Hadhramout University Journal of Natural & Applied Science Vol 22 No 1 (2025) 19 –38

NAS journal Hadhramout University

Contents lists available at https://digitalcommons.aaru.edu.jo/huj_nas/.
Hadhramout University Journal of Natural & Applied Science

Article

Digital Object Identifier:
Received 26 April 2025,
Accepted 20 May 2025,
Available online 25 July 2025

A Review on Biological Synthesis of Nanoparticles: Medical and Agricultural Applications

Yousef abdulwahab[1,3*], Ahyar Ahmad[1], Isra wahid[2], Paulina Taba[1] and Nabil Alkadasi

[1]Department of Chemistry, Faculty of Mathematics and Natural Sciences, Hasanuddin University, Makassar, Indonesia.
[2]Department of parasitology, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia.
[3]Department of Medical laboratory, Faculty of Medical Sciences, Taiz University, Taiz, Yemen.
[4]Department of Chemistry Faculty of Education and Sciences, Albaydha University, Yemen and Department of pharmacy
[5]Dental National University, Taiz , Yemen.

*Corresponding author: youdefahmef@gmail.com

Abstract: Nanoparticles (NPs) are materials made up of a collection of atoms that have one or more sizes that fall within the range of 1-100 nm on the nanometer scale. Metallic bionanoparticles are currently a very important and dynamic area of research, with significant implications for practical research. Due to its eco-friendly, non-toxic, low energy requirement, and multifunctionality, biological synthesis of NPs is preferable to physical and chemical synthesis. Because they contain significant secondary metabolites that speed up the reduction and stability of the NPs, plants and microbes are effective reducing agents. The created NPs can subsequently be characterization of physical and chemical properties under an electronic microscope (TEM, SEM, AFM) and using spectroscopy (UV-Visible, XRD, IR, etc). A metallic ion or its oxide can be biologically reduced to a nanoparticle quickly, easily, and up to constant temperature and pressure. One of the main causes of illness and mortality in humans is the rise in multi-drug resistance microorganisms brought on by the overuse of antibiotics in individuals who are not diseased. It is crucial that novel antibiotics with various modes of action are developed today to combat bacteria. At low concentrations, metals and its oxides are extremely hazardous to microorganisms. Additionally, widespread illnesses in human and plants are causing grave concern throughout the planet. Due to their wide range of bioactivity, NPs make excellent antibacterial mediators in both the agricultural and medicinal industries. The current research summarizes the creation of NPs via microbial and botanical sources, which allows metals to remain in a stable form and after ionization. Additionally, it displayed an important database on the use of synthetic nanopesticides in many agricultural and medicinal fields.

Keywords: Nanoparticles, Nanopesticides, Agriculture, Antimicrobial Activity, Green synthesis.

1. Introduction :

Nanotechnology is a small area of research, and the word "nano" is derived from the Greek phrase for "dwarf." One billionth of a part is referred to as a "nano"10^9. Nanotechnology is essentially the application of nanometer-sized particles (1-100 nanometers) [1]. For upcoming applications, nanotechnology has created a variety of cutting-edge materials over the last ten years. One of the biggest issues facing civilization is environmental cleanup, which can be tackled by using nanoparticles [2].

Over the past ten years, there has been a significant increase in the manufacturing of nanoparticles, and now these materials are widely employed in applications such as devices, biomedical, drugs, skincare, power, the environment, catalysis, and materials. significance and opportunity Nanotechnology is one of most lucrative and rapidly developing fields of technology. Recently, the cofriendly nanoparticles synthesis has been considered as an effective and optimum strategy for further exploitation of bio-organisms as nano factories as the 21st century approaches and billion dollars sales of nano items are expected [3,4].

By employing nanotechnology fertilizers or by promoting plant development, nanomaterials can improve agricultural and medical operations including insecticidal, soil quality, and improve the quality of products. Inside Furthermore, chemicals and carriers based on nanoparticles cut back on the use of pesticides and fertilizers without reducing yield[5].

Metals are reduced to their corresponding oxides by phytochemicals like flavonoids, saponins, quinones, alkaloids, glycosides, polyphenols, amides, tannins, and terpenoids. As decreasing capping, and stabilizing agents, organic substances derived from plants and plant components are used. The biological foundation of green synthesis techniques depends on several factors, including the solvent, temperature, pressure, and pH levels (acidic, basic, or neutral).

In the straightforward one-step synthesis of NPs, extract and metallic solution are added, and within minutes, nanostructures are formed of the oxidation / reduction processes. [6,7]

On the other hand, nanomaterials are in good quality for a variety of uses, from biomedical to bioenergy. This is because the nano shape is supported by a large surface area that can assist loading of the target molecule for a variety of scientific applications, such as drug carrier for pathogen infections and molecular disorders specially cancer. Analyzed the toxicity of the drug carrier is important by using nanomaterials as drug carriers; this idea led to the development of synthesis and characterization, that can replace chemical processes that result in hazardous nanostructures. Drug distribution can be targeted to the desired region by synthesizing a metal oxide which reacts to a variety of effects [8]. These nanoparticles could be effectively employed in environmental remediation in addition to drug delivery applications since they can decompose pollutants without harming the environment because the nanocarriers are made from natural substances [8]. This research primarily focuses on novel and cutting-edge green synthesis techniques for nanomaterial that are sensitive to a variety of stimuli. These techniques produce prominent and cost-effective nanoparticles which can be used for a variety of applications and have the added benefit of being bio recyclable. This environmentally friendly synthesis not only creates extremely effective nanostructures but also completes its intended task without endangering living things or the environment [9,10].

The current article demonstrates traditional synthetic techniques while emphasizing more recent advancements in environmentally friendly ways to produce metallic nanoparticles, and other significant NPs. The formation methods and the environmental factors that affect the surface shape, size distribution, and other characteristics of these biologically synthesized NPs are then discussed.

2. The Search Methodology

These objectives are three objectives are based on the huge potential of plants as sources for the synthesis of nanoparticles. it is first necessary to describe the investigation of plants, microorganisms, and their extracts. In the second section, information is given regarding the numerous characterization tools that are employed to locate synthesized NPs. The biological and agricultural uses of the green synthetic NPs are finally explained. Search methodologies and selection criteria for the literature pertaining to scientific journals were meticulously employed. Hindawi, PubMed and others served as comprehensive resources for this review. Research publications spanning the last 15 years were thoroughly consulted.

3. Background history

3.1 Classes of nanoparticles

Chemically, the chemical structure of manufactured nanoparticles, quantum dots, metal-containing nanoparticles (including metal oxides), carbon-based nanoparticles, zero-valent metals, and dendrimers can be divided into five main classes. In recent years, toxicological research has mainly concentrated on the impacts of three of the five kinds of nanoparticles based on their composition: carbon-based nanoparticles (such as carbon nanotubes and fullerenes) and metal or metal-oxide nanoparticles (Ag, Cu, TiO_2 NPs)[9].

3.2 Synthesis of NPs

3.2.1 Views of Nanoparticle Synthesis

As shown in Figure 1, the breakdown (top-down) and build-up (bottom-up) methods have been used to create ultrafine NPs since ancient times.

The breakdown approach is frequently employed during the physiochemical synthesis of NPs. By using physical forces like grinding, pulverization, and other processes, substance is size decreased as a step to the nano size in the degradation process, also known as the thermomechanical technique [10]. Physical processes are hard to access with NPs; normally, microparticles less than 3 m are not difficult to obtain. The second technique for getting NPs is the build-up procedure.

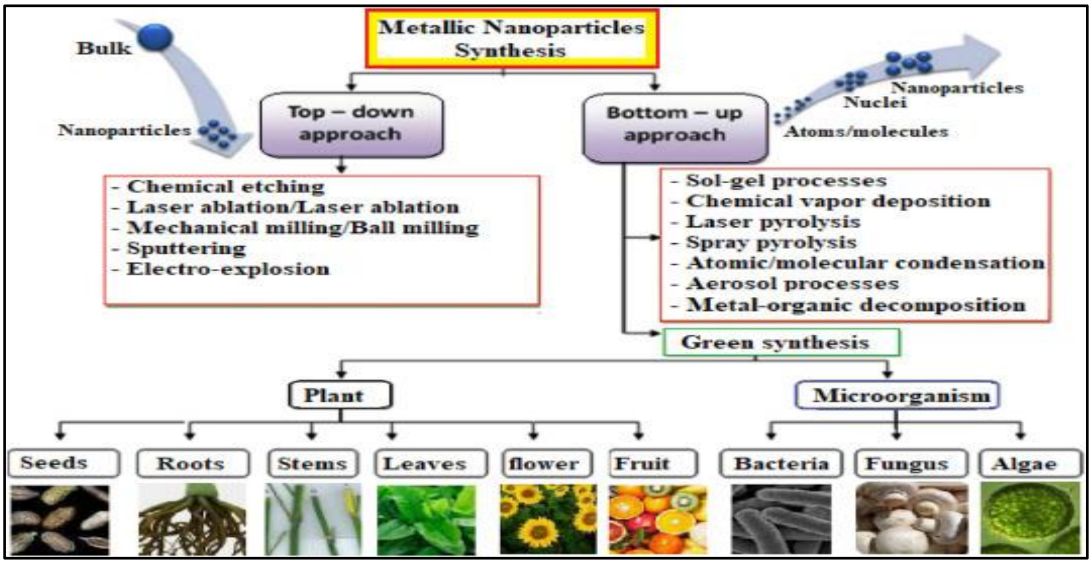


Figure 1. Schematic diagram of Various approaches for the synthesis of NPs. (This figure has been adapted from ref [11])

Main strategies for the production of Nanoparticles are possible in the liquid and solid phases of matter, without the employment of potentially harmful substances in biogenic synthesis, and with a markedly increased level of chemical synthesis. In the bottom-up method, the applications of the biological process or its components can be observed in the synthesis of biogenic NP. One must take into account a number of characteristics, such as biosynthetic processes, phytochemical content, biochemical processes, growth factors circumstances, and ideal reaction conditions, in order to select the right organisms or extracts[12].

3.2.2 Secondary Biomolecules for Capping and Stabilization

As shown in Figure2, plant extract serves as a covering and binding agent in addition to being a reductant.

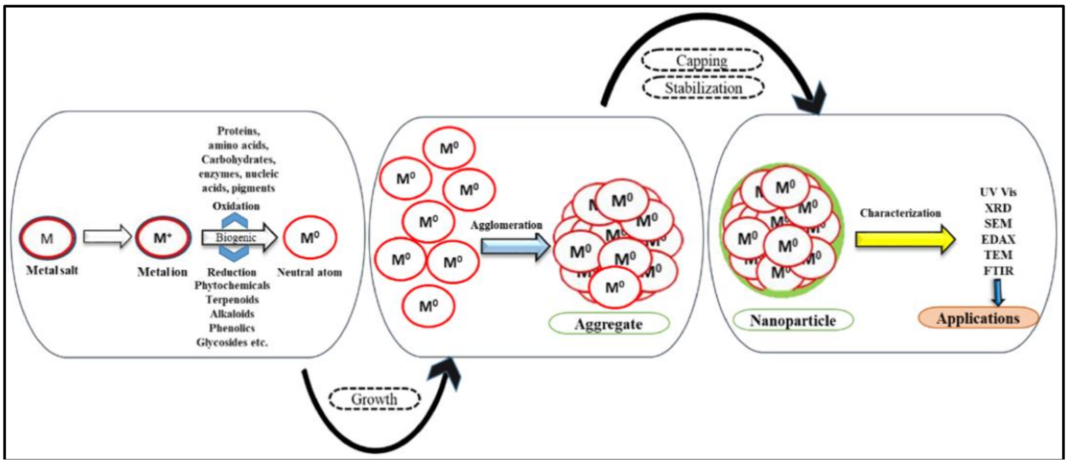


Figure 2. Schematic diagram of biological reduction of NPs. (This figure has been adapted from ref[13]).

When combined with the Fourier Transform Infrared (FTIR) analysis, the Infrared (IR) spectrum of Camellia sinensis crude revealed the presence of polyphenols, carboxylic acids, polysaccharides, amino acids, and proteins. This proved the prophetic of biomolecules functioning as covering and stabilizing agents to be correct. [14]. ZnO Nanoparticles displayed peaks in the range of 682-457 cm^{-1}, indicating a higher concentration of phenolics. The stability investigations of silver nanoparticles (Ag NPs) made from Ziziphora spp extract at room temperature showed that several metabolite functional groups, including aldehyde, ketone, amine, alcohol, and carboxylic acid compounds, were responsible for the bio nanofabrication of Ag NPs. Significant differences could be seen in the FTIR peak graph between the treatment and untreated samples, which suggested that proteins with amide groups might serve as the covering layer for metal NPs. [15]. Ascorbic acid's FTIR peak extends inside this OH, CH, C=C circle, and CH_2 wagging revealed that ascorbic acid is present in the Hibiscus cannabis extract and is responsible for lowering Ag NPs. The phenolic components in coconut shell extract were produced the synthesis of Au NPs. A big shrub called Calotropis gigantea contains phytoconstituents like trisaccharide, glycosides, saponins, beta-sitosterol , alkaloids, flavanols and tannins. The associations of the macromolecules with the Au NPs are indicated by FTIR spectra [16].

3.3 Characterization of Nanoparticles

An essential step in improving nanoparticle synthesis is nanoparticle characterization. The effectiveness of an activity is enhanced by the use of suitable nanoparticles. Various diagnostic methods have been used to study the produced.

Table 1. Illustrated various methods used in the characteristic Nanoparticles

	Instruments	Number	Size Distribution	Agglomeration State	Shape	Surface Area	Chemical Composition
Microscopy techniques	(Scanning Electron Microscopy) SEM	✓	✓	✓	✓		
	(Transmission Electron Microscopy) TEM	✓	✓	✓	✓		
	(Scanning Probe Microscopy) SPM	✓	✓	✓	✓		
Spectroscopy techniques	Visual ultraviolet spectroscopy		✓				✓
	X-ray Diffraction		✓				✓
	FTIR analysis						✓
	Atomic absorption spectroscopy						✓
	Photoelectron X-ray						✓
	Dynamic light Scattering		✓	✓			
	Zeta potential					✓	

NPs based on different features such special functional classes, light scattering and absorption potentials, and so on. In most cases, UV-visible spectroscopy is utilized to confirm the stability and synthesis of NPs.
The features of NPs, including composition and concentration, surface characteristics, surface functional groups, and atomic organization, are measured using Fourier - transform infrared (FTIR) spectroscopy[17]. The location, size, and morphology of NPs can be seen by transmission electron (TEM), scanning electron microscopy (SEM), and atomic force microscope (AFM) [18]. The crystalline structure is determined via X-ray diffraction (XRD). Energy - dispersive x-ray spectroscopy (EDS) is typically apply to determine the elemental analysis of NPs, while the dynamic light scatter (DLS) approach is mostly utilized to show the size and external charge of NPs [19]. All information about the techniques, Instruments, Number, Size Distribution, Agglomeration, State Shape, Surface Area, and Chemical Composition in Table 1.

3.4 Employment of green synthetic nanoparticles

Green synthesis offers an eco-friendly approach to producing nanoparticles (NPs) by utilizing biological sources such as plants, algae, fungi, and bacteria, thus avoiding toxic chemicals and reducing energy consumption. This method leverages natural biomolecules for reducing and stabilizing agents. Plant-based synthesis (Table 2) uses extracts from various plant parts, while algae-based synthesis (Table 3) employs marine and freshwater algae. Fungi-based synthesis (Table 4) utilizes filamentous fungi and yeast, and bacteria-based synthesis (Table 5) involves both Gram-positive and Gram-negative bacteria, including extremophiles, all contributing to diverse NP applications from biomedicine to environmental remediation.

Table 2. A number of plants used in the synthesis of NPs and their effects

Botanical Names	NPs	image	NP size (nm)	Application	Refs
Ricinus communis	gold		40–80	Antimicrobial Anticancer	20
Anacardium occidentale	gold		10–60	Antimicrobial Anticancer	21
Dracocephalu m kotschyi	gold		5–21	Anticancer	22
Euphorbia peplus Fruit	gold		50	• Anticancer •Antibacterial • Insecticidal	23
Gnidia glauca L. Flower	gold		5-20	•Chemocatalytic	24
Abelmoschus esculentus (L.) Moench	gold		45–75	• Antifungal	12
Ananas comosus (L.) Fruit	gold		10 ± 5	• Antimicrobial	25
Cocos nucifera Linn. Liquid endosperm	gold		.022	• Cytotoxicity	26

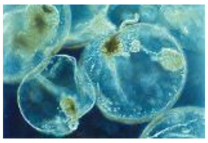
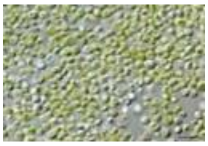
Ficus religiosa L. Bark	gold		20-30	• MTT assay	27
Morinda citrifolia L. Root	gold		12.17–38.26	• NM	28
Pistia stratiotes L. Aerial and submerged parts	gold		2-40	• NM	29
Senna siamea (Lam.) Leaf	gold		70	• Antibacterial	30
Plumeria alba Linn. Flower	gold		20-30	• Antimicrobial	31
Euphorbia fischeriana Root	gold			• Antioxidant	32
Tropaeolum majus L Flower	silver		38.26	• Antibacterial	33
Camellia sinensis	silver		4-50	• Antibacterial	34
Ferula gumosa, Ferula latisecta, Leaf	silver		20-80	• Antibacterial	35
Teucrium polium, Trachomitum Venetum Leaf	silver		20-80	• Antibacterial	36
Juniperus procera Fruit	silver		30-90	• Antimicrobial	37
Holoptelea integrifolia Unripe fruits	silver		32-38	• Anti-diabetic • Antibacterial •Antiinflammatory	38

Prosopis farcta Leaf	silver		11-15	• Antioxidant •antibacterial	39
Piper longum L. Leaf	silver		28.8	• Antioxidant • Anti-cancer • Antilarvicidal	40
Solidago canadensis Latex	silver		100-300	• Cytotoxic	41
Cocos nucifera Linn. Coir	silver		23 ± 2	• Larvicidal	42
Coriandrum sativum L. Seed	silver		13.9	•Antimicrobial	43
Euphorbia hirta L. Leaf	silver		30-60	• Pesticidal	44
Musa acuminata colla L. flower	silver		Nanoclust ers	• Antibacterial • Antifungal	45
Nelumbo nucifera Gaertn. Root	silver		~16.7	• Protein binding • Antioxidant • Anticancer	46
Withania somnifera Linn. Leaf	silver		5-30	•Antimicrobial	47
Ocimum sanctum Linn. Leaf	Silver		50	•Antimicrobial	48
Sapium sebiferum Leaves	platinum		2-12	• Antibacterial	49
Moringa oleifera Leaves	platinum		35	• Antibacterial • Antioxidant • Anticancer	50

Diospyros kaki Leaves	platinum		2-12	NM	51
Lantana camara (L.) Leaves	platinum		35	NM	52
Trianthema portulacastru m Extract	Zinc oxide		25-90	• Cytotoxic • Cytotoxic •Antibacterial • Antifungal •Antioxidant	53
Matricaria Chamomilla Lycopersicon esculentum	Zinc oxide	 	40-124	•Antibacterial	54
Punica granatum Extract	Zinc oxide		32.98–81.84	• Cytotoxic •Antibacterial	55
Rheum turketanicum Extract	Zinc oxide		17-20	• Cytotoxic	56
Tecoma castanifolia Extract	Zinc oxide		70-75	•Antiseptic •Antioxidant • Antitumor	57
Silybum marianum	Zinc oxide		31	• Cytotoxic • Antifungal • Antibacterial	58
Anchusa italic Flower	Zinc oxide		8-14	• Antibacterial • Cytotoxic	59
Aloe vera Leaves	Zinc oxide		8-20	• Antibacterial • Cytotoxic	60
Rosa canina Fruit	Zinc oxide		50-400	• Antibacterial • Antioxidant • Cytotoxic	61
Boswellia ovalifoliata Bark	Zinc oxide		20	•Antimicrobial	62

Emblica officinalis Fruit	Magnesium oxide		27	• Antibacterial	63
Clitoria ternatea Whole plant	Magnesium oxide		50-400	• Antioxidant	15
Ocimum tenuiflorum Extract	Copper oxide		20-30	• Antibacterial	64
Moringa oleifera Extract	Copper oxide		35-95	• Antifungal	65
Eichhornia crassipes Leaves	Copper oxide		28	• Antifungal	66
Gloriosa superba Leaves	Copper oxide		5-10	• Antibacterial	67
Artocarpus heterophyllus Extract	Titanium dioxide		15-20	• Cytotoxic • antibacterial • anticancer	68
Citrus sinensis fruit	Titanium dioxide		20-50	• Antibacterial, Cytotoxic, and Anticancer	69
Musa alinsanaya Fruit	Titanium dioxide		31	• Larvicidal • antibacterial	70
Psidium guajava Leaves	Titanium dioxide		32	• Antibacterial • Antioxidant	71
Vitex negundo Leaves	Titanium dioxide		93	• Antibacterial	72
Medicago sativa leaves	Samarium		10	• Antitumor	73
Medicago sativa Leaves	Neodymium		10	• NM	74

Table 3. various algae used in the synthesis NPs and their applications

Algae	NPs	Image	size (nm)	Applications in agriculture	Refd.
Amphiroa rigida	Ag		25	Antibacterial and anticancer	75
Chara vulgaris	Ag		16.99 ± 0.3	antibacterial	76
Noctiluca Scintillans	Ag		4-5	Anticancer and antibacterial	77
Botryococcus Brauni	Ag		40-90	Catalyst in synthesis of benzimidazoles	78
Portieria Hornemanni	Ag		-	Antibiotics in the treatment of diseases	79
Ulva armoricana	Ag		12.5	Antibacterial	80
Chlorella Vulgaris	Ag		40-90	Catalyst for the synthesis of quinolines	81
Laminaria Japonica	Ag		20-30	Seed treatment, Pharmacy	82
Spyridia Fusiformis	Ag		Spherical, Rounded, Rectangle	Antibacterial	83
Sargassum Wighti	Ag		18.45–41.59	Pharmacological effect	84

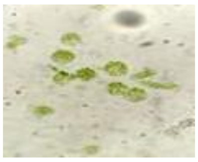
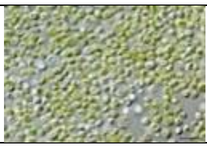
Neodesmus pupukensis	Au and Ag		5-34	Antioxidant, antimicrobial	85
Cystoseira baccata	Au		Spherical	Anticancer	86
Gelidiella acerosa	Au		5 -117	antibacterial, antioxidant	87
Sargassum crassifolium	Au		5-300	Biomedical	88
Anabaena cylindric	ZnO		40-60	Antimicrobial	89
Cladophora glomerata	ZnO		14 -37	Biomedical	90
Tetraselmis indica	ZnO		20-40	Fabric, cosmetic, biomedical, food wrapping	91
Chlorella vulgaris	Pd		15	NM	92
Padina boryana	Pd		11	Antibacterial and anticancer	93
Macrocystis pyrifera	CuO		2-50	NM	94
Botryococcus braunii	Cu and Ag		10-70 (Cu) 40-100 Ag	Antimicrobial	95
Chlamydomonas reinhardtii	CdS		Spherical	Photodegradation of biological dyes	96

Table 4. various fungi used in the synthesis NPs and their applications

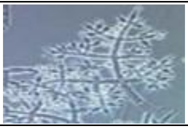
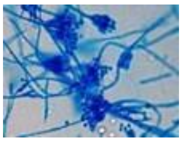
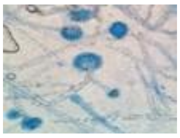
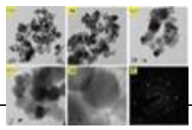
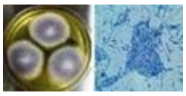
Fungi	NPs	Image	size (nm)	Applications in agriculture	Refd.
Pleurotus sajorcaju	Au,Ag		20-40	NM	97
Phanerochaete chrysosporium	ZnO		50	Antimicrobial	98
Trichoderma Harzianum	Ag		21	Antioxidant, antibacterial	99
Rhizopus oryzae	MgO		20	Germicide, insecticidal, and tanning treatment	100
Morchella esculenta	Au		16	Biomedical	101
Aspergillus sydowii	Ag		1-24	Fungicidal and antiproliferative action to HeLa cells	102
Aspergillus flavus	Cu		2-60	Biomedical	103
Ganoderma lucidum	Ag		15-22	Antimicrobial, antiseptic, antimycotic	104
Periconium sp	ZnO		16-78	Germicide and antioxidant	105
Fusarium solani	Au		40-45	Antitumor	106
Trichoderma harzianum	Ag, CuO		5-18	biotechnological method	107
Fusarium oxysporum	Au		22-30	Therapeutic	108

Table 5. various bacteria used in the synthesis NPs and their application

Bacteria	NPs	NP size (nm)	Application	Refs
Actinobacter spp	Au	5–500	Antimicrobial, fungicidal, nano compost	109
Bacillus subtilis	Au	80	NM	110
Escherichia coli	Au	50	NM	111
L. casei	Au	29	NM	112
Haloferax volcanii	Au	*10*	*Antiseptic activity, Nano biosensors*	113
Deinococcus radiodurans	Au	*43*	*Antibacterial action*	114
Deinococcus radiodurans	Au	*149*	*Environmental treatment*	115
Acintobacter species	Au	*15*	*Antioxidant action*	116
Acintobacter species	Au	10	*Ecological remediation*	117
Plectonema boryanum	Au	10-25	*NM*	118
Lactobacillus kimchicus	Au	5–30	NM	119
Lactobacillus. casei	Ag	12 –27	Herbal-development stimulator, antimicrobial action, antimycotic effect	120
L. acidophilus	Ag	4–40	NM	121
Pseudomonas stutzeri	Ag	Up to 200	Herbal-development stimulator, antimicrobial action, antimycotic effect	122
Staphylococcus aureus	Ag	160–180	Herbal-development stimulator, antimicrobial action, antimycotic effect	123
Brevibacterium casei	Ag	10–50	NM	124
Escherichia coli	Ag	100	stimulant of plant growth, antibacterial action, and antifungal action	125
Bacillus cereus	Ag	4 - 5	NM	126
Bacillus licheniformis	Ag	18–63	Fungicidal effect	127
Lactobacillus plantarum	Ag	19	NM	128
Lactobacillus rhamnosus	Ag	233	NM	129
Lactobacillus sp.	Ag	15–25	NM	130
Pseudomonas deceptionensis	Ag		antibacterial action and bio film suppression	131
Pseudomonas fluorescens	Ag	5-50	Antibacterial activity and pesticide	132
Sporosarcina koreensis	Ag	varied	Antibacterial action	133
Acinetobacter sp.	Ag	10	Fungicidal - biofilm inhibition	134
Pseudomonas rhodesiae	Ag	20-100	Antibacterial action	135
Pseudomonas poae	Ag	19-44	Antifungal action	136
Streptomyces capillispiralis *Streptomyces zaomyceticus* *Streptomyces pseudogri*	Ag Ag Ag	23-63 11-36 11-44	Antibacterial action Antifungal action Larvicidal	137
Haloalkaliphilic Streptomyces	Ag	16	Antibacterial action and Antifungal action	138
Streptomyces griseus	Cu	5-50	fungicides	139
Lactobacillus casei	Cu	30–75	Plant fertilizer	140

3.5 Mode of Action of NPs

Various studies indicate that metallic NPs cause damage to microorganisms by generating superoxide radicals (ROS) such hydroxyl and superoxide anion, which destroy cell walls and membranes as well as cause DNA damage and other oxidative and destructive effects. Figure3 displays a diagram representation of the NPs action process.

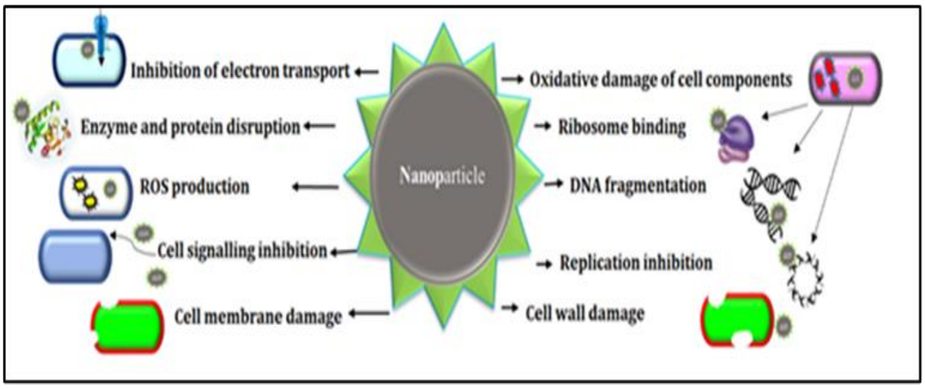


Figure 3. Schematic diagram of mechanism of action of NPs against microorganisms. (This figure has been adapted from ref. [13])

4. Conclusions and Future Perspectives:

A paper illustrated the most recent advances in bioactive nanoparticle (NP) green production, characterization, and applications. It also explains how secondary metabolites generated from plants and microbes, like alkaloids, terpenoids, quinones, others and, are applied as capping and reducing agents in these environmentally friendly methods. These bioactive compounds are organically formed from safe plant materials including algae, fungi, and bacteria, as well as plant extracts from many widely available species like bananas, tea, onions, and coconuts. The avoidance of hazardous or toxic substances can be overcome by green synthesis; also, synthesis on a reasonable scale can be accomplished. Fine size control, which increases the stability and lifespan of biologically synthesized NPs over chemical and physical alternatives, is their main advantage. Based on the different metal kinds, several methods have been suggested for simpler nanoparticle generation. Due to its less well-known mechanism of action, physiological studies of NPs are significant in vitro experiments, but there are few data on in vivo studies. Due to its quick production in the liquid state and its collaborative action against microorganisms, a biostatic analysis of utilized metals reveals extensive utilization. However, the region-specific, varietal, and part time variations in the chemical components of plant crude extract may frequently result in different outcomes in various laboratories, which calls for additional research into identifying important plant phytochemicals or metabolites in order to develop more modern processes for NP synthesis. Nutritional value, global food production, plant defense, disease detection in plants and animals, and environmental monitoring can all benefit from nanotechnology.

Acknowledgement

For their cooperation in completing this review work, the authors are grateful to Hasanuddin University's Mathematics and Natural Science Faculty (FMIPA).

References

[1]Bhattacharyya, A.; Bhaumik, A.; Rani, P. U.; Mandal, S.; Epidi, T. T. Nano-Particles - A Recent Approach to Insect Pest Control. *African Journal of Biotechnology* **2012**, *9* (24), 3489–3493. https://doi.org/10.4314/ajb.v9i24.

[2] Chinnamuthu, C. R., and Boopathi, P. M. ,. *Nanotechnology and agroecosystem.* Madras Agricultural Journal,. https://www.cabdirect.org/cabdirect/abstract/20093323550 (accessed 2022-07-23).

[3] Tiede, K.; Hassellöv, M.; Breitbarth, E.; Chaudhry, Q.; Boxall, A. B. A. Considerations for Environmental Fate and Ecotoxicity Testing to Support Environmental Risk Assessments for Engineered Nanoparticles. *Journal of Chromatography A* **2009**, *1216* (3), 503–509. https://doi.org/10.1016/J.CHROMA.2008.09.008.

[4] Danie Kingsley, J.; Ranjan, S.; Dasgupta, N.; Saha, P. Nanotechnology for Tissue Engineering: Need, Techniques and Applications. *Journal of Pharmacy Research* **2013**, *7* (2), 200–204. https://doi.org/10.1016/J.JOPR.2013.02.021.

[5] Singh, P.; Kim, Y. J.; Zhang, D.; Yang, D. C. Biological Synthesis of Nanoparticles from Plants and Microorganisms. *Trends in Biotechnology* **2016**, *34* (7), 588–599. https://doi.org/10.1016/J.TIBTECH.2016.02.006.

[6] Duhan, J. S.; Kumar, R.; Kumar, N.; Kaur, P.; Nehra, K.; Duhan, S. Nanotechnology: The New Perspective in Precision Agriculture. *Biotechnology Reports* **2017**, *15*, 11–23. https://doi.org/10.1016/J.BTRE.2017.03.002.

[7] Gour, Aman, Jain, Narendra Kumar. Advances in Green Synthesis of Nanoparticles. *Artificial Cells, Nanomedicine and Biotechnology* **2019**, *47* (1), 844–851. https://doi.org/10.1080/21691401.2019.1577878.

[8] Hassanisaadi, M.; Bonjar, G. H. S.; Rahdar, A.; Pandey, S.; Hosseinipour, A.; Abdolshahi, R. Environmentally Safe Biosynthesis of Gold Nanoparticles Using Plant Water Extracts. *Nanomaterials* **2021**, *11* (8). https://doi.org/10.3390/nano11082033.

[9] Bhatt, I.; Tripathi, B. N. Interaction of Engineered Nanoparticles with Various Components of the Environment and Possible Strategies for Their Risk Assessment. *Chemosphere* **2011**, *82* (3), 308–317. https://doi.org/10.1016/j.chemosphere.2010.10.011.

[10] Jamkhande, P. G.; Ghule, N. W.; Bamer, A. H.; Kalaskar, M. G. Metal Nanoparticles Synthesis: An Overview on Methods of Preparation, Advantages and Disadvantages, and Applications. *Journal of Drug Delivery Science and Technology* **2019**, *53*, 101174. https://doi.org/10.1016/j.jddst.2019.101174.

[11] Ghotekar, S.; Pansambal, S.; Bilal, M.; Pingale, S. S.; Oza, R. Environmentally Friendly Synthesis of Cr2O3 Nanoparticles: Characterization, Applications and Future Perspective ─ a Review. *Case Studies in Chemical and Environmental Engineering* **2021**, *3*. https://doi.org/10.1016/j.cscee.2021.100089.

[12] Jayaseelan, C.; Ramkumar, R.; Rahuman, A. A.; Perumal, P. Green Synthesis of Gold Nanoparticles Using Seed Aqueous Extract of Abelmoschus Esculentus and Its Antifungal Activity. *Industrial Crops and Products* **2013**, *45*, 423–429. https://doi.org/10.1016/j.indcrop.2012.12.019.

[13] Begum, S. J. P.; Pratibha, S.; Rawat, J. M.; Venugopal, D.; Sahu, P.; Gowda, A.; Qureshi, K. A.; Jaremko, M. Recent Advances in Green Synthesis, Characterization, and Applications of Bioactive Metallic Nanoparticles. *Pharmaceuticals* **2022**, *15* (4). https://doi.org/10.3390/ph15040455.

[14] Jeevanandam, J.; Kiew, S. F.; Boakye-Ansah, S.; Lau, S. Y.; Barhoum, A.; Danquah, M. K.; Rodrigues, J. Green Approaches for the Synthesis of Metal and Metal Oxide Nanoparticles Using Microbial and Plant Extracts. *Nanoscale* **2022**, *14* (7), 2534–2571. https://doi.org/10.1039/D1NR08144F.

[15] Sushma, N. J.; Prathyusha, • D.; Swathi, • G.; Madhavi, • T.; Deva, • B.; Raju, P.; Mallikarjuna, • K.; Kim, • Hak-Sung. Facile Approach to Synthesize Magnesium Oxide Nanoparticles by Using Clitoria Ternatea-Characterization and in Vitro Antioxidant Studies. **2016**. https://doi.org/10.1007/s13204-015-0455-1.

[16] Mathew, S.; Victório, C. P.; S, J. S. M.; B.H, B. T. Biosynthesis of Silver Nanoparticle Using Flowers of Calotropis Gigantea (L.) W.T. Aiton and Activity against Pathogenic Bacteria. *Arabian Journal of Chemistry* **2020**, *13* (12), 9139–9144. https://doi.org/10.1016/j.arabjc.2020.10.038.

[17] Jeyaraj, M.; Gurunathan, S.; Qasim, M.; Kang, M.-H.; Kim, J.-H. A Comprehensive Review on the Synthesis,

Characterization, and Biomedical Application of Platinum Nanoparticles. *Nanomaterials* **2019**, *9* (12). https://doi.org/10.3390/nano9121719.
[18] Ingale, A. G.; Chaudhari, A. N. Biogenic Synthesis of Nanoparticles and Potential Applications: An Eco-Friendly Approach. *J Nanomed Nanotechol* **2013**, *4* (165), 1–7.
[19] Strasser, P.; Koh, S.; Anniyev, T.; Greeley, J.; More, K.; Yu, C.; Liu, Z.; Kaya, S.; Nordlund, D.; Ogasawara, H. Lattice-Strain Control of the Activity in Dealloyed Core–Shell Fuel Cell Catalysts. *Nature chemistry* **2010**, *2* (6), 454–460. https://doi.org/10.1038/nchem.623.
[20] Ghramh, H. A.; Khan, K. A.; Ibrahim, E. H.; Setzer, W. N. Synthesis of Gold Nanoparticles (AuNPs) Using Ricinus Communis Leaf Ethanol Extract, Their Characterization, and Biological Applications. *Nanomaterials* **2019**, *9* (5), 765.
[21] Sunderam, V.; Thiyagarajan, D.; Lawrence, A. V.; Mohammed, S. S. S.; Selvaraj, A. In-Vitro Antimicrobial and Anticancer Properties of Green Synthesized Gold Nanoparticles Using Anacardium Occidentale Leaves Extract. *Saudi Journal of Biological Sciences* **2019**, *26* (3), 455–459.
[22] Chahardoli, A.; Karimi, N.; Fattahi, A.; Salimikia, I. Biological Applications of Phytosynthesized Gold Nanoparticles Using Leaf Extract of Dracocephalum Kotschyi. *Journal of Biomedical Materials Research Part A* **2019**, *107* (3), 621–630.
[23] Ghramh, H. A.; Khan, K. A.; Ibrahim, E. H. Biological Activities of Euphorbia Peplus Leaves Ethanolic Extract and the Extract Fabricated Gold Nanoparticles (AuNPs). *Molecules* **2019**, *24* (7), 1431.
[24] Ghosh, S.; Patil, S.; Ahire, M.; Kitture, R.; Gurav, D. D.; Jabgunde, A. M.; Kale, S.; Pardesi, K.; Shinde, V.; Bellare, J. Gnidia Glauca Flower Extract Mediated Synthesis of Gold Nanoparticles and Evaluation of Its Chemocatalytic Potential. *Journal of Nanobiotechnology* **2012**, *10* (1), 1–9.
[25] Basavegowda, N.; Sobczak-Kupiec, A.; Malina, D.; HS, Y.; VR, K.; Dinkar, S. Plant Mediated Synthesis of Gold Nanoparticles Using Fruit Extracts of Ananas Comosus (L.)(Pineapple) and Evaluation of Biological Activities. *Advanced materials letters* **2013**, *4* (5), 332–337. https://doi.org/10.5185/amlett.2012.9423.
[26] Babu, P. J.; Das, R. K.; Kumar, A.; Bora, U. Microwave-Mediated Synthesis of Gold Nanoparticles Using Coconut Water. *International Journal of Green Nanotechnology* **2011**, *3* (1), 13–21. https://doi.org/10.1080/19430892.2011.574534.
[27] León-Jimenez, E.; Valdéz-Salas, B.; González-Mendoza, D.; Tzintzun-Camacho, O. Synthesis and Insecticide Activity of Cu-Nanoparticles from Prosopis Juliflora (Sw) DC and Pluchea Sericea (Nutt.) on Phenacoccus Solenopsis Tinsley (Hemiptera: Pseudococcidae). *Revista de la Sociedad Entomológica Argentina* **2019**, *78* (2), 12–21. https://doi.org/10.25085/rsea.780202.
[28] Suman, T. Y.; Radhika Rajasree, S. R.; Ramkumar, R.; Rajthilak, C.; Perumal, P. The Green Synthesis of Gold Nanoparticles Using an Aqueous Root Extract of Morinda Citrifolia L. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **2014**, *118*, 11–16. https://doi.org/10.1016/j.saa.2013.08.066.
[29] Anuradha, J.; Abbasi, T.; Abbasi, S. A. An Eco-Friendly Method of Synthesizing Gold Nanoparticles Using an Otherwise Worthless Weed Pistia (Pistia Stratiotes L.). *Journal of advanced research* **2015**, *6* (5), 711–720.
[30] Gandhi, N. Green Synthesis, Characterization and in Vitro Antibacterial Studies of Gold Nanoparticles by Using Senna Siamea Plant Seed Aqueous Extract at Ambient Conditions. *Asian Journal of Chemistry*, 2012, *25*. https://doi.org/10.14233/ajchem.2013.14830.
[31] Malakar, B.; Divya, T.; Krishnamurthy, N.; Liny, P.; Dinesh, R. Environmental Benign Synthesis of Gold Nanoparticles from the Flower Extracts of Plumeria Alba Linn.(Frangipani) and Evaluation of Their Biological Activities. *International Journal of Drug Development and Research* **2012**, *4* (1), 0–0.
[32] Zhang, T.; Dang, M.; Zhang, W.; Lin, X. Gold Nanoparticles Synthesized from Euphorbia Fischeriana Root by Green Route Method Alleviates the Isoprenaline Hydrochloride Induced Myocardial Infarction in Rats. *Journal of Photochemistry and Photobiology B: Biology* **2020**, *202*, 111705. https://doi.org/10.1016/j.jphotobiol.2019.111705.
[33] Valsalam, S.; Agastian, P.; Arasu, M. V.; Al-Dhabi, N. A.; Ghilan, A.-K. M.; Kaviyarasu, K.; Ravindran, B.; Chang, S. W.; Arokiyaraj, S. Rapid Biosynthesis and Characterization of Silver Nanoparticles from the Leaf Extract of Tropaeolum Majus L. and Its Enhanced in-Vitro Antibacterial, Antifungal, Antioxidant and Anticancer Properties. *Journal of Photochemistry and Photobiology B: Biology* **2019**, *191*, 65–74. https://doi.org/10.1016/j.jphotobiol.2018.12.010.
[34] Göl, F.; Aygün, A.; Seyrankaya, A.; Gür, T.; Yenikaya, C.; Şen, F. Green Synthesis and Characterization of Camellia Sinensis Mediated Silver Nanoparticles for Antibacterial Ceramic Applications. *Materials Chemistry and Physics* **2020**, *250*, 123037. https://doi.org/10.1016/j.matchemphys.2020.123037.
[35] Ahmed Uttu, J.; Sallau, M. s; Risikat, O.; Iyun, A.; Ibrahim, H. *Review Article: Recent Advances in Isolation and Antimicrobial Efficacy of Selected Strychnos Species: A Mini Review*; 2022. https://doi.org/10.22034/JCR.2022.314381.1129.
[36] Rahman, A.; Prasanna, A. CHARACTERIZATION OF SILVER NANOPARTICLES BIOSYNTHESIZED USING FICUS RELIGIOSA PLANT LEAF EXTRACT. **2018**, *05* (12), 5.
[37] Ibrahim, E. H.; Kilany, M.; Ghramh, H. A.; Khan, K. A.; ul Islam, S. Cellular Proliferation/Cytotoxicity and Antimicrobial Potentials of Green Synthesized Silver Nanoparticles (AgNPs) Using Juniperus Procera. *Saudi Journal of Biological Sciences* **2019**, *26* (7), 1689–1694. https://doi.org/10.1016/j.sjbs.2018.08.014.
[38] Kumar, V.; Singh, S.; Srivastava, B.; Bhadouria, R.; Singh, R. Green Synthesis of Silver Nanoparticles Using Leaf Extract of Holoptelea Integrifolia and Preliminary Investigation of Its Antioxidant, Anti-Inflammatory, Antidiabetic and Antibacterial Activities. *Journal of Environmental Chemical Engineering* **2019**, *7* (3), 103094. https://doi.org/10.1016/j.jece.2019.103094.
[39] Salari, S.; Esmaeilzadeh Bahabadi, S.; Samzadeh-

Kermani, A.; Yosefzaei, F. In-Vitro Evaluation of Antioxidant and Antibacterial Potential of GreenSynthesized Silver Nanoparticles Using Prosopis Farcta Fruit Extract. *Iran J Pharm Res* **2019**, *18* (1), 430–455.
[40] Yadav, R.; Saini, H.; Kumar, D.; Pasi, S.; Agrawal, V. Bioengineering of Piper Longum L. Extract Mediated Silver Nanoparticles and Their Potential Biomedical Applications. *Materials Science and Engineering: C* **2019**, *104*, 109984. https://doi.org/10.1016/j.msec.2019.109984.
[41] Botha, T. L.; Elemike, E. E.; Horn, S.; Onwudiwe, D. C.; Giesy, J. P.; Wepener, V. Cytotoxicity of Ag, Au and Ag-Au Bimetallic Nanoparticles Prepared Using Golden Rod (Solidago Canadensis) Plant Extract. *Sci Rep* **2019**, *9* (1), 4169. https://doi.org/10.1038/s41598-019-40816-y.
[42] Roopan, S. M.; Rohit; Madhumitha, G.; Rahuman, A. A.; Kamaraj, C.; Bharathi, A.; Surendra, T. V. Low-Cost and Eco-Friendly Phyto-Synthesis of Silver Nanoparticles Using Cocos Nucifera Coir Extract and Its Larvicidal Activity. *Industrial Crops and Products* **2013**, *43*, 631–635. https://doi.org/10.1016/j.indcrop.2012.08.013.
[43] Nazeruddin, G. M.; Prasad, N. R.; Prasad, S. R.; Shaikh, Y. I.; Waghmare, S. R.; Adhyapak, P. Coriandrum Sativum Seed Extract Assisted in Situ Green Synthesis of Silver Nanoparticle and Its Anti-Microbial Activity. *Industrial Crops and Products* **2014**, *60*, 212–216. https://doi.org/10.1016/j.indcrop.2014.05.040.
[44] Devi, G. D.; Murugan, K.; Selvam, C. P. Green Synthesis of Silver Nanoparticles Using Euphorbia Hirta (Euphorbiaceae) Leaf Extract against Crop Pest of Cotton Bollworm, Helicoverpa Armigera (Lepidoptera: Noctuidae). *Journal of Biopesticides* **2014**, *7*, 54.
[45] Valsalam, S.; Agastian, P.; Esmail, G. A.; Ghilan, A.-K. M.; Al-Dhabi, N. A.; Arasu, M. V. Biosynthesis of Silver and Gold Nanoparticles Using Musa Acuminata Colla Flower and Its Pharmaceutical Activity against Bacteria and Anticancer Efficacy. *Journal of Photochemistry and Photobiology B: Biology* **2019**, *201*, 111670. https://doi.org/10.1016/j.jphotobiol.2019.111670.
[46] Sreekanth, T. V. M.; Ravikumar, S.; Eom, I.-Y. Green Synthesized Silver Nanoparticles Using Nelumbo Nucifera Root Extract for Efficient Protein Binding, Antioxidant and Cytotoxicity Activities. *Journal of Photochemistry and Photobiology B: Biology* **2014**, *141*, 100–105. https://doi.org/10.1016/j.jphotobiol.2014.10.002.
[47] Raut, R. W.; Mendhulkar, V. D.; Kashid, S. B. Photosensitized Synthesis of Silver Nanoparticles Using Withania Somnifera Leaf Powder and Silver Nitrate. *Journal of Photochemistry and Photobiology B: Biology* **2014**, *132*, 45–55. https://doi.org/10.1016/j.jphotobiol.2014.02.001.
[48] Rout, Y. Green Synthesis of Silver Nanoparticles Using Ocimum Sanctum (Tulashi) and Study of Their Antibacterial and Antifungal Activities. *J. Microbiol. Antimicrob.* **2012**, *4* (6), 103–109. https://doi.org/10.5897/JMA11.060.
[49] Tahir, K.; Nazir, S.; Li, B.; Ahmad, A.; Nasir, T.; Khan, A. U.; Shah, S. A. A.; Khan, Z. U. H.; Yasin, G.; Hameed, M. U. Sapium Sebiferum Leaf Extract Mediated Synthesis of Palladium Nanoparticles and in Vitro Investigation of Their Bacterial and Photocatalytic Activities. *Journal of Photochemistry and Photobiology B: Biology* **2016**, *164*, 164–173. https://doi.org/10.1016/j.jphotobiol.2016.09.030.
[50] Surendra, T. V.; Roopan, S. M.; Arasu, M. V.; Al-Dhabi, N. A.; Rayalu, G. M. RSM Optimized Moringa Oleifera Peel Extract for Green Synthesis of M. Oleifera Capped Palladium Nanoparticles with Antibacterial and Hemolytic Property. *Journal of Photochemistry and Photobiology B: Biology* **2016**, *162*, 550–557. https://doi.org/10.1016/j.jphotobiol.2016.07.032.
[51] Attar, A.; Altikatoglu Yapaoz, M. Biosynthesis of Palladium Nanoparticles Using Diospyros Kaki Leaf Extract and Determination of Antibacterial Efficacy. *Preparative Biochemistry & Biotechnology* **2018**, *48* (7), 629–634. https://doi.org/10.1080/10826068.2018.1479862.
[52] Mavukkandy, M. O.; Chakraborty, S.; Abbasi, T.; Abbasi, S. A. A Clean-Green Synthesis of Platinum Nanoparticles Utilizing a Pernicious Weed Lantana (Lantana Camara). *American Journal of Engineering and Applied Sciences* **2016**, *9* (1), 84.
[53] Khan, Z. U. H.; Sadiq, H. M.; Shah, N. S.; Khan, A. U.; Muhammad, N.; Hassan, S. U.; Tahir, K.; safi, S. Z.; Khan, F. U.; Imran, M.; Ahmad, N.; Ullah, F.; Ahmad, A.; Sayed, M.; Khalid, M. S.; Qaisrani, S. A.; Ali, M.; Zakir, A. Greener Synthesis of Zinc Oxide Nanoparticles Using Trianthema Portulacastrum Extract and Evaluation of Its Photocatalytic and Biological Applications. *Journal of Photochemistry and Photobiology B: Biology* **2019**, *192*, 147–157. https://doi.org/10.1016/j.jphotobiol.2019.01.013.
[54] Ogunyemi, S. O.; Abdallah, Y.; Zhang, M.; Fouad, H.; Hong, X.; Ibrahim, E.; Masum, Md. M. I.; Hossain, A.; Mo, J.; Li, B. Green Synthesis of Zinc Oxide Nanoparticles Using Different Plant Extracts and Their Antibacterial Activity against Xanthomonas Oryzae Pv. Oryzae. *Artificial Cells, Nanomedicine, and Biotechnology* **2019**, *47* (1), 341–352. https://doi.org/10.1080/21691401.2018.1557671.
[55] Mohamad Sukri, S. N. A.; Shameli, K.; Mei-Theng Wong, M.; Teow, S.-Y.; Chew, J.; Ismail, N. A. Cytotoxicity and Antibacterial Activities of Plant-Mediated Synthesized Zinc Oxide (ZnO) Nanoparticles Using Punica Granatum (Pomegranate) Fruit Peels Extract. *Journal of Molecular Structure* **2019**, *1189*, 57–65. https://doi.org/10.1016/j.molstruc.2019.04.026.
[56] Nemati, S.; Hosseini, H. A.; Hashemzadeh, A.; Mohajeri, M.; Sabouri, Z.; Darroudi, M.; Oskuee, R. K. Cytotoxicity and Photocatalytic Applications of Biosynthesized ZnO Nanoparticles by Rheum Turketanicum Rhizome Extract. *Mater. Res. Express* **2019**, *6* (12), 125016. https://doi.org/10.1088/2053-1591/ab46fb.
[57] Sharmila, G.; Thirumarimurugan, M.; Muthukumaran, C. Green Synthesis of ZnO Nanoparticles Using Tecoma Castanifolia Leaf Extract: Characterization and Evaluation of Its Antioxidant, Bactericidal and Anticancer Activities. *Microchemical Journal* **2019**, *145*, 578–587. https://doi.org/10.1016/j.microc.2018.11.022.
[58] Hameed, S.; Khalil, A. T.; Ali, M.; Numan, M.; Khamlich, S.; Shinwari, Z. K.; Maaza, M. Greener Synthesis of ZnO and Ag–ZnO Nanoparticles Using Silybum Marianum for Diverse Biomedical Applications. *Nanomedicine* **2019**, *14* (6), 655–673.

https://doi.org/10.2217/nnm-2018-0279.
[59] Azizi, S.; Mohamad, R.; Bahadoran, A.; Bayat, S.; Rahim, R. A.; Ariff, A.; Saad, W. Z. Effect of Annealing Temperature on Antimicrobial and Structural Properties of Bio-Synthesized Zinc Oxide Nanoparticles Using Flower Extract of Anchusa Italica. *Journal of Photochemistry and Photobiology B: Biology* **2016**, *161*, 441–449. https://doi.org/10.1016/j.jphotobiol.2016.06.007.
[60] Ali, K.; Dwivedi, S.; Azam, A.; Saquib, Q.; Al-Said, M. S.; Alkhedhairy, A. A.; Musarrat, J. Aloe Vera Extract Functionalized Zinc Oxide Nanoparticles as Nanoantibiotics against Multi-Drug Resistant Clinical Bacterial Isolates. *Journal of Colloid and Interface Science* **2016**, *472*, 145–156. https://doi.org/10.1016/j.jcis.2016.03.021.
[61] Jafarirad, S.; Mehrabi, M.; Divband, B.; Kosari-Nasab, M. Biofabrication of Zinc Oxide Nanoparticles Using Fruit Extract of Rosa Canina and Their Toxic Potential against Bacteria: A Mechanistic Approach. *Materials Science and Engineering: C* **2016**, *59*, 296–302. https://doi.org/10.1016/j.msec.2015.09.089.
[62] Supraja, N.; Prasad, T. N. V. K. V.; Krishna, T. G.; David, E. Synthesis, Characterization, and Evaluation of the Antimicrobial Efficacy of Boswellia Ovalifoliolata Stem Bark-Extract-Mediated Zinc Oxide Nanoparticles. *Applied Nanoscience (Switzerland)* **2016**, *6* (4), 581–590. https://doi.org/10.1007/s13204-015-0472-0.
[63] Ramanujam, K.; Sundrarajan, M. Antibacterial Effects of Biosynthesized MgO Nanoparticles Using Ethanolic Fruit Extract of Emblica Officinalis. *Journal of Photochemistry and Photobiology B: Biology* **2014**, *141*, 296–300. https://doi.org/10.1016/j.jphotobiol.2014.09.011.
[64] Altikatoglu, M.; Attar, A.; Erci, F.; Cristache, C. M.; Isildak, I. Green Synthesis of Copper Oxide Nanoparticles Using Ocimum Basilicum Extract and Their Antibacterial Activity. *Fresenius Environ. Bull* **2017**, *25* (12), 7832–7837.
[65] Pagar, K.; Ghotekar, S.; Pagar, T.; Nikam, A.; Pansambal, S.; Oza, R.; Sanap, D.; Dabhane, H. Antifungal Activity of Biosynthesized CuO Nanoparticles Using Leaves Extract of Moringa Oleifera and Their Structural Characterizations. *Asian Journal of Nanosciences and Materials* **2020**, *3* (1), 15–23. https://doi.org/10.26655/AJNANOMAT.2020.1.2.
[66] VANATHI, P.; RAJIV, P.; SIVARAJ, R. Synthesis and Characterization of Eichhornia-Mediated Copper Oxide Nanoparticles and Assessing Their Antifungal Activity against Plant Pathogens. *Bull Mater Sci* **2016**, *39* (5), 1165–1170. https://doi.org/10.1007/s12034-016-1276-x.
[67] Naika, H. R.; Lingaraju, K.; Manjunath, K.; Kumar, D.; Nagaraju, G.; Suresh, D.; Nagabhushana, H. Green Synthesis of CuO Nanoparticles Using Gloriosa Superba L. Extract and Their Antibacterial Activity. *Journal of Taibah University for Science* **2015**, *9* (1), 7–12. https://doi.org/10.1016/j.jtusci.2014.04.006.
[68] Ullah, A. K. M. A.; N. Tamanna, A.; Hossain, A.; Akter, M.; F. Kabir, M.; M. Tareq, A. R.; Kibria, A. K. M. F.; Kurasaki, M.; M. Rahman, M.; I. Khan, M. N. In Vitro Cytotoxicity and Antibiotic Application of Green Route Surface Modified Ferromagnetic TiO 2 Nanoparticles. *RSC Advances* **2019**, *9* (23), 13254–13262. https://doi.org/10.1039/C9RA01395D.
[69] Rueda, D.; Arias, V.; Zhang, Y.; Cabot, A.; Agudelo, A. C.; Cadavid, D. Low-Cost Tangerine Peel Waste Mediated Production of Titanium Dioxide Nanocrystals: Synthesis and Characterization. *Environmental Nanotechnology, Monitoring & Management* **2020**, *13*, 100285. https://doi.org/10.1016/j.enmm.2020.100285.
[70] Kirthi, A. V.; Jayaseelan, C.; Rahuman, A. A. -Biosynthesis and Characterization of Different Nanoparticles and Its Larvicidal Activity against Human Disease Vectors. In *Marine Biomaterials*; CRC Press, 2013.
[71] Santhoshkumar, T.; Rahuman, A. A.; Jayaseelan, C.; Rajakumar, G.; Marimuthu, S.; Kirthi, A. V.; Velayutham, K.; Thomas, J.; Venkatesan, J.; Kim, S.-K. Green Synthesis of Titanium Dioxide Nanoparticles Using Psidium Guajava Extract and Its Antibacterial and Antioxidant Properties. *Asian Pacific Journal of Tropical Medicine* **2014**, *7* (12), 968–976. https://doi.org/10.1016/S1995-7645(14)60171-1.
[72] S., A.; M., S. [EMIM] BF4 Ionic Liquid-Mediated Synthesis of TiO2 Nanoparticles Using Vitex Negundo Linn Extract and Its Antibacterial Activity. *Journal of Molecular Liquids* **2016**, *221*, 986–992. https://doi.org/10.1016/j.molliq.2016.06.079.
[73] Hu, R.; Beguiristain, T.; De Junet, A.; Leyval, C. Bioavailability and Transfer of Elevated Sm Concentration to Alfalfa in Spiked Soils. *Environ Sci Pollut Res* **2020**, *27* (35), 44333–44341. https://doi.org/10.1007/s11356-020-09223-z.
[74] Rezaee, A.; Hale, B.; Santos, R. M.; Chiang, Y. W. Accumulation and Toxicity of Lanthanum and Neodymium in Horticultural Plants (Brassica Chinensis L. and Helianthus Annuus L.). *The Canadian Journal of Chemical Engineering* **2018**, *96* (10), 2263–2272. https://doi.org/10.1002/cjce.23152.
[75] Gopu, M.; Kumar, P.; Selvankumar, T.; Senthilkumar, B.; Sudhakar, C.; Govarthanan, M.; Selva Kumar, R.; Selvam, K. Green Biomimetic Silver Nanoparticles Utilizing the Red Algae Amphiroa Rigida and Its Potent Antibacterial, Cytotoxicity and Larvicidal Efficiency. *Bioprocess Biosyst Eng* **2021**, *44* (2), 217–223. https://doi.org/10.1007/s00449-020-02426-1.
[76] Hassan, K. T.; Ibraheem, I. J.; Hassan, O. M.; Obaid, A. S.; Ali, H. H.; Salih, T. A.; Kadhim, M. S. Facile Green Synthesis of Ag/AgCl Nanoparticles Derived from Chara Algae Extract and Evaluating Their Antibacterial Activity and Synergistic Effect with Antibiotics. *Journal of Environmental Chemical Engineering* **2021**, *9* (4), 105359. https://doi.org/10.1016/j.jece.2021.105359.
[77] Elgamouz, A.; Idriss, H.; Nassab, C.; Bihi, A.; Bajou, K.; Hasan, K.; Abu Haija, M.; Patole, S. P. Green Synthesis, Characterization, Antimicrobial, Anti-Cancer, and Optimization of Colorimetric Sensing of Hydrogen Peroxide of Algae Extract Capped Silver Nanoparticles. *Nanomaterials* **2020**, *10* (9), 1861. https://doi.org/10.3390/nano10091861.
[78] Arya, A.; Mishra, V.; Chundawat, T. S. Green Synthesis of Silver Nanoparticles from Green Algae (Botryococcus Braunii) and Its Catalytic Behavior for the Synthesis of Benzimidazoles. *Chemical Data Collections* **2019**, *20*, 100190. https://doi.org/10.1016/j.cdc.2019.100190.

[79] Fatima, R.; Priya, M.; Indurthi, L.; Radhakrishnan, V.; Sudhakaran, R. Biosynthesis of Silver Nanoparticles Using Red Algae Portieria Hornemannii and Its Antibacterial Activity against Fish Pathogens. *Microbial Pathogenesis* **2020**, *138*, 103780. https://doi.org/10.1016/j.micpath.2019.103780.
[80] Massironi, A.; Morelli, A.; Grassi, L.; Puppi, D.; Braccini, S.; Maisetta, G.; Esin, S.; Batoni, G.; Della Pina, C.; Chiellini, F. Ulvan as Novel Reducing and Stabilizing Agent from Renewable Algal Biomass: Application to Green Synthesis of Silver Nanoparticles. *Carbohydrate Polymers* **2019**, *203*, 310–321. https://doi.org/10.1016/j.carbpol.2018.09.066.
[81] Mahajan, A.; Arya, A.; Chundawat, T. S. Green Synthesis of Silver Nanoparticles Using Green Alga (Chlorella Vulgaris) and Its Application for Synthesis of Quinolines Derivatives. *Synthetic Communications* **2019**, *49* (15), 1926–1937. https://doi.org/10.1080/00397911.2019.1610776.
[82] Kim, D.-Y.; Saratale, R. G.; Shinde, S.; Syed, A.; Ameen, F.; Ghodake, G. Green Synthesis of Silver Nanoparticles Using Laminaria Japonica Extract: Characterization and Seedling Growth Assessment. *Journal of Cleaner Production* **2018**, *172*, 2910–2918. https://doi.org/10.1016/j.jclepro.2017.11.123.
[83] Subbiah, M.; Bhuvaneswari, S.; Vajiravelu, S. GREEN SYNTHESIS, CHARACTERIZATION OF SILVER NANOPARTICLES OF A MARINE RED ALGA SPYRIDIA FUSIFORMIS AND THEIR ANTIBACTERIAL ACTIVITY. *International Journal of Pharmacy and Pharmaceutical Sciences* **2017**, *9*, 192. https://doi.org/10.22159/ijpps.2017v9i5.17105.
[84] Deepak, P.; Amutha, V.; Birundha, R.; Sowmiya, R.; Kamaraj, C.; Balasubramanian, V.; Balasubramani, G.; Aiswarya, D.; Arul, D.; Perumal, P. Facile Green Synthesis of Nanoparticles from Brown Seaweed and Its Biological Application Potential. *Adv. Nat. Sci: Nanosci. Nanotechnol.* **2018**, *9* (3), 035019. https://doi.org/10.1088/2043-6254/aadc4a.
[85] Omomowo, I. O.; Adenigba, V. O.; Ogunsona, S. B.; Adeyinka, G. C.; Oluyide, O. O.; Adedayo, A. A.; Fatukasi, B. A. Antimicrobial and Antioxidant Activities of Algal-Mediated Silver and Gold Nanoparticles. *IOP Conf. Ser.: Mater. Sci. Eng.* **2020**, *805* (1), 012010. https://doi.org/10.1088/1757-899X/805/1/012010.
[86] González-Ballesteros, N.; Prado-López, S.; Rodríguez-González, J. B.; Lastra, M.; Rodríguez-Argüelles, M. C. Green Synthesis of Gold Nanoparticles Using Brown Algae Cystoseira Baccata: Its Activity in Colon Cancer Cells. *Colloids and Surfaces B: Biointerfaces* **2017**, *153*, 190–198. https://doi.org/10.1016/j.colsurfb.2017.02.020.
[87] Senthilkumar, P.; Surendran, L.; Sudhagar, B.; Ranjith Santhosh Kumar, D. S. Facile Green Synthesis of Gold Nanoparticles from Marine Algae Gelidiella Acerosa and Evaluation of Its Biological Potential. *SN Appl. Sci.* **2019**, *1* (4), 284. https://doi.org/10.1007/s42452-019-0284-z.
[88] Maceda, A. F.; Ouano, J. J. S.; Que, M. C. O.; Basilia, B. A.; Potestas, M. J.; Alguno, A. C. Controlling the Absorption of Gold Nanoparticles via Green Synthesis Using Sargassum Crassifolium Extract. *Key Engineering Materials* **2018**, *765*, 44–48. https://doi.org/10.4028/www.scientific.net/KEM.765.44.
[89] Bhattacharya, D.; Gupta, R. K. Nanotechnology and Potential of Microorganisms. *Critical Reviews in Biotechnology* **2005**, *25* (4), 199–204. https://doi.org/10.1080/07388550500361994.
[90] Abdulwahid, K. E.; Dwaish, A. S.; Dakhil, O. A. A. GREEN SYNTHESIS AND CHARACTERIZATION OF ZINC OXIDE NANOPARTICLES FROM CLADOPHORA GLOMERATA AND ITS ANTIFUNGAL ACTIVITY AGAINST SOME FUNGAL ISOLATES; 2019.
[91] Thirumoorthy, G. S.; Balasubramaniam, O.; Kumaresan, P.; Muthusamy, P.; Subramani, K. Tetraselmis Indica Mediated Green Synthesis of Zinc Oxide (ZnO) Nanoparticles and Evaluating Its Antibacterial, Antioxidant, and Hemolytic Activity. *BioNanoSci.* **2021**, *11* (1), 172–181. https://doi.org/10.1007/s12668-020-00817-y.
[92] Arsiya, F.; Sayadi, M. H.; Sobhani, S. Green Synthesis of Palladium Nanoparticles Using Chlorella Vulgaris. *Materials Letters* **2017**, *186*, 113–115. https://doi.org/10.1016/j.matlet.2016.09.101.
[93] Sonbol, H.; Ameen, F.; AlYahya, S.; Almansob, A.; Alwakeel, S. Padina Boryana Mediated Green Synthesis of Crystalline Palladium Nanoparticles as Potential Nanodrug against Multidrug Resistant Bacteria and Cancer Cells. *Sci Rep* **2021**, *11* (1), 5444. https://doi.org/10.1038/s41598-021-84794-6.
[94] Araya-Castro, K.; Chao, T.-C.; Durán-Vinet, B.; Cisternas, C.; Ciudad, G.; Rubilar, O. Green Synthesis of Copper Oxide Nanoparticles Using Protein Fractions from an Aqueous Extract of Brown Algae Macrocystis Pyrifera. *Processes* **2021**, *9* (1), 78. https://doi.org/10.3390/pr9010078.
[95] Arya, A.; Gupta, K.; Chundawat, T. S.; Vaya, D. Biogenic Synthesis of Copper and Silver Nanoparticles Using Green Alga Botryococcus Braunii and Its Antimicrobial Activity. *Bioinorganic Chemistry and Applications* **2018**, *2018*, e7879403. https://doi.org/10.1155/2018/7879403.
[96] Rao, M. D.; Pennathur, G. Green Synthesis and Characterization of Cadmium Sulphide Nanoparticles from Chlamydomonas Reinhardtii and Their Application as Photocatalysts. *Materials Research Bulletin* **2017**, *85*, 64–73. https://doi.org/10.1016/j.materresbull.2016.08.049.
[97] Chaturvedi, V. K.; Yadav, N.; Rai, N. K.; Ellah, N. H. A.; Bohara, R. A.; Rehan, I. F.; Marraiki, N.; Batiha, G. E.-S.; Hetta, H. F.; Singh, M. P. Pleurotus Sajor-Caju-Mediated Synthesis of Silver and Gold Nanoparticles Active against Colon Cancer Cell Lines: A New Era of Herbonanoceutics. *Molecules* **2020**, *25* (13), 3091. https://doi.org/10.3390/molecules25133091.
[98] Sharma, J. L.; Dhayal, V.; Sharma, R. K. White-Rot Fungus Mediated Green Synthesis of Zinc Oxide Nanoparticles and Their Impregnation on Cellulose to Develop Environmental Friendly Antimicrobial Fibers. *3 Biotech* **2021**, *11* (6), 269. https://doi.org/10.1007/s13205-021-02840-6.
[99] Konappa, N.; Udayashankar, A. C.; Dhamodaran, N.; Krishnamurthy, S.; Jagannath, S.; Uzma, F.; Pradeep, C. K.; De Britto, S.; Chowdappa, S.; Jogaiah, S. Ameliorated Antibacterial and Antioxidant Properties by Trichoderma

Harzianum Mediated Green Synthesis of Silver Nanoparticles. *Biomolecules* **2021**, *11* (4), 535. https://doi.org/10.3390/biom11040535.
[100] Hassan, S. E.-D.; Fouda, A.; Saied, E.; Farag, M. M. S.; Eid, A. M.; Barghoth, M. G.; Awad, M. A.; Hamza, M. F.; Awad, M. F. Rhizopus Oryzae-Mediated Green Synthesis of Magnesium Oxide Nanoparticles (MgO-NPs): A Promising Tool for Antimicrobial, Mosquitocidal Action, and Tanning Effluent Treatment. *Journal of Fungi* **2021**, *7* (5), 372. https://doi.org/10.3390/jof7050372.
[101] Acay, H. Utilization of Morchella Esculenta-Mediated Green Synthesis Golden Nanoparticles in Biomedicine Applications. *Preparative Biochemistry & Biotechnology* **2021**, *51* (2), 127–136. https://doi.org/10.1080/10826068.2020.1799390.
[102] Wang, D.; Xue, B.; Wang, L.; Zhang, Y.; Liu, L.; Zhou, Y. Fungus-Mediated Green Synthesis of Nano-Silver Using Aspergillus Sydowii and Its Antifungal/Antiproliferative Activities. *Sci Rep* **2021**, *11* (1), 10356. https://doi.org/10.1038/s41598-021-89854-5.
[103] Saitawadekar, A.; KAKDE, U. GREEN SYNTHESIS OF COPPER NANOPARTICLES USING ASPERGILLUS FLAVUS. *J Crit Rev 7:* **2020**, 1083–1090.
[104] Aygün, A.; Özdemir, S.; Gülcan, M.; Cellat, K.; Şen, F. Synthesis and Characterization of Reishi Mushroom-Mediated Green Synthesis of Silver Nanoparticles for the Biochemical Applications. *Journal of Pharmaceutical and Biomedical Analysis* **2020**, *178*, 112970. https://doi.org/10.1016/j.jpba.2019.112970.
[105] Ganesan, V.; Hariram, M.; Vivekanandhan, S.; Muthuramkumar, S. Periconium Sp. (Endophytic Fungi) Extract Mediated Sol-Gel Synthesis of ZnO Nanoparticles for Antimicrobial and Antioxidant Applications. *Materials Science in Semiconductor Processing* **2020**, *105*, 104739. https://doi.org/10.1016/j.mssp.2019.104739.
[106] Clarance, P.; Luvankar, B.; Sales, J.; Khusro, A.; Agastian, P.; Tack, J.-C.; Al Khulaifi, M. M.; AL-Shwaiman, H. A.; Elgorban, A. M.; Syed, A.; Kim, H.-J. Green Synthesis and Characterization of Gold Nanoparticles Using Endophytic Fungi Fusarium Solani and Its In-Vitro Anticancer and Biomedical Applications. *Saudi Journal of Biological Sciences* **2020**, *27* (2), 706–712. https://doi.org/10.1016/j.sjbs.2019.12.026.
[107] Consolo, V. F.; Torres-Nicolini, A.; Alvarez, V. A. Mycosinthetized Ag, CuO and ZnO Nanoparticles from a Promising Trichoderma Harzianum Strain and Their Antifungal Potential against Important Phytopathogens. *Sci Rep* **2020**, *10* (1), 20499. https://doi.org/10.1038/s41598-020-77294-6.
[108] Naimi-Shamel, N.; Pourali, P.; Dolatabadi, S. Green Synthesis of Gold Nanoparticles Using Fusarium Oxysporum and Antibacterial Activity of Its Tetracycline Conjugant. *Journal de Mycologie Médicale* **2019**, *29* (1), 7–13. https://doi.org/10.1016/j.mycmed.2019.01.005.
[109] Bharde, A.; Kulkarni, A.; Rao, M.; Prabhune, A.; Sastry, M. Bacterial Enzyme Mediated Biosynthesis of Gold Nanoparticles. *Journal of Nanoscience and Nanotechnology* **2007**, *7* (12), 4369–4377. https://doi.org/10.1166/jnn.2007.891.
[110] Tariq, F.; Ahmed, N.; Afzal, M.; Khan, M. A. U.; Zeshan, B. Synthesis, Characterization and Antimicrobial Activity of Bacillus Subtilis-Derived Silver Nanoparticles Against Multidrug-Resistant Bacteria. *Jundishapur J Microbiol* **2020**, *13* (5). https://doi.org/10.5812/jjm.91934.
[111] Srivastava, S. K.; Yamada, R.; Ogino, C.; Kondo, A. Biogenic Synthesis and Characterization of Gold Nanoparticles by Escherichia Coli K12 and Its Heterogeneous Catalysis in Degradation of 4-Nitrophenol. *Nanoscale Res Lett* **2013**, *8* (1), 1–9. https://doi.org/10.1186/1556-276X-8-70.
[112] Kikuchi, F.; Kato, Y.; Furihata, K.; Kogure, T.; Imura, Y.; Yoshimura, E.; Suzuki, M. Formation of Gold Nanoparticles by Glycolipids of Lactobacillus Casei. *Sci Rep* **2016**, *6* (1), 34626. https://doi.org/10.1038/srep34626.
[113] Costa, M. i.; Álvarez-Cerimedo, M. s.; Urquiza, D.; Ayude, M. a.; Hoppe, C. e.; Fasce, D. p.; De Castro, R. e.; Giménez, M. i. Synthesis, Characterization and Kinetic Study of Silver and Gold Nanoparticles Produced by the Archaeon Haloferax Volcanii. *Journal of Applied Microbiology* **2020**, *129* (5), 1297–1308. https://doi.org/10.1111/jam.14726.
[114] Li, J.; Li, Q.; Ma, X.; Tian, B.; Li, T.; Yu, J.; Dai, S.; Weng, Y.; Hua, Y. Biosynthesis of Gold Nanoparticles by the Extreme Bacterium Deinococcus Radiodurans and an Evaluation of Their Antibacterial Properties. *Int J Nanomedicine* **2016**, *11*, 5931–5944. https://doi.org/10.2147/IJN.S119618.
[115] Weng, Y.; Li, J.; Ding, X.; Wang, B.; Dai, S.; Zhou, Y.; Pang, R.; Zhao, Y.; Xu, H.; Tian, B.; Hua, Y. Functionalized Gold and Silver Bimetallic Nanoparticles Using Deinococcus Radiodurans Protein Extract Mediate Degradation of Toxic Dye Malachite Green. *Int J Nanomedicine* **2020**, *15*, 1823–1835. https://doi.org/10.2147/IJN.S236683.
[116] Nadhe, S. B.; Wadhwani, S. A.; Singh, R.; Chopade, B. A. Green Synthesis of AuNPs by Acinetobacter Sp. GWRVA25: Optimization, Characterization, and Its Antioxidant Activity. *Frontiers in Chemistry* **2020**, *8*.
[117] Wadhwani, S. A.; Shedbalkar, U. U.; Singh, R.; Chopade, B. A. Biosynthesis of Gold and Selenium Nanoparticles by Purified Protein from Acinetobacter Sp. SW 30. *Enzyme and Microbial Technology* **2018**, *111*, 81–86. https://doi.org/10.1016/j.enzmictec.2017.10.007.
[118] Lengke, M. F.; Fleet, M. E.; Southam, G. Morphology of Gold Nanoparticles Synthesized by Filamentous Cyanobacteria from Gold(I)−Thiosulfate and Gold(III)−Chloride Complexes. *Langmuir* **2006**, *22* (6), 2780–2787. https://doi.org/10.1021/la052652c.
[119] Markus, J.; Mathiyalagan, R.; Kim, Y.-J.; Abbai, R.; Singh, P.; Ahn, S.; Perez, Z. E. J.; Hurh, J.; Yang, D. C. Intracellular Synthesis of Gold Nanoparticles with Antioxidant Activity by Probiotic Lactobacillus Kimchicus DCY51T Isolated from Korean Kimchi. *Enzyme and Microbial Technology* **2016**, *95*, 85–93. https://doi.org/10.1016/j.enzmictec.2016.08.018.
[120] Singh, S.; Singh, B. K.; Yadav, S.; Gupta, A. Applications of Nanotechnology in Agricultural and Their Role in Disease Management. *Res J Nanosci Nanotechnol* **2015**, *5* (1), 1–5.
[121] Chhipa, H. Nanofertilizers and Nanopesticides for Agriculture. *Environ Chem Lett* **2017**, *15* (1), 15–22. https://doi.org/10.1007/s10311-016-0600-4.

[122] Gudkov, S. V.; Shafeev, G. A.; Glinushkin, A. P.; Shkirin, A. V.; Barmina, E. V.; Rakov, I. I.; Simakin, A. V.; Kislov, A. V.; Astashev, M. E.; Vodeneev, V. A.; Kalinitchenko, V. P. Production and Use of Selenium Nanoparticles as Fertilizers. *ACS Omega* **2020**, *5* (28), 17767–17774. https://doi.org/10.1021/acsomega.0c02448.
[123] Nanda, A.; Saravanan, M. Biosynthesis of Silver Nanoparticles from Staphylococcus Aureus and Its Antimicrobial Activity against MRSA and MRSE. *Nanomedicine: Nanotechnology, Biology and Medicine* **2009**, *5* (4), 452–456. https://doi.org/10.1016/j.nano.2009.01.012.
[124] Kalishwaralal, K.; Deepak, V.; Ram Kumar Pandian, S.; Kottaisamy, M.; BarathManiKanth, S.; Kartikeyan, B.; Gurunathan, S. Biosynthesis of Silver and Gold Nanoparticles Using Brevibacterium Casei. *Colloids and Surfaces B: Biointerfaces* **2010**, *77* (2), 257–262. https://doi.org/10.1016/j.colsurfb.2010.02.007.
[125] Kannan, N.; Selvaraj, S.; Murty, R. V. Microbial Production of Silver Nanoparticles. *Digest journal of nanomaterials and biostructures* **2010**, *5* (1), 135–140.
[126] Ahmed, T.; Shahid, M.; Noman, M.; Niazi, M. B. K.; Mahmood, F.; Manzoor, I.; Zhang, Y.; Li, B.; Yang, Y.; Yan, C.; Chen, J. Silver Nanoparticles Synthesized by Using Bacillus Cereus SZT1 Ameliorated the Damage of Bacterial Leaf Blight Pathogen in Rice. *Pathogens* **2020**, *9* (3), 160. https://doi.org/10.3390/pathogens9030160.
[127] Shanthi, S.; David Jayaseelan, B.; Velusamy, P.; Vijayakumar, S.; Chih, C. T.; Vaseeharan, B. Biosynthesis of Silver Nanoparticles Using a Probiotic Bacillus Licheniformis Dahb1 and Their Antibiofilm Activity and Toxicity Effects in Ceriodaphnia Cornuta. *Microbial Pathogenesis* **2016**, *93*, 70–77. https://doi.org/10.1016/j.micpath.2016.01.014.
[128] Garmasheva, I.; Kovalenko, N.; Voychuk, S.; Ostapchuk, A.; Livins'ka, O.; Oleschenko, L. Lactobacillus Species Mediated Synthesis of Silver Nanoparticles and Their Antibacterial Activity against Opportunistic Pathogens in Vitro. *Bioimpacts* **2016**, *6* (4), 219–223. https://doi.org/10.15171/bi.2016.29.
[129] Aziz Mousavi, S. M. A.; Mirhosseini, S. A.; Rastegar Shariat Panahi, M.; Mahmoodzadeh Hosseini, H. Characterization of Biosynthesized Silver Nanoparticles Using Lactobacillus Rhamnosus GG and Its In Vitro Assessment Against Colorectal Cancer Cells. *Probiotics & Antimicro. Prot.* **2020**, *12* (2), 740–746. https://doi.org/10.1007/s12602-019-09530-z.
[130] Manjunatha, S. B.; Biradar, D. P.; Aladakatti, Y. R. Nanotechnology and Its Applications in Agriculture: A Review. *J farm Sci* **2016**, *29* (1), 1–13.
[131] Jo, J. H.; Singh, P.; Kim, Y. J.; Wang, C.; Mathiyalagan, R.; Jin, C.-G.; Yang, D. C. Pseudomonas Deceptionensis DC5-Mediated Synthesis of Extracellular Silver Nanoparticles. *Artificial cells, nanomedicine, and biotechnology* **2016**, *44* (6), 1576–1581.
[132] Syed, B.; Prasad, N.; Dhananjaya, B. L.; Yallappa, S.; Satish, S. Synthesis of Silver Nanoparticles by Endosymbiont Pseudomonas Fluorescens CA 417 and Their Bactericidal Activity. *Enzyme and Microbial Technology* **2016**, *95*, 128–136. https://doi.org/10.1016/j.enzmictec.2016.10.004.
[133] Singh, P.; Singh, H.; Kim, Y. J.; Mathiyalagan, R.; Wang, C.; Yang, D. C. Extracellular Synthesis of Silver and Gold Nanoparticles by Sporosarcina Koreensis DC4 and Their Biological Applications. *Enzyme and Microbial Technology* **2016**, *86*, 75–83. https://doi.org/10.1016/j.enzmictec.2016.02.005.
[134] Nadhe, S. b.; Singh, R.; Wadhwani, S. a.; Chopade, B. a. Acinetobacter Sp. Mediated Synthesis of AgNPs, Its Optimization, Characterization and Synergistic Antifungal Activity against C. Albicans. *Journal of Applied Microbiology* **2019**, *127* (2), 445–458. https://doi.org/10.1111/jam.14305.
[135] Hossain, A.; Hong, X.; Ibrahim, E.; Li, B.; Sun, G.; Meng, Y.; Wang, Y.; An, Q. Green Synthesis of Silver Nanoparticles with Culture Supernatant of a Bacterium Pseudomonas Rhodesiae and Their Antibacterial Activity against Soft Rot Pathogen Dickeya Dadantii. *Molecules* **2019**, *24* (12), 2303. https://doi.org/10.3390/molecules24122303.
[136] Ibrahim, E.; Zhang, M.; Zhang, Y.; Hossain, A.; Qiu, W.; Chen, Y.; Wang, Y.; Wu, W.; Sun, G.; Li, B. Green-Synthesization of Silver Nanoparticles Using Endophytic Bacteria Isolated from Garlic and Its Antifungal Activity against Wheat Fusarium Head Blight Pathogen Fusarium Graminearum. *Nanomaterials* **2020**, *10* (2), 219. https://doi.org/10.3390/nano10020219.
[137] Fouda, A.; Hassan, S. E.-D.; Abdo, A. M.; El-Gamal, M. S. Antimicrobial, Antioxidant and Larvicidal Activities of Spherical Silver Nanoparticles Synthesized by Endophytic Streptomyces Spp. *Biol Trace Elem Res* **2020**, *195* (2), 707–724. https://doi.org/10.1007/s12011-019-01883-4.
[138] Marathe, K.; Naik, J.; Maheshwari, V. Biogenic Synthesis of Silver Nanoparticles Using Streptomyces Spp. and Their Antifungal Activity Against Fusarium Verticillioides. *J Clust Sci* **2021**, *32* (5), 1299–1309. https://doi.org/10.1007/s10876-020-01894-5.
[139] Ponmurugan, P.; Manjukarunambika, K.; Elango, V.; Gnanamangai, B. M. Antifungal Activity of Biosynthesised Copper Nanoparticles Evaluated against Red Root-Rot Disease in Tea Plants. *Journal of Experimental Nanoscience* **2016**, *11* (13), 1019–1031. https://doi.org/10.1080/17458080.2016.1184766.
[140] Kouhkan, M.; Ahangar, P.; Babaganjeh, L. A.; Allahyari-Devin, M. Biosynthesis of Copper Oxide Nanoparticles Using Lactobacillus Casei Subsp. Casei and Its Anticancer and Antibacterial Activities. *Current Nanoscience* **2020**, *16* (1), 101–111. https://doi.org/10.2174/1573413715666190318155801.

مراجعة التخليق البيولوجي للجسيمات النانوية: تطبيقات طبية وزراعية

يوسف عبدالوهاب[1,3*]، اخيار أحمد[1]، إسراء وحيد[2]، باولينا تابا[1] ونبيل القدسي[4]
[1]قسم الكيمياء، كلية الرياضيات والعلوم الطبيعية، جامعة حسن الدين، ماكاسار، إندونيسيا.
[2]قسم الطفيليات، كلية الطب، جامعة حسن الدين، ماكاسار، إندونيسيا.
[3]قسم المختبرات الطبية، كلية العلوم الطبية، جامعة تعز، تعز، اليمن.
[4-3] قسم الكيمياء، كلية التربية والعلوم، جامعة البيضاء ، جامعة تعز ، جامعة الوطنية ، اليمن

الملخص: الجسيمات النانوية (NPs) هي مواد تتكون من مجموعة من الذرات التي يتراوح حجم واحد أو أكثر منها بين 1−100 نانومتر على مقياس النانومتر. تُعد الجسيمات النانوية الحيوية المعدنية حاليًا مجالًا بحثيًا مهمًا وديناميكيًا للغاية، ولها تأثيرات كبيرة على البحث العملي. نظرًا لكونه صديقًا للبيئة، وغير سام، ومنخفض متطلبات الطاقة، ومتعدد الوظائف، فإن التخليق البيولوجي للجسيمات النانوية مفضل على التخليق الفيزيائي والكيميائي. تُعد النباتات والميكروبات عوامل اختزال فعالة لأنها تحتوي على مستقلبات ثانوية مهمة تسرع اختزال واستقرار الجسيمات النانوية. يمكن بعد ذلك توصيف الجسيمات النانوية المتكونة بالخصائص الفيزيائية والكيميائية تحت المجهر الإلكتروني (TEM ، SEM، AFM) وباستخدام المطيافية (UV−Visible ، IR) (XRD، إلخ. يمكن اختزال أيون معدني أو أكسيده بيولوجيًا إلى جسيم نانوي بسرعة وسهولة وعند درجة حرارة وضغط ثابتين. أحد الأسباب الرئيسية للمرض والوفاة لدى البشر هو تزايد الكائنات الدقيقة المقاومة للأدوية المتعددة، والناتج عن الإفراط في استخدام المضادات الحيوية لدى الأفراد غير المصابين بالمرض. من الأهمية بمكان تطوير مضادات حيوية جديدة ذات آليات عمل مختلفة اليوم لمكافحة البكتيريا. بتركيزات منخفضة، تكون المعادن وأكاسيدها شديدة السمية للكائنات الدقيقة. بالإضافة إلى ذلك، تسبب الأمراض المنتشرة في الإنسان والنبات قلقًا بالغًا في جميع أنحاء الكوكب. نظرًا لنطاقها الواسع من النشاط البيولوجي، تُعد الجسيمات النانوية وسائط ممتازة مضادة للبكتيريا في كل من الصناعات الزراعية والطبية. يلخص البحث الحالي تكوين الجسيمات النانوية عبر المصادر الميكروبية والنباتية، مما يسمح للمعادن بالبقاء في شكل مستقر بعد التأين. بالإضافة إلى ذلك، عرضت الدراسة قاعدة بيانات مهمة حول استخدام المبيدات النانوية الاصطناعية في العديد من المجالات الزراعية والطبية.

الكلمات المفتاحية: الجسيمات النانوية؛ المبيدات النانوية؛ الزراعة؛ النشاط المضاد للميكروبات؛ التخليق الأخضر.