are mediated by fructose (Majhi & Yadav, 2021). Amino acids were found to differ in their ability to bind metal ions and to reduce them. For example, Gruen and coworkers observed that amino acids including lysine, cysteine, arginine, and methionine has the capability to bind silver ions and converted them into silver NPs. Some other studies have shown that aspartate is the key reducing agent for the reduction of tetra chloroauric acid to form NPs (al Masud et al., 2021). Plant extract also contain proteins and carbohydrates for the reduction of metal ions, studies had been shown that protein and carbohydrate monomers had been observed on the surface of NPs. For the synthesis of different nanomaterials plant has been considered as promising candidate. Owing to the ecofriendly nature of plant, this method is dominant over the other procedures used for the NPs synthesis. Researches has been explored different species of plants for effective synthesis of biocompatible NPs. For this purpose, Plant biomass is used as extract in the fabrication process. Generally, the plant extract mixed with metal salt solution at desired pH and specific temperature and fabrication process is completed after continuous stirring the reaction mixture. In a short span of time, synthesis of nanoparticles will be completed (Shafey, 2020). Phyto synthesized metal/metal oxide NPs grabbing researcher's attention owing to their exclusive properties and applications in different fields such as chemistry, physics, materials, engineering, agriculture. Here we are discussing some of the metal/metal oxide NPs which are extensively used in biomedical fields. The NPs synthesized *via* green route have grabbing substantial attention from researchers in the past 4–5 years owing to its vast applications in bioengineering, agronomy and environmental fields ("Green Synthesis of Zinc Oxide Nanoparticles from Plant Extract: A Review," 2019). Up till now broad research has been done to explore the applications of plant fabricated ZnO NPs. Synthesis process start by the addition of precursor salt solution, hydrated zinc sulfate/zinc oxide/zinc nitrate in plant extract and stir at basic pH, high temperature at specific time interval. Color change in the reaction mixture revealed the confirmation of ZnO NPs. After these different characterizations techniques were applied to find shape, size and morphology of NPs(Chikkanna et al., 2019). Most frequent plant used for the synthesis of ZnO NPs named as *Azadirachta indica* of Meliaceae family and *Vitex negundo* plant attributed the synthesis of ZnO NPs size which was 38.17 nm by the X-Rays diffraction (XRD)(Bhuyan et al., 2015). In another research M. Saqib and co-workers illustrate the synthesis of flower shape ZnO NPs by the use of *Withania coagulans* plant extract with the size of 25 nm characterized by XRD, phytosynthesized ZnO NPs showed 85 % microbicidal effect and 100% fungicidal effect. Studies reveled that ZnO NPs retains high binding energy of 60 m eV and bandgap of 3.37 eV which make them an efficient catalyst and act as a Ultra violet filter so, widely in various cosmetics such as sunscreen (Saif et al., 2021). The fundamentals required for the fabrication of Ag nanoparticles is the precursor salt solution along with bioactive molecule rich plant extract which act as reducing, capping and stabilizing agent (Iravani et al., 2013). Most frequent used salt for AgNPs is silver nitrate All the parts of plant's extract contain biomolecules having extreme therapeutic potential and environment friendly properties. And having the ability to replace all toxic chemicals that are used in reduction process. While using plant extract the reduction of silver ion is favored by poly phenols and heterocyclic biologically active components (Gudikandula & Charya Maringanti, 2016). Flavonoids and terpenoids assist the Ag NPs to get stable configuration. Salvia spinosa was the first plant extract used for the synthesis of Ag NPs (Mat Yusuf et al., 2020). Up till now various plants including Medicinal plants (*Boerhaaviadiffusa, Terminalia chebula, aloe vera, Catharanthus roseus, Moringa oleifera, Azadirachta indica*) common spices *Piper nigrum, Cocos nucifera, Cinnamon zeylanicum*, some tropical weeds such as *Parthenium hystero-phorus* and plant like angiosperms have been used for the synthesis of Ag nanoparticles (Tarannum et al., 2019). Chen Yu et al *Eriobotrya japonica* extract for the synthesis of silver nanoparticles which size of 3–30nm and monodisperse spherical shape, used for dye catalytic reduction(C. Yu et al., 2019). Some other recently synthesized Ag NPs from different plants is listed in the Table 1. Au NPs gain attention owing to its unique biomedical properties and highly biocompatible nature with no toxicity (Yulizar et al., 2017). Numerous plants have been used for its synthesis, for instance N.Thangamani et al synthesized Au NPs form Simarouba glauca leaf extract formed prism and spherical shaped morphology with performing high antibacterial activity (Thangamani & Bhuvaneshwari, 2019) . Castillo-Henríquez L et al. studied that, by the use of *Eclipta prostrate* leaves extract Au NPs synthesized in triangle, pentagon, and hexagon shapes. Size ranging from 10nm–130nm with sphere shaped morphology and used for antibacterial assay. Studies reveled that, various plants have been used to produce Au NPs, shape size and morphology vary according to the nature of plant (Castillo-Henríquez et al., 2020), some important plants are listed in the Table 1. Biosynthesized iron oxide NPs have been studied due to its biocompatible nature. So far, few plants have been used for its synthesis. As mentioned above, bioactive molecules of plants play a vital role for the formation in NPs. Same as for Phyto synthesized iron oxide nanoparticles (Castillo-Henríquez et al., 2020).

Table 1. Plant templated nanoparticles synthesis, characterization and their activity

Plants	NPs	Size(nm), Shape	Application	Ref
Areca catechu	ZnO	20, Spherical	Antibacterial activity	(Raghavendra et al., 2021)
Thymbra Spicata L.	ZnO	6.5 -7.5, Spherical	Antimicrobial activity	(Gur et al., 2022)
Cissus quadrangularis	ZnO	75- 90, spherical	Antimicrobial and Anticancer	(Sathappan et al., 2021)
Justicia adhatoda	ZnO	15–20, Cubic	Antimicrobial activity	(Pachaiappan et al., 2021)
Orange peels	ZnO	2-6, Spherical	Antibacterial activity	(Menazea et al., 2021)
Salvia officinalis	ZnO	12, Threads, plates and flower shaped	Photocatalytic and antifungal activity	(Abomuti et al., 2021)
Phoenix dactylifera	ZnO	30, Spherical	Dye degradation and antibacterial property	(Rambabu et al., 2021)
Prosopis juliflora	ZnO	31-32 , Irregular	Degradation of methylene blue dye	(Abbas et al., 2021)
Acalypha fruticosa	ZnO	50, Spherical, hexagonal	Antimicrobial	(Abbas et al., 2021)
Calotropis gigantea	ZnO	31, Hexagonal and pyramidal	Nitrite sensing, photocatalytic, and antibacterial	(S. P. Patil, 2020)
Cydonia oblonga	ZnO	25, uniform crystals	Photocatalytic degradation	(Tabrizi Hafez Moghaddas et al., 2020)
Musa acuminate	ZnO	30-80, Triangular	Visible-light degradation of methylene blue	(F. H. Abdullah et al., 2020)
Melia azedarach	ZnO	33-96, Spherical	Antibacterial & antioxidant activities	(Dhandapani et al., 2020)
Euphorbia hirta	ZnO	20-25 Spherical	Antibacterial activity	(Gomathi & Suhana, 2021)
Urtica dioica	ZnO	22, Spherical	Antidiabetic agent	(Kalia et al., 2021)
Aloe vera	ZnO	24, Oval		(Rasli et al., 2020)
Paris polyphylla Sm	ZnO	Spherical	Anticancer activity	(Cheng et al., 2011)
Prosopis juliflora	ZnO	65, Hexagonal	Antibacterial activity	(Sheik Mydeen et al., 2020)
Aloe perryi	ZnO	10-15, Spherical	Drug delivery carrier & antibacterial agent	(Suliman et al., 2021)
Deverra tortuosa	ZnO	9.26-31.8	Anticancer Activities	(Selim et al., 2020)
Magnoliae officinalis	ZnO	150, Spherical	Antimicrobials and antiseptic agents.	(Gilavand et al., 2021)
Sphagneticola trilobata	ZnO	65-80 Irregular	Metal removal	[33]
Glycosmis pentaphylla	Ag	17, Monodispersed	Antifungal activity	(Dutta et al., 2022)
Humulus lupulus	Ag	17.4, Spherical	Anticancer & antibacterial activity	(Das et al., 2022)
Soybean	Ag	2–4, Spherical	Antibacterial activity	(Ma et al., 2021)
Diospyros malabarica	Ag	17.4, Spherical	Antimicrobial, Anticancer, Catalytic Reduction of dye	(Bharadwaj et al., 2021)
Morinda citrifolia L.	Ag	3-11 Spherical	antibacterial activity	(Morales-Lozoya et al., 2021)
Eriobotrya japonica	Ag	15–37 Spherical	Anti- cancer,anti-inflammation, allergic disorders, phagocytosis	(Jabir, Hussien, et al., 2021)

			induction	
Annona muricata	Ag	11-23 Spherical	Anticancer activity	(Jabir, Saleh, et al., 2021)
Araucaria angustifolia	Ag	91.0 ± 0.5 Spherical	Sensor for drug detection	(Zamarchi & Vieira, 2021)
Herbal medicine residues	Ag	10-20 Spherical	Anticancer, antioxidant antibacterial activity	(Wei et al., 2021)
Palm oil	Ag	18-20 Spherical	Antioxidant, Antibacterial	(Zevallos Torres et al., 2021)
Rhodiola rosea	Ag	20, Spherical	Antioxidant	(Hu et al., 2021)
Berberis vulgaris, Brassica nigra, Capsella bursa pastoris, Lavandula angustifolia and Origanum vulgare,	Ag	5, Random	Antioxidant, antibacterial	(Salayová et al., 2021)
Lysiloma acapulcensis	Ag	5, Quasi-spherical	Antibacterial activity	(Garibo et al., 2020)
A. millefolium methanolic	Ag	14.27 Cubic shape	Antibacterial antioxidant	(H. Yousaf et al., 2020)
Melia azedarach	Ag	23, Spherical	Antifungal activity	(Jebril et al., 2020)
Allium cepa	Ag	S49 -73 Pherical	Antidiabetic	(Jini & Sharmila, 2020)
pomegranate leaves	Ag	26.22, Polygonal	Antibacterial	(Saad et al., 2021)
Allium fistulosum	Ag	28-10, Cubic	Antimicrobial, Harvesting efficiency	(Khoshnamvand et al., 2020)
Curcumae kwangsiensis	Au	8–25, Spherical	anti-ovarian cancer activity	(Chen et al., 2021)
Tribulus terrestris	Au	10–15 , Spherical	Antioxidant, catalytic activity	(P. Zhao et al., 2021)
lignin	Au	15.67 , Spherical	Colorimetric sensor	(Y. Yu et al., 2021)
Rosa damascena	Au	10-45 Spheres and triangles	Antioxidant, Apoptosis assay	(Kyzioł et al., 2021)
Mentha Longifolia	Au	36.4, Spherical	Anticancer activity	(S. Li et al., 2021)
Fritillaria cirrhosa	Au	40–45, Spherical	anti-diabetic activity	(Guo et al., 2020)
Lawsonia inermis	Au	20, Spherical	Dye degradation	(Kumari & Meena, 2020)
Hygrophila spinosa T.	Au	68.44 ± 0.30	Anticancer activity	(Satpathy et al., 2020)
Sargassum carpophyllum	Au	9-12, Monodisperse	detection of melamine	(M. Zhou et al., 2020)
Leucosidea sericea	Au	21, Spherical	Antioxidant,	(Badeggi et al., 2020)
Vitex negundo	Au	20–80, Rod	Antioxidant, Antinflamatory	(Sunayana et al., 2020)
Ficus Carica	Iron oxide	43–57, Amalgamated	antioxidant	(Üstün et al., 2022)
Artocarpus heterophyllus	Iron oxide	33, Spherical	Dye degradation	(R. Jain et al., 2021)
Tea-pruning waste	Iron oxide	20–35, Spherical	Antioxidant	(Periakaruppan et al., 2021)
Chlorophytum comosum	Iron oxide	100, Spherical	Dye degradation	(Shaker Ardakani et al., 2021)
Phoenix dactylifera L	Iron oxide	30, Spherical	Antibacterial activity	(Majid et al., 2021)
Moringa Oleifera	Iron oxide	29-64 cubes	Optimization study	(Laid et al., 2021)
Ramalina sinensis	Iron oxide	20-40 spherical	Removing Heavy Metals	(Arjaghi et al., 2021).
Pheonix dactylifera	Iron oxide	12, Spherical	Antioxidant	(J. A. A. Abdullah et al., 2020)
Laurus nobilis L	Iron oxide	21, Hexagonal rhombohedral	Antimicrobial, photocatalytic	(Jamzad & Kamari Bidkorpeh, 2020)
Mentha Pulegium L.	Iron oxide Variable	Cubic	Antimicrobial application	(Bouafia & Laouini, 2020)
Cymbopogon citratus	Iron oxide	8-17, Cubic	Environmental	(Patiño-Ruiz et al.,

			remediation	2020)
Carica papaya	Iron oxide	21, Agglomerated clusters	Dye degradation	(Bhuiyan et al., 2020)
Hibiscus rosa-sinensis	Iron oxide	65, Spines	Fortifying wheat	(Razack et al., 2020)

For instance, Herrera-Becerra et al. studied the fabrication of Iron oxide NPs using tannin powder. Polyphenolic compounds are abundantly present in Tannins plants that are not toxic and can be used as stabilizing, reducing and capping agent for the generation of iron Oxide (Herrera-Becerra et al., 2010). Prasad et al utilized the leaves of Garlic Vine for fabricating iron (III) oxide NPs with crystalline appearance by $FeSO_4.7H_2O$ as a precursor salt (Prasad, 2016). Recently explored plants for iron oxide NPs synthesis are listed in the Table 1.

2.2. Algal templated nanomaterials

Algae is most primitive plant having multiple advantages having good source of bioethanol production, fossils fuel and now very good precursors for the production of nanoparticles. Algae is considered to be easy access source for nanoparticles synthesis as it can be harvested anytime from anyplace. Algae has ability to grow anywhere without fertilizers and soil rich with chemicals. Like plants, algae have complex biomolecules in their composition which are responsible for the reducing of metal into nanometals form and stabilized. There are two pathways for the synthesis of nanoparticles. From Fig 3(a), Khalafi et al reported the mechanistic study of zinc oxide nanoparticles synthesis with different optimized condition and possible reducing agent like carbohydrates, vitmanins etc. The precursors, algae extract concentration with other factors such as temperature 58 ºC, pH 8 and time point was 8 minutes can by optimization process. The whole mechanism of biosynthesis of zinc oxide nanoparticles (ZnO NPs) using algae chlorella extract as reducing and capping agent has shown in the Fig 3(a). The possible reducing agent can be carbohydrates, triglycerides, proteins, vitamins and fiber. From Fig 3(b) X. Li et al results of SEM images having spherical FeNPs were immobilized on the surface of the *C. zofingiensis* cells. They also proposed mechanism of *in situ* formation of FeNPs on the surface of *C. zofingiensis* Fig 3(c). However, green synthesized iron oxide nanoparticles have shown excellent dye degradation as Fig 3(d).

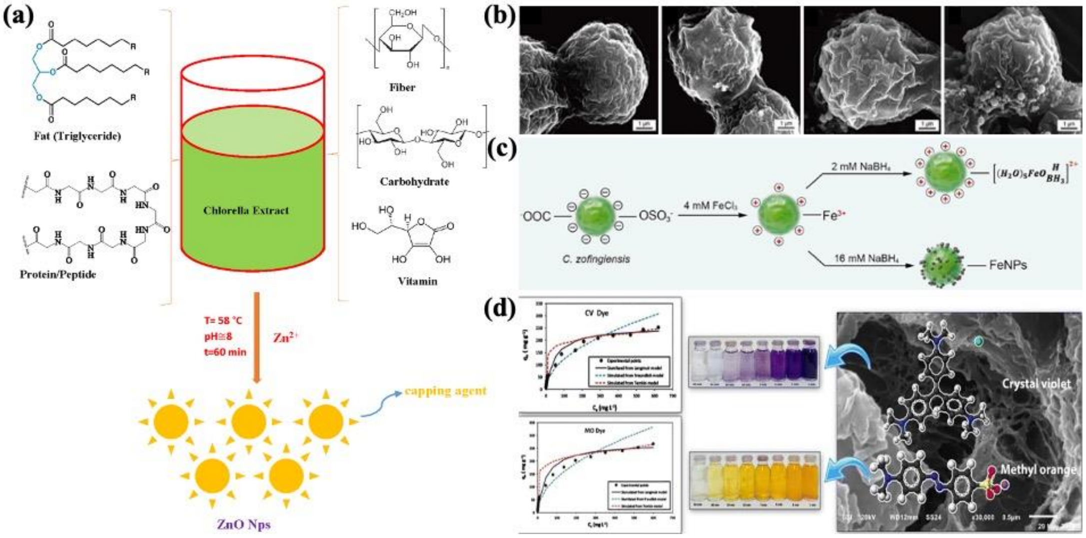

Fig 3. Algae templated nanomaterials **(a)** zinc oxide nanoparticles (ZnO NPs) using algae chlorella extrac (Khalafi et al., 2019), **(b)** TEM analysis of iron oxide nanoparticles via *C. zofengensis* with capping molecules (X. Li et al., 2021), **(c)** degradation of dye *via* iron oxide nanoparticles

2.2.1. Extracellular approach to synthesize NPs

Extracellular processing takes place outside the cell by the aid of cell metabolites extrude out in the extract Fig 4(a). This mode of synthesis is more convenient because nanoparticles are purified more easily and we can effortlessly modulate certain physiochemical properties such as pH, temperature, concentration of metal and substrate stimulus the size, shape, and agglomeration of NPs (Zhang et al., 2016). Researchers reported extracellular synthesis of Au nanoparticles synthesized by variable concentrations of chloroauric acid was confirmed by the absorbance peak at 530 nm, that gives the idea of the involvement of proteins, polysaccharides and secondary metabolites in algae-mediated synthesis of nanoparticles (Agarwal et al., 2019). Up till now, different metal and metal oxide nanoparticles were synthesized by algae.

2.2.2. Intracellular approach to synthesize NPs:

The Process that takes place inside the cell is referred to as intracellular method of fabrication. And interestingly, like plants microalgae also have the ability to synthesize NPs within itself by the intrinsic metabolic pathways required for photosynthesis, respiration and nitrogen fixation (Ahmed et al., 2016). The technique of intracellular synthesis explained by transportation of particular ions penetrate through cell wall shown in Fig 4(b). Within the algae NADPH act as a reducing agent to carry out metabolic pathways and also used for NPs synthesis. Algae require a precursor salt for the fabrication of NPs by this process (Hasan et al., 2015). Up till now some algal strains have been used for this purpose. For example, *Rhizoclonium fontinale* and *Ulva intestinalis* when treated with chloroauric acid at 20 °C for 72 hours, it generates a visual change in the colour of thallus from green to purple that confirms the fabrication of Au-NPs (Chaudhary et al., 2020). The fact of this process was supported by an experiment in which gold solution was incubated with dried biomass and results showed that there was no change in colour. This thing confirms that the process of bioreduction is not connected with the metabolic pathways involving enzymes or other metabolites and the cells were poisoned by Au^{3+} when converted to Au^0 with zero oxidation state (Costa et al., 2020). Another example found to be efficient and effective in the conversion of metal ion ($Au3^+$) to metal NPs (Au^0) with zero oxidation state. Chlorophycean algae *Spirogyra submaxima* used for this process. After exposure to gold solution, colour of the biomass turned pinkish purple and then Au nanoparticles were extracted by the use of sodium citrate solution (N. Singh et al., 2020).

Some biologically important nanoparticles were listed in the Tables 2.

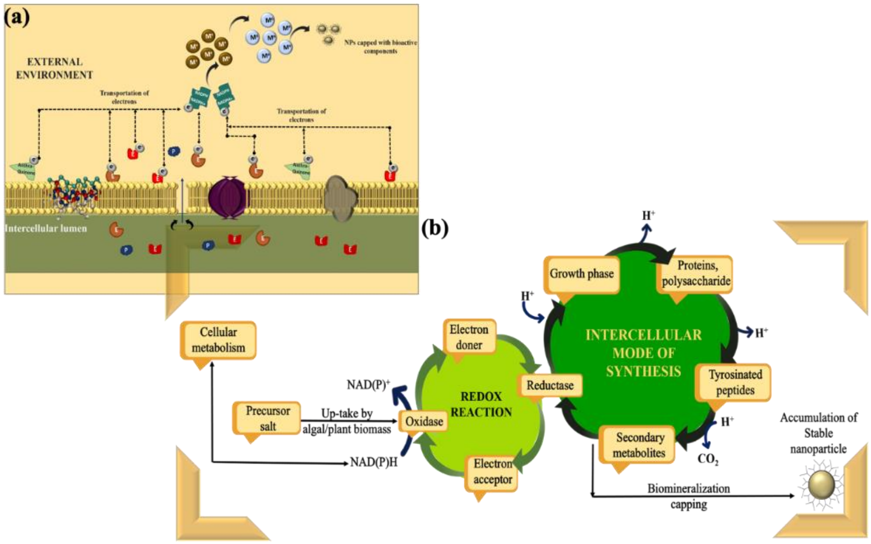

Fig 4. Schematic illustration of Algae based mechanism of nanomaterials synthesis **(a)** Extracellular Nanoparticles Synthesis **(b)** Intracellular Nanoparticles Synthesis

Table 2. Algae as a biological entity for synthesizing NPs

Algae as bioreactor	NPs	Size (nm, Shape of NPs	Application	Ref
Arthrospira platensis	ZnO	30-55, Spherical	Antimicrobial	(Ningaraju et al., 2021)
Tetraselmis indica	ZnO	27, Spherical	Antibacterial, Antioxidant, and Hemolytic Activity	(Thirumoorthy et al., 2021)
Anabaena cylindrica	ZnO	40-60, Amalgam	Antibacterial	(Bhattacharya et al., 2020)
Sargassaceae	ZnO	23 -200, Multilayered rectangular	Antimicrobial and antioxidant	(Elrefaey et al., 2021)
microalgae strain ZAA1 (MF140241), ZAA2 (MF114592) and ZAA3 (MF114594)	ZnO	100 nm Sphere and poly-dispersive	Antibacterial	(Jamil et al., 2020)
Desmodesmus abundans	Ag	8.5–72.5, Agglomerates	CO_2 generation	(Mora-Godínez et al., 2022)
Spirogyra hyalina)	Ag	52.7, spherical	Insecticidal, antioxidant activities,	(Abdullah et al., 2022)
Spirogyra	Ag	20, Polydisperse spherical crystalline	Antimicrobial, antioxidant, antibiofilm	(Danaei et al., 2021)
C. calcitrans	Ag	30-35, Spherical	Photocatalytic dye degradation	(Rajkumar et al., 2021)
Padina sp	Ag	25–60, Uniform	Antibacterial activity	(Bhuyar et al., 2020)
Sargassum myriocystum	Ag	20, Hexagonal	Antibacterial, cytotoxic activity	(Balaraman et al., 2020)
Hydroclathrus clathratus	Ag	7 -31, Spherical and polygona	Antibacterial	(Alzahrani et al., 2020)
Cladophora glomerata	Ag	8–11, Spherical	Anticancer activity	(Acharya et al., 2020)
Chlorella ellipsoidea	Ag	,31.3, Spherical	Photophysical, catalytic and antibacterial activity	(Borah et al., 2020)
Gelidium corneum	Ag	20–50, Cubic	Antibiofilm, antimicrobial.	(Borah et al., 2020)
Portieria hornemannii	Ag	70-75, Spherical		(Fatima et al., 2020)
Turbinaria decurrens	Au	10- 19, Spherical	Antioxidant and anticancer activities	(Farag & Al-Mahdy, 2013)
Chlorella vulgaris	Au	20-25 Spherical	Antimicrobial activities	(Al dayel et al., 2020)
Sargassum cymosum	Au	7 and 20, Spherical	Optimization study	(Costa et al., 2020)
Microalgae	Au	5-34, Circular	Antibacterial, antifungal	(Omomowo et al., 2020)
Spirulina platensis	Iron oxide	5.54, non-regular	Removal of cationic and anionic dyes	(Shalaby et al., 2021)
Petalonia fascia, Colpomenia sinuosa, and Padina pavonica	Iron oxide	6.54- 13.46, 10.56-19.91, 26.60- 34.01, Spherical, cubic, Spherical	Antimicrobial activities.	(El-Sheekh et al., 2021)
Sargassum vulgare, *Ulva fasciata* and *Jania rubens*	Iron oxide	17.05–34.09, 22.73–39.77, 22.22–33.33, Spherical	Antimicrobial	(Salem et al., 2020)

2.3. Microbes templated synthesis of nanomaterials

As like plant and algae, bacteria can also use as a biological material for the synthesis of nanoparticles. But here the mechanism of nanoparticle synthesis is bit different form algae and plant. Owing to its high reproduction rate it is considered as a good candidate for nanoparticles production. Research showed that actinomycetes are able to secret secondary metabolites which are used for the reduction of metal ions (X. Li et al., 2011). Intra and extracellular process of nanoparticle production can also be done by actinomycetes. And In response to oxidative stress bacteria have capability to produce some vital thiol group compounds which act as capping agent on nanoparticles. But Extracellular production is commercially advantageous as compared to intracellular one because of its capacity for bioremediation process (Lahiri et al., 2021). *Pseudomonas stutzeri A.G 259* strain extracted from silver mine for the production of AgNPs form bacteria (Punjabi et al., 2017). Research reveals that bacterial genus *Shewanella* synthesize various metal oxides in response to the microbial respiration process. Because of this process there is movement of electrons in response to the oxidation of organic acids as electron donors and reduction of inorganic metals (Kim et al., 2018). This property reveled bioremediation process as well as the production of nanoparticles. We can also fabricate Nps in controlled condition by the use of bacterial biomass. AgNPs were synthesized by using bacterial biomass with precursor salt solution of silver nitrate. the mechanism involved here is biological reduction of Ag ion into Ag NPs with the help of reductase enzyme of bacteria at specific temperature and pH. The working of this enzyme depends upon the oxidation and reduction of NADH (Zou et al., 2021). Up till now different strains were isolated and used for the production of Ag NPs. Extract of Pseudomonas aeruginosa *and Bacillus brevis NCIM 2533* strain contain protein which act as capping and stabilizing agent for the synthesis of Ag NPs (Koul et al., 2021). Several researchers have explicated different bacteria for the synthesis of gold nanoparticles. Research showed that *Bacillus marisflavi* bacterial strain cell free extract was used for the synthesis of gold nanoparticles having spherical shape with the size of 10nm (Velmurugan et al., 2014). Another bacteria Acinetobacter sp. SW30 and *Micrococcus yunnanensis* were utilized for the production of Au NPs and here an enzyme Lignin peroxidase produce by this bacterium were responsible for the fabrication of gold NPs with spherical shape and size of 53.8 nm (Saravanan et al., 2021). Fig 5(a). showed mechanism of metal NPs synthesis with the help of fresh culture of microorganisms, by washed microbial culture, and cell free extracts(Kato & Suzuki, 2020). Similarly, Fig 5(b) Schematic representation of extracellular synthesis mechanisms of ZnO NPs (Mohd Yusof et al., 2019a). However, TEM analysis of various nanoparticles synthesized by green process has shown confirmation in Fig 5(c-f). The extracellular mechanisms involve enzyme-mediated synthesis such as nitrate reductase enzyme, which is secreted in the growth medium, to reduce the metal ions to their respective metal atoms and lead to nucleation and growth of NPs. The extracellular protein secreted by the microbes acts as a capping agent for NPs stabilization. The formation of white precipitation in the medium shows the production of NPs

Some bacterial strains were synthesized magnetic iron-oxide Nps, strain isolated form soil sample named as HMH1, fabricated iron oxide nanoparticles having spherical shape with the size of 18.8e28.3 nm (Liu et al., 2018). Two other strains of bacteria were isolated form waste water, retain the capability to produce tellurite Nps because of tellurite resistance capacity of strains (Gahlawat & Choudhury, 2019). Some other important stains and nanoparticles are listed in the table below.

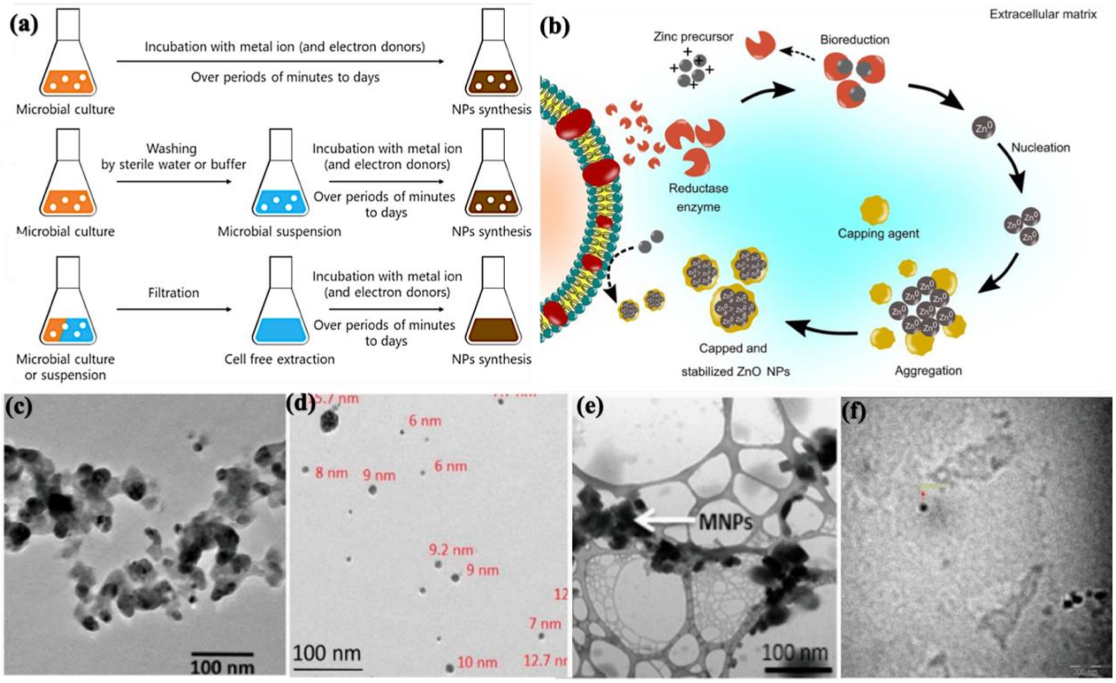

Fig 5. Microbial based synthesis of nanomaterials **(a)** synthesis of MNPs by simple microbial culture, washed culture and cell free culture (Kato & Suzuki, 2020).**(b)** Mechanisms of ZnO NPs (Mohd Yusof et al., 2019a) **(c-f)** TEM analysis of different microbial based synthesis of nanomaterials.

Table 3. Microbes based synthesis of different nanomaterials

Bacterial strain	NPs	Size and Shape of NPs	Application	Ref
Cytobacillus firmus	Ag	Spherical, 30-45 nm	Antimicrobial	(Sudarsan et al., 2021a)
Pseudoduganella eburnea MAHUQ-39	Ag	Spherical, 8 to 24nm	Antimicrobial	(Huq, 2020a)
Pseudomonas sp.	Ag	20–70 nm	Antibacterial activity	(Huq, 2020a)
Lactococcus lactis NCDO1281(T) and *Bacillus sp* PTCC 1538.	ZnO	Nanosphere, 55–60.5 nm. Nanorods 99 nm	electrochemical determination of bisphenol A	(Mahdi et al., 2021a)
Serratia nematodiphila	ZnO	Spherical, 15 to 30 nm	Antimicrobial, Photocatalytic	(D. Jain et al., 2020a)
Lactobacillus plantarum strain TA4	ZnO	Rods, 124.2 nm	Antioxidant, antibacterial	(Mohd Yusof et al., 2020a)
Cytobacillus firmus	Ag	Spherical, 30-45 nm	Antimicrobial	(Sudarsan et al., 2021b)
Bacillus paramycoides	Ag_2O	Spherical, 25–70	cytotoxicity activity	(Dharmaraj et al., 2021)
Lactobacillus mindensis	Ag NPs	Spherical, 2–20	-	(Dhoondia & Chakraborty, 2012)
Pseudoduganella eburnea MAHUQ-39	Ag	Spherical, 8 to 24nm	Antimicrobial	(Huq, 2020b)
Pseudomonas sp.	Ag	20–70 nm	Antibacterial	(H. Singh et al., 2018)

			activity	
Lactococcus lactis NCDO1281(T) and Bacillus sp PTCC 1538.	ZnO	Nanosphere, 55–60.5 nm. Nanorods 99 nm	electrochemical determination of bisphenol A	(Mahdi et al., 2021b)
Serratia nematodiphila	ZnO	Spherical, 15 to 30 nm	Antimicrobial, Photocatalytic	(D. Jain et al., 2020b)
Lactobacillus plantarum strain TA4	ZnO	Rods, 124.2 nm	Antioxidant, antibacterial	(Mohd Yusof et al., 2020b)
Proteus vulgaris ATCC-29905	Iron oxide	Spherical, 19.23 nm- 30.51	Antibacterial, Antioxidant	(Majeed et al., 2021)
Bacillus subtilis	Iron oxide	Cubic, 60-80nm	Optimization study	(Sundaram et al., 2012)
Thermus scotoductus SA-01	Au	Nanoplate, spherical	-	(Erasmus et al., 2014)
Geobacillus sp. strain ID17	Au	quasi-hexagonal, 5-50nm	-	(Correa-Llantén et al., 2013)
Geobacillus stearothermophilus	Ag, Au	Spherical, 5–35nm ,5–8nm	-	(Mohammed Fayaz et al., 2011)
Pseudomonas aeruginosa and Rhodopseudomonas capsulata	Au	Spherical nanoplates, 10–20	-	(P. K. Singh & Kundu, 2014)
P. aeruginosa ATCC 90271	Au	Spherical, 15–30nm	-	(Husseiny et al., 2007)

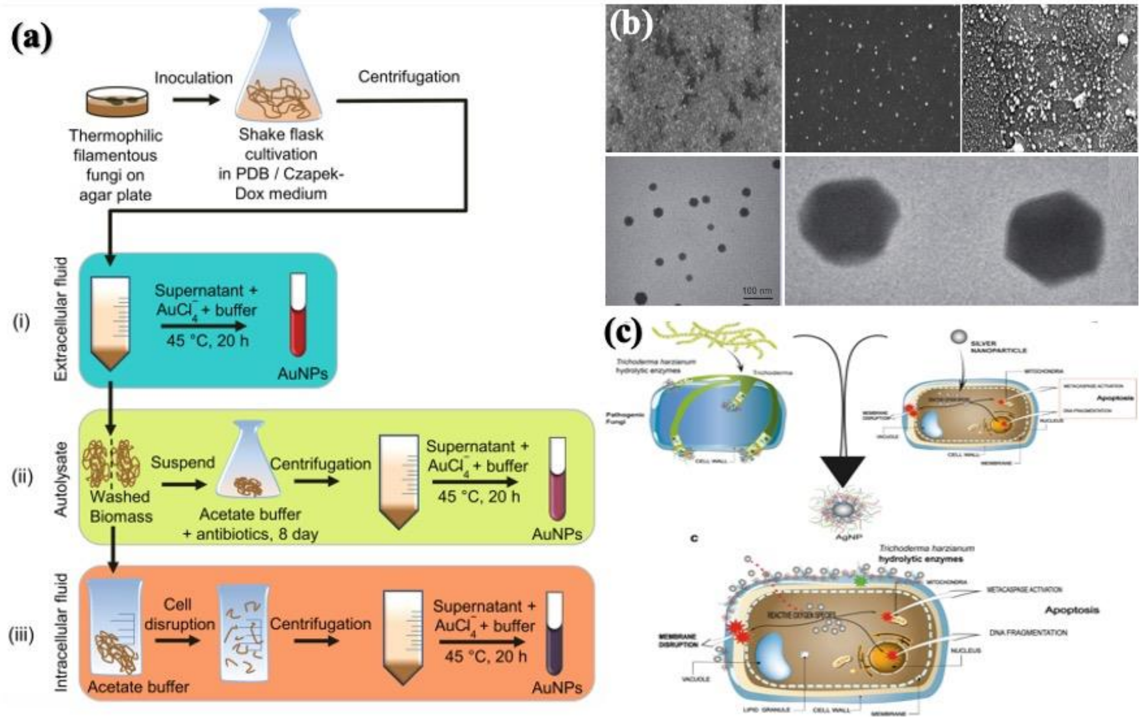

Fig 6. Fungi templated synthesis of nanomaterials **(a)** Different mechanism of gold nanoparticles with the help of fungi(Molnár et al., 2018). **(b)** TEM analysis of fungi mediated nanoparticles synthesis. **(c)** Antimicrobial activity of fungi-based nanoparticles synthesis

2.4. Fungal templated nanomaterials:

Fungus is a key candidate for the synthesis of nanoparticles. It is also capable of synthesizing nanoparticles by both external and internal mode. The Extracellular mechanism in fungus to synthesize NPs is bit different due to its unique characteristics of excreting various metabolites (Mohd Yusof et al., 2019b). Researches reveled that when fungus exposed to different environmental stress in return, they secrete large amounts of enzymes, proteins, flavonoids, steroids which are used to reduce metal ions into metal nanoparticles. And these metabolites act as caping and stabilizing agent for NPs (Bhardwaj et al., 2020). In similar reports it has been stated that Ag Nps synthesized by an enzyme NADPH-dependent nitrate reductase together with anthraquinone *secreted* by *F. oxysporum.*

TEM analysis of fungi mediated nanoparticles synthesis. (c) Antimicrobial activity of fungi-based nanoparticles synthesis

These enzymes act as an electron doner to silver ions (Ag^+) and convert it into neutral Ag (Ag^0)/ Ag NPs. NADP+ and NADPH act as electron carrier for Ag ions (X. Zhao et al., 2018). From Fig 6, showing the mechanism of fungi templated nanoparticles synthesis, characterization and their antimicrobial activity. Fig 6(a) showed that three ways to synthesized nanoparticles, extracellular, autolyzed and intracellular for nanomaterials preparation reported by (Molnár et al., 2018). Characterization of prepared nanoparticles were confirmed by the SEM and TEM analysis for biomedical application as shown in Fig 6(b). Finally, antimicrobial mechanism has shown in Fig 6(c). Usually, the mechanism proposed for intracellular fabrication of NPs in fungus is similar as in bacteria. It is a two-step process. In first step, metal solution added in the fungal extract. metal ions attached to the fungal cell surface by electrostatic interaction through lysine residues (Priyadarshini et al., 2021). In the second step, the process of reduction of metal ions takes place by the assistance of fungal enzymes that leads to the formation of nanoparticles (Bhainsa & D'Souza, 2006). In this way, Uptill now various metal and metal oxide nanoparticles has been synthesized by researchers. Recently synthesized medically important metal/metal oxide NPs are listed in the table 4 below.

Table 4. Fungi templated synthesis of nanomaterials

Fungi	NPs	Size & Shape of NPs	Application	Ref
Phanerochaete chrysosporium	ZnO	50, Hexagonal	Antimicrobial	(J. L. Sharma et al., 2021)
P. floridanus	ZnO	7nm, hexagonal	Optimization study	(Rafeeq et al., 2021)
Aspergillus fumigatus	ZnO	60- 80nm, Spherical	Antibacterial	
Aspergillus terreus	ZnO	54.8 to 82.6nm, Spherical	Antifungal	
endophytic fungus	Ag	66 to 88.6 nm, spherical	antioxidant	(Mabrouk et al., 2021)
Ganoderma enigmaticum, Trametes ljubarskyi	Ag	-	Anticancer activity	(Krishna et al., 2021)
Aspergillus brunneoviolaceus	Ag	0.72 to 15.21, spherical	Antioxidant, antibacterial	(Mistry et al., 2021)
Penicillium oxalicum strain LA-1	Ag	52.26, spherical	Antilarval	(Seetharaman et al., 2021)
Penicillium oxalicum	Ag	60 to 80 nm, spores	Antibacterial	(Feroze et al., 2020)
Alternaria sp.	Ag	3-10 nm, spherical	Antifungal	(Win et al., 2020)
Beauveria bassiana	Ag	10-50, triangular, circular, hexagonal	Antibacterial activity	(Banu & Balasubramanian, 2014)
Aspergillus terreus	Ag	1 to 20	Antimicrobial activity	(Khan & Jamee, 2016)
Chaetomium cupreum	Iron Oxide	25nm, spherical	anticancer	(Wani et al., 2020)
Penicillium oxalicum	Iron Oxide	140nm, spherical	Dye	(Mathur et al., 2021)

Penicillium commune	Iron Oxide	20-50, quasi-spherical	degradation evaluation of nano gel	(Mahanty et al., 2019)
Aspergillus niger BSC-1	Iron Oxide	20-40, nanoflakes	Removal of heavy metal	(Chatterjee et al., 2020)
Fusarium solani	Au	41nm, Spherical,	-	(Clarance et al., 2020)
Penicillium brevicompactum	Au	20- 80nm, Spherical, hexagonal, triangular,	Anticancer activity	(A. Mishra et al., 2011)
Hormoconis resinae	Au	3–20nm, Hexagonal,	Optimization study	(A. N. Mishra et al., 2010)
Alternaria alternata	Au	2–30nm, Spherical, Triangular,		(Sarkar et al., 2012)
Phanerochaete Chrysosporium	Au	10-100nm, Spherical,	-	(Sanghi et al., 2011)

3. Biomedical incentives of green synthesized nanomaterials

Green surface chemistry of nanoparticles made them a favorable candidate to show their aptitude in the field of biomedical sciences. Metal/metal oxide nanoparticles discussed in this review used in various applications. Biologically synthesized zinc oxide, iron oxide and gold nanoparticles used in drug delivery system due to their biocompatible nature, nontoxic effect and controlled biodegradable property that allows the prolonged discharge of drugs at targeted site over a specific period of time (Rasmussen et al., 2010). Studies reveled that for targeted delivery nanoparticles were labeled with fluorescent tag. For instance, in the treatment of cancer ZnO NPs labeled with blue fluorescence dye and loaded with doxorubicin (DOX). Results showed that DOX was entrapped on ZnO NPs with the loading efficiency of 75 %. Then controlled delivery of DOX were seen at specific pH(Y. Wang & Chen, 2011). In same way ZnO NPs also used for targeted gene delivery. ZnO NPs also retain semiconducting properties like biosensing, and high catalytic efficiency. Due to the toxic effect of AgNPs, they have been vastly used in antibacterial and antifungal activities. Curcumin-mediated synthesis of Ag NPs were used in Antiviral activities against respiratory syncytial virus (RSV) (Karthikeyan et al., 2020). Phytosynthesized Ag NPs form the extract of *Andrographis paniculata*, *Phyllanthus niruri* and *Tinospora cordifolia* plants were used to reduce the infection triggered by chikungunya virus (V. Sharma et al., 2019). Recently, Green-reduction method was used to prepared cobalt nano-precipitates having capping of *Withania* biomolecules in the form of nano-sponges enhances trapping of bacteria through specific interaction and leads to apoptotic cell death(Zafar et al., 2021).

In another report, bio compatibles iron carbide were synthesis and coated with various surfactant for fishing biomarker in differential protein form for the diseases diagnosis and treatment. These unique surface modified nanoparticles are very effective in future for identification of diseases at early stage(Hasan, Gulzar, et al., 2021). Fan et al, reported a bio-conditioned poly-dihydromyricetin-fused zinc oxides NPs were fabricated with the help of green tonic technique showed excellent potential against graham positive and negative bacteria and different industrial effluents degradation. However, it has been observed that *Ampelopsis grossedentata* functional bioactive molecules play key role for the release of Zn^{2+} in gastrointestinal ffluids. This bio-conditioned nanomaterial showed very stable and ecofriendly ways to treat drug resistant bacteria infections as well as degradation of toxic dye efuents (Luo, Zeng, Wang, et al., 2021). In similar reports, they used tea saponin as grafting PEGylated dihydromyricetin-loaded liposomes as an efficient cationic antibacterial agent against *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*). Preparation of hybrid nanostructure displayed an effective breaking of bacterial energy metabolism and cytoplasmic membranes, resulting in the deformation of the cell wall and leaking of cytoplasmic constituents(Luo, Zeng, Chen, et al., 2021).

According to Murtaza et al, different fractions of *Withania coagulans* were tested for activity in the biogenic synthesis of cobalt oxide nanoparticles, biofilm and antifungal activities. The results showed that plant extract with bioactive fractions showed more potent bioreducing power, effectiveness against biofilm formation by *Pseudomonas aeruginosa* and *Staphylococcus aureus*. However, hexane/H_2O fraction showed excellent antifungal activity against *Aspergillus niger* and *Candida albicans*, so these fractions are potentially useful for the treatment of various fungal infections. In their another reports, silver nanoparticles were prepared by the functional biomolecules from the Chinese plants *Dracaena. cochinchinensis* (Lour.) S.C.Chen (Hasan et al., 2013; Hasan, Zafar, et al., 2020).

In case of nanoparticles effect on plants for their applications, Ghazala et al, observed that the effects of bio synthesized (BS) and chemically synthesized (CS) silver NPs on soybean and it was seen that biosynthesized results found that biological prepared silver NPs enhanced the growth of soybean by regulating proteins related to protein-degradation and ATP contents, which are negatively affected by CS silver NPs. Similarly, reports were also observed that in compared of chemically and biologically synthesized iron oxide nanorods on maize (*Zea mays*) cell cycle stages. Furthermore, it was also observed that chemically prepared iron oxides NRs inhibit the growth and impaired plant physiological and anti-oxidative activities at a concentration higher than 25 mg/L due to toxicity by over accumulation. While iron released form biologically synthesized NRs have shown significantly positive results(Hasan, Rafique, et al., 2020; Mustafa et al., 2020). Gold NPs synthesized from garlic extract were used against measles virus. Moreover, these under discussion Nanoparticles were also used against Multidrug resistance bacterial strains (*Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Klebsiella pneumoniae)* and provided with highly efficient potential to kill them (Yin et al., 2020). These NPs also have efficient efficacy to act as anticancer agent. For instance, *Trichosanthes kirilowii* synthesized Au NPs potentially arrest the cell cycle in G_0/G_1 phase and create the induction of antiinflammation and apoptosis of colon cancer cells via bax/bcl2, caspases pathway(Han et al., 2019). So, in a nutshell, green synthesized nanoparticles have been widely used in biomedical fields as shown in **Fig 7.**

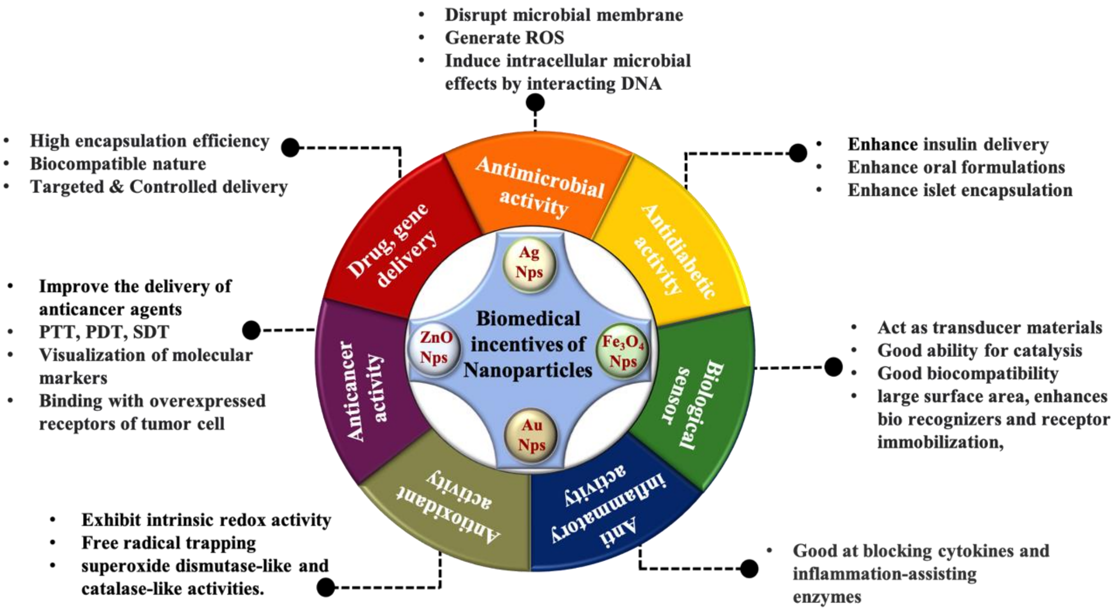

Fig 7. Biomedical incentives of green synthesized nanomaterials in practical approaches

4. Conclusion and future concern

Green chemistry process for the synthesis of nanomaterials is eco-friendly and easy to affordable in term of cost. Biological resources such as bacteria, algae fungi and plants are very rich in reducing, stabilizing and oxidizing agent for synthesis of nanomaterials. These biological agents are locally available in every environment but there is need to bring these raw materials into practical approach to attain maximum benefit without adding any harmful agent into the environment. In other way, there are many challenging in the future regarding the reproducibility of result via green chemistry methods, enhance the reliability of results and to investigate the information of single biological agent for the synthesis of nanomaterials. We do believe that this review article will be very useful for young researcher in the field of green chemistry, nanobiotechnology and nanoscience and nanotechnology to develop efficient methodologies and useful applications to enhanced the biomedical and physical application.

Contribution of Authors

Tuba tariq: write-up, graphics
Ayesha Zafar: graphics, outline designing
Murtaza hasan: supervision, conceptualization
Xue Huang: data collection
Fatima tariq: Data collection
Riaz Hussain: Data collection
Saif MS: Drafting the article
Waqas M: Drafting the article
Manzoor Y: Critical revision
Muniba Anum Nazir: writeup
Shahbaz Gul Hassan: Critical revision
Hafiz Umer Javed: writeup
Syed Ishtiaq Anjum: data interpretation.
Shu X: data interpretation.

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