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Prospects of Biosynthetically produced Nanoparticles in Biocontrol of Pests and Phytopathogens: A Review

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Modern nanotechnology is playing a vital role in our daily life by contributing in different domains such as usage of nanoparticles for target-specific drug delivery system, as these nanoparticle are being used as scratch proof coating on glass for tracking of biomolecules. Some emerging applications of nanoparticles include usage of nanoparticles for diagnostic purposes such as biomedical imaging and as green technology producing nano pesticides. The use of endophytic or plant beneficial bacteria for the production of metallic nanoparticles have shown promising results in not only controlling the pest but also contributing in enhanced developmental growth due to their small size, target specificity, and enhanced interaction with the plant in controlled environment. As for increasing environmental crisis, use of biological methods to remediate the environment is becoming a necessity. Green technology based nano-materials being used now a days in multiple fields, especially in bio-control of pests. This review is based on the microbial synthesized metallic nanoparticles, which are being used as nano pesticides (nanoparticles are pesticides).

Keywords: Bio-control, Nanoparticles, Phyto synthesis, Microbial synthesis, Phytopathogens

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Project details. The aim of this research was to highlight the importance of biosynthesized nanoparticles and their beneficial use as biocontrol for pests and phytopathogens.

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Abdul Nafeh: main idea and collection of data
Hamza Abbas Jaffari: helped in data collection, rephrasing and final proof reading.

INTRODUCTION

Now a days, cell, organic chemistry, and sub-atomic systems that intervene the mix of organic nanoparticles need to be targeted very well to make the pace of combination and improve properties of nanoparticles [1]. Cells, organic chemicals, and sub-nuclear frameworks that mediate the combination of natural nanoparticles ought to be gathered well to maximize the synthesis and improve the properties of nanoparticles against pests and Phytopathogens [2]. However, with the notable exception of silicon dioxide, alumina, silver, and graphene compound nanoparticles as insecticides, detailed information on the working mechanism of nanoparticles is still unknown, whilst little information is now accessible for mites [3]. To broaden an easy and environmentally friendly technology for synthesis of nanoparticles with novel properties, researchers worked to grew and to make an organic system known as green technology [4], [5]. Synthesis methods in which utilizing both microorganisms or plant extracts have some distance-famed a simple and novel but varied to chemical approaches in which biological synthesis of nanoparticles by means of microorganisms may be a brand-new type of bottom-up method with the aid of that atoms unite to make larger sized nanoparticles [6][7]. If one wants to know the role of nanoparticles in organic nature, it is a need to understand the the interaction of nanoparticles with the cells [8]. This bio–nano interface, which includes nanoparticles and organic element interactions, offers with the physics and kinetic exchange that makes a giant interaction between nanoparticles and biological parts like association, energy forces, van der Waals forces, solvophobic, and depletion forces [9] [10]. Nanoparticles' antibacterial activity is dependent on the assembly of large numbers of active ions and their interaction with the organism's cell wall [11].

Novelty Statement

The novelty of this review resides as using specific strains of endophytic microorganisms to biologically synthesize the metallic nanoparticles, and their efficacy against pests, have not been investigated previously.

For this review, different articles from Google Scholar, Wiley library, and PubMed library were searched. More than 75 articles, including books, case reports, and case series, were searched. However, out of 75, 48 articles that were found relavant to our topic.

Endophytic Bacteria

Though the word "endophyte" is more often associated with fungus, there is a substantial amount of literature referring to bacteria as endophytes together, with some units of measurement thought to have a beneficial effect on plants, while others are thought to have a neutral or detrimental effect [12]. Bacteria have been known to live at intervals plants for over fifty years without causing any disease signs [13]. According to several findings, such bacteria appear in very silent tissue variations among various plant species, implying that they are present in most, if not all, higher plants.

The term endophyte can be defined in a variety of ways, each with its own specific meaning. It was identified inside the tissues of stratum endophytes [14]. Bacteria that colonize the insides of plants, both active and latent pathogens, can become infective under certain conditions and among completely different host genotypes, this changed the definition to include all bacteria that colonize the insides of plants both active and latent pathogens [15].

When considering all bacterium that colonize the midst of flora, one must also consider those bacteria that live among residing plant tissues without causing significant harm or gaining profit apart from securing residency [16], as well as the bacterium that establishes endosymbiosis with the plant, wherein the plant receives ecological partner and pleasure from the bacterium. According to the definition of endomycorrhizal fungus, the term "endophytic bacterium" should also include bacteria that live in the cortex of the premise [17]. These sub-definitions should provide a partner operational overview of what is considered to be a companion "endophyte," and so this should be considered the most current definition of the term "endophyte." In practice, the superiority of endophytic bacteria residing in specific parts of the rhizoplane and bacteria populating the rhizoplane is usually decided by the surface sterilization procedure used.

Plant and Endophytic Bacterial Interaction: Beneficial Effects

Plant growth-promoting rhizobacteria (PGPR) [18], [19] appear to facilitate endophytes' positive effects on their host plant. Being endophytes identified from trees, healthy crops, and weeds are considered cultatively endophytic and capable of living in outside plant tissues as rhizospheric microbes [20]. In addition, a number of endophytic being taxa from sweet corn or cotton have been discovered to be common soil microorganisms [21].

Plant increase-selling humans may directly or indirectly create a plant boom. To begin, direct marketing of plant development via PGPR includes giving the plant a chemical produced by the human or assisting the plant's absorption of vital vitamins from the environment. Oblique merchandising of plant growth happens when PGPR decreases or prevents the detrimental effects of one or more phytopathogenic microbes.

Growth Promoting Activity

A number of PGPR assist their plant hosts grow in a few different ways. PGPR can restore soil components and provide them to flora; they synthesize siderophores that can solubilize and sequester iron from the soil and provide it to the plant; they synthesize a variety of phytohormones that can act to boost various tiers of plant growth; they will have mechanisms for the solubilization of minerals like phosphorus that can result in a lot of tillage.

Direct proof for plant increase-selling hobby with the aid of endophytic bacteria came from research where a few of organism isolates recovered among potato tubers had been shown to plug plant growth. Diverse experiments with tracheophyte and potatoes in crop rotation found that twenty preliminary of the isolated endophytic bacteria promoted plant growth, reflected in exaggerated shoot height (63%), shoot wet weight (66%), and exaggerated root wet weight (55%) [22].

Nanoparticles Structural Identification

Nanoparticles exist in nature either in non-clear or in an exceptionally less stable configuration. In in-consequential size and structure, undermine notice of the firmest structure is large that later on can select the chemical, biological and physical aspects of the nanoparticles. Size, shape, dissolvability, association characteristics, and mixture configuration are some of the essential elements that have an impact on nanoparticles, their supply, and their interaction with the body [23]. Nanoparticles exhibit undeniable and unique characteristics despite a small surface area to volume ratio. Nanoparticles have a large surface area because of their subordination in nurturing indubitable surface nature and interior characteristics. During the period spent mixing and varying, the surface characteristics that are considerably uncompromising and exceptional to every nanoparticle are lost.

In essence, a nanoparticle is divided into three sections: a functionalized surface, a shell, and a focus, the latter of which is the most important in determining the nanoparticle's characteristics.

Surface area and Surface Interaction

Nanoparticles must have a charge on their surface in order to separate in a highly liquid media. These charged surfaces are frequently obtained by covalently affixing them to biomolecules that have bonded charged communal concerns. Because of this sort of functionalization of nanoparticle surface, valence buffing of nanoparticle surface with biomolecules, metal particles, and chemical substances is anticipated [24]. X-ray crystallography is frequently used to weigh the three-dimensional arrangement of nanoparticles [25]. Surfactants, such as sodium dodecyl-sulfate (SDS), are frequently used in place of chemical agglomerates to change the properties of unchanging nanoparticles.

Outer Shell and Core

The outer layer of the inorganic nanoparticle may display contradictory synthetic and surface properties if isolated from the center of the nanoparticle. This layer stays untouched due to the shell of a nanoparticle. Some nanoparticles may have a single extraordinary shell in the center or two shells, one layered over the other, as shown in a spectacular middle shell quantum spot. The quantum yield of quantum bit nanoparticles with a CdSe mix in the core and ZnS in the shell is known to be greater than that of other nanoparticles [26]. When a shell layer advances, it is said to be advanced [27].

The merging of the center is frequently responsible for all of a nanoparticle's characteristics. The chemistry and pharmacological medicine qualities of the nanoparticle thus produced appear to be an intrinsic trait or aptitude of the nanoparticle. A positive stage structure may not appear feasible, given that secondary inorganic nanoparticles may exist in many stages, and two specific phases exposure is also common, which can mimic the chemical characteristics of a nanoparticle to mimic how real nanoparticles behave.

Mechanism of Work

Lipopolysaccharides (LPS) might be an important component of gram-negative bacteria [28]. LPS have a number of intriguing shared actions that affect Nanoparticles. Within the cell mass of gram-positive living forms, peptidoglycan and teichoic damaging are elemental powerful designations. When compared to gram-negative microscopic animals, gram-positive bacteria appear to have an additional electric charge on the cell wall surface. Nanoparticles have a higher affinity for gram-positive germs than gram-negative bacterial flora.

Nanoparticles generate a variety of reactive oxygen species, such as superoxide, hydroxyl groups, oxide, and other chemical elements, which enter the cell layer without being detected and spread throughout microbial cells [29]. The antibacterial properties of nanoparticles are affected by the thickness of gram-negative microbes' cell walls. To get together in a microorganism cell film, metal molecular nanoparticles connect to oppositely charged recognized common things, such as carboxyl and phosphate groups. Zn particles have a strong affinity for the – SH group, which is involved in a variety of protein functions [30].

Through the Fenton reaction, a superparamagnetic iron compound forces microorganism necrobiosis by denaturing DNA, lipids, and proteins in the microorganism cell [31]. Nanoparticles, such as oxide nanoparticles, control the interaction of proteins with gas absorption and regulate acceptable activity, such as nitrate enzyme and group enzyme [32].

Exopolysaccharides (EPS) layer development is restricted by Ag nanoparticles, which act as a counterbalance to the poisonous strains of *E. coli* and *Enteric pneumonia*.

Table 1: Mechanism of action of different nanoparticles.

Sr. #	Metal (nanoparticles)	Targeted Bacteria Used	Mechanism of work	References
1	Silver nanoparticles	*Bacillus subtilis, E. Coli, Staphylococcus aureus, Pseudomonas fluorescens*	Change in cellular permeability, cellular lysis, metabolic disturbance, blocking of DNA transcription, interactivity between Sulphur and phosphorus components of cell	[27]
2	Gold nanoparticles	*Staphylococcus aureus, Bacillus subtilis, E. Coli*	Change in electric potential inside and outside the cell, inhibit production of ATP, prevent translation by inhibition tRNA binding to ribosomal component	
3	Titanium dioxide nanoparticles	*Streptococcus mutans, E. Coli, Bacillus subtilis, Pseudomonas fluorescens*	Enhanced reactive oxygen species formation, peroxidation of membrane lipids of cell	
4	Zinc oxide nanoparticles	*Listeria monocytogenes, Staphylococcus aureus, Pseudomonas fluorescens*	Enhanced reactive oxygen species formation, physical changes in cellular membrane, movement of Nanoparticles inside the cell and their interaction with cellular components	
5	Copper oxide nanoparticles	*Staphylococcus aureus, E. Coli, Listeria monocytogenes, Bacillus subtilis*	Movement of Nanoparticles inside the cell and prevention of important enzymatic activities	

Factors in Antimicrobial activity: Control of Nanoparticles

The antibacterial effect of nanoparticles on living cells is controlled by their size, charge, surface roughness, surface, and shape. Apart from the chemical characteristics of nanoparticles, the strain and duration of nanoparticle production are important elements in the antimicrobial actions of nanoparticles [33]. When compared to bigger nanoparticles, tons of tiny nanobodies termed nanoparticles with enormous surface areas have a better probability of entering a live cell layer once injected [34], [35].

The impact of nanoparticles on microbial cells varied depending on the circumstances of the nanoparticles [36]. Once injected into the body, silver nanoparticles have a huge antibacterial effect [37]. Nanoparticles with unfavorable surfaces are also responsible for a reduction in protein function [38]. Nanoparticle surface area has an effect on the development of strong connections between them. When compared to antagonistically charged nanoparticles, consistently charged nanoparticles demonstrated a lot of electrical attraction for opposingly charged microbial cell film. Clearly charged nanoparticles unleash tons of reactive oxygen species as compared to oppositely charged and neutral nanoparticles [39].

The connection between nanoparticles and microbial life forms is controlled via doping modifications. When ZnO nanoparticles are doped in this way, they cause a lot of harm to microbial cells by forming reactive oxygen species once they are introduced into the cell [40][41]. Increased temperature improves the antibacterial activity of ZnO nanoparticles. The breaking down movement of ZnO nanoparticles is created by an acidic pH scale, which results in a slew of antibacterial characteristics for ZnO nanoparticles [42]. Carbapenems, fluoroquinolones, Cephalosporins, and bactericides, in combination with nanoparticles, have synergistic effects against *P. aeruginosa* and *A. baumannii*[43].

Nanoparticles as Pesticides

The perseverance limit of pesticides is viewed as of significance throughout the beginning phases of plant advancement as a result of it helps in decreases pest over population throughout, this method has a dominating property over vermin for extended stage [44]. Consequently, the utilization of chemical pesticides by means that they have been applied to crops and ingestion of these chemicals have adverse effects on living organisms. Extensive use of chemical pesticides, however, saves the plant up to some extent but shortens the life of the plant. For a biopesticide to act efficiently and consequently, the cycle of nano-epitome is going to be actualizing effectively. Since the cycle of nano-exemplification of the pesticides makes it potential for time-controlled delivery or delivered upon the event of natural stimuli like temperature, viscosity, and photoperiod. Therefore, on the event of nano-epitomized pesticides is on the mounting movement. In any case, its profit capability inside the business market is, even so, to occur sooner rather than later, although late explores have urged that the exemplification of bug sprays and fungicides will facilitate in the nano-plans uprising and, on the other hand, destroy the soil as well making it less eco-friendly. The advancement of nanotechnology detailing that has moderate delivering assets with upgraded dissolvability, porousness, and trustworthiness. These benefits are in the main accomplishment through either shielding the encapsulated chemicals from early debasement. Nano-epitomized chemical detailing can cut back the activity of pesticides and, through this, suggests no human danger will occur. Also, it would ponder as high caliber of eco-accommodating material for crop insurance. Fitting information of an expense benefit examination of nano-exemplification materials delayed their application cycle to keep with chemical conveyance.

The scientific analysis convey basic and foremost information for technocrats inside the engineering, increasing the probability of using nano pesticides more abundantly [45].

Throughout current years, organic bio-synthesis of nanoparticles by microorganisms has been obtaining increasing thought [46]. Atomic number 51-changing bacteria was isolated from the Caspian Sea in northern Asian nation and was used for living thing biogenesis of antimony compound nanoparticles. This disengage was recognized as non-pigmented *Serratia marcescens* utilizing normal (conventional) assays and measurement by 16S rDNA section sweetening technique and was used to urge prepared inorganic atomic number 51 nanoparticles. The biogenic nanoparticles were discharged by fluid N and removed utilizing 2 consecutive soluble extraction frameworks. varied portrayals of the take away inorganic nanoparticles, as an example, molecule form, size, and organization, were completed with varied instruments. The energy dispersing x-rays exhibited that the removed nanoparticles comprised of atomic number 51 and sulphur particles. Moreover, the transmission negatron micrograph incontestable the small and traditional non-totaled nanoparticles stepping into size underneath 35 nm. In spite of the very fact that the microbic synthesis of atomic number 51 compound nanoparticles have been accounted for within the writing, the organic combination of atomic number 51 compound nanoparticles has not recently been distributed. This is often the primary report back to show associate degree organic technique for incorporating inorganic nanoparticles created out of atomic number 51. An easy extraction strategy for confinement of atomic number 51 compound nanoparticles from microorganism biomass is to boot within the current examination.

A microorganism isolates acceptable enduring silver nitrate ($AgNO_3$) was collected from soil tainted with industrial waste. The isolate was recognized by 16S rRNA as Enterobacter cloacae, and its ability to biologically synthesis silver nanoparticles (Ag nanoparticles) was examined. Ag nanoparticles were synthesized by compounding 1 mm $AgNO_3$ arrangement with microorganism cell lysate underneath lightweight conditions. The UV-Vis vary of the fluid medium containing Ag nanoparticles showed a high peak at 440 nm with reference to the surface plasmon resonance of the Ag nanoparticles. The crystalline nature of the particles was thoroughbred by X-ray diffractometer. High-resolution transmission microscopy uncovered that the Ag nanoparticles were circular and really abundant, scattered, and ran in size from seven to 25 nm. the conventional size scope of the delivered Ag nanoparticles was thoroughbred by distinctive lightweight dissipating. Fourier modification infrared qualitative analysis uncover conceivable inclusion of subtractive gatherings on the surface of the nano--particles. The biosynthesized Ag nanoparticles were steady for a year and hindered each gram-positive and gram-negative microbe. This work depicts the misuse of a negligible effort biomaterial and a straightforward strategy for the microbic synthesis of Ag nanoparticles with enticing and profitable qualities.

The advancement of solid procedures for the microorganism synthesis of nanoparticles may be an important perspective of engineering [47], [48]. Organically mixed nanoparticles may have endless applications in varied regions, as an example, catalyzer, bio-labelers, so forth. within the current survey, we tend to underscore the wealth of the microorganism world, which incorporates a many endophytic elements/bodies as a rising tool within the biogenesis of nanoparticles. the present preview is that the initial of its type whereby it provides an inspiration and vision of unknown uses of endophytes.

Technology could be a multidisciplinary field developed within recent decades and presuming appreciable job in condition, industry, farming, and medicine. mixture of technology and biotechnology has prompted the institution of nanomedicine [49]. It is given novel achievements in fix of various sicknesses and disorders, discovery and medicine of varied diseases in animals and plants additionally. In any case, utilization of microbially integrated nanoparticles in eudaemonia and drugs is heretofore restricted. this text options the inexperienced methodology of nanomaterials bio-synthesis utilizing organisms and current standing of their applications in medical specialty field[50].

Despite their great potential as pesticides and acaricides, there are several concerns about nanoparticles' appropriate usage in both terrestrial and aquatic environments. With such a limited understanding of them from an ecotoxicological standpoint, it is difficult to predict their impact on the environment and consequences for human health [3].

Despite a large number of reports on their toxicity toward certain pests and vectors [51]–[55], detailed information on the realizable mode of motion of nanoparticles against insects and mites is severely limited. This information is critical in predicting the medical implications of nanoparticle pesticide usage on a global scale. Because their toxicity in organic forms is strongly promoted by their length, shape, and price, the processes leading to toxicity and genotoxicity have been investigated, in particular for silver nanoparticles Furthermore, the majority of this research has been done on organism models or *in vitro* toxicity experiments with the most basic type of studies focusing on the observable mechanisms of action in the fight against insects and mites.

Concluding Remarks

As for a conclusion, the application of chemical pesticides to crops and the consumption of these chemicals have negative impacts on living organisma. Because of the pesticides, nano-exemplification cycle may be given on a timer or in response to natural situations such as temperature, viscosity, and photoperiod. As a result, there is a growing trend in favor of nano-epitomized insecticides. In any event, its profit potential in the business sector is likely to come sooner rather than later, despite recent research suggesting that the exemplification of insect sprays and fungicides would aid in the uprising of nano-plans while also destroying the soil and making it less eco-friendly. The development of a green nanotechnology details the following: improved interaction, permeability, and target specificity. Also, the experimental findings provide fundamental and critical information in the biotechnology field, boosting the likelihood of more widespread use of nano pesticides.

REFERENCES

[1] J. M. Palomo, "Nanobiohybrids: a new concept for metal nanoparticles synthesis," *Chem. Commun.*, vol. 55, no. 65, pp. 9583–9589, Aug. 2019, doi: 10.1039/C9CC04944D.

[2] Y. S. Pestovsky and A. Martínez-Antonio, "The use of nanoparticles and nanoformulations in agriculture," *J. Nanosci. Nanotechnol.*, vol. 17, no. 12, pp. 8699–8730, 2017, doi: 10.1166/JNN.2017.15041.

[3] G. Benelli, "Mode of action of nanoparticles against insects," *Environ. Sci. Pollut. Res. Int.*, vol. 25, no. 13, pp. 12329–12341, May 2018, doi: 10.1007/S11356-018-1850-4.

[4] H. Duan, D. Wang, and Y. Li, "Green chemistry for nanoparticle synthesis," *Chem. Soc. Rev.*, vol. 44, no. 16, pp. 5778–5792, Aug. 2015, doi: 10.1039/C4CS00363B.

[5] A.-R. Shahverdi, M. Shakibaie, and P. Nazari, "Basic and Practical Procedures for Microbial Synthesis of Nanoparticles," *Met. Nanoparticles Microbiol.*, pp. 177–195, 2011, doi: 10.1007/978-3-642-18312-6_8.

[6] M. Razavi, E. Salahinejad, M. Fahmy, M. Yazdimamaghani, D. Vashaee, and L. Tayebi, "Green chemical and biological synthesis of nanoparticles and their biomedical applications," *Green Process. Nanotechnol. From Inorg. to Bioinspired Nanomater.*, pp. 207–235, Jan. 2015, doi: 10.1007/978-3-319-15461-9_7/COVER/.

[7] S. Mazhar, R. Yasmeen, A. Chaudhry, and K. Summia, "Role of Microorganisms in Modern Food Industry," *Int. J. Innov. Sci. Technol.*, vol. 4, no. 1, pp. 65–77, 2022.

[8] D. Septiadi, F. Crippa, T. L. Moore, B. Rothen-Rutishauser, and A. Petri-Fink, "Nanoparticle–Cell Interaction: A Cell Mechanics Perspective," *Adv. Mater.*, vol. 30, no. 19, p. 1704463, May 2018, doi: 10.1002/ADMA.201704463.

[9] C. A. S. Batista, R. G. Larson, and N. A. Kotov, "Nonadditivity of nanoparticle interactions," *Science (80-.).*, vol. 350, no. 6257, Oct. 2015, doi: 10.1126/SCIENCE.1242477/ASSET/5E558520-CD42-44B7-B743-ACC7333CFEE2/ASSETS/GRAPHIC/350_1242477_FA.JPEG.

[10] S. Iravani, H. Korbekandi, S. V. Mirmohammadi, and B. Zolfaghari, "Synthesis of silver nanoparticles: chemical, physical and biological methods," *Res. Pharm. Sci.*, vol. 9, no. 6, p. 385, Dec. 2014.

[11] N. Durán, M. Durán, M. B. de Jesus, A. B. Seabra, W. J. Fávaro, and G. Nakazato, "Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity," *Nanomedicine Nanotechnology, Biol. Med.*, vol. 12, no. 3, pp. 789–799, Apr. 2016, doi: 10.1016/J.NANO.2015.11.016.

[12] C. Lodewyckx *et al.*, "Endophytic bacteria and their potential applications," *CRC. Crit. Rev. Plant Sci.*, vol. 21, no. 6, pp. 583–606, 2002, doi: 10.1080/0735-260291044377.

[13] M. P. Mishra and R. N. Padhy, "Antibacterial activity of green silver nanoparticles synthesized from Anogeissus acuminata against multidrug resistant urinary tract infecting bacteria in vitro and host-toxicity testing," *http://jab.zsf.jcu.cz/doi/10.1016/j.jab.2017.11.003.html*, vol. 16, no. 2, pp. 120–125, May 2018, doi: 10.1016/J.JAB.2017.11.003.

[14] C. Chen, E. M. Bauske, G. Musson, R. Rodríguez Kábana, and J. W. Kloepper, "Biological Control of Fusarium Wilt on Cotton by Use of Endophytic Bacteria," *Biol. Control*, vol. 5, no. 1, pp. 83–91, Mar. 1995, doi: 10.1006/BCON.1995.1009.

[15] R. Anand, L. Paul, and C. Chanway, "Research on Endophytic Bacteria: Recent Advances with Forest Trees," *Microb. Root Endophytes*, pp. 89–106, May 2006, doi: 10.1007/3-540-33526-9_6.

[16] P. Balint-Kurti, "The plant hypersensitive response: concepts, control and consequences," *Mol. Plant Pathol.*, vol. 20, no. 8, p. 1163, Aug. 2019, doi: 10.1111/MPP.12821.

[17] A. Hashem, E. F. Abd-Allah, A. A. Alqarawi, A. A. Al-Huqail, S. Wirth, and D. Egamberdieva, "The interaction between arbuscular mycorrhizal fungi and endophytic bacteria enhances plant growth of Acacia gerrardii under salt stress," *Front. Microbiol.*, vol. 7, no. JUL, p. 1089, Jul. 2016, doi: 10.3389/FMICB.2016.01089/BIBTEX.

[18] E. J. Wagenmakers, T. Lodewyckx, H. Kuriyal, and R. Grasman, "Bayesian hypothesis

testing for psychologists: A tutorial on the Savage–Dickey method," *Cogn. Psychol.*, vol. 60, no. 3, pp. 158–189, May 2010, doi: 10.1016/J.COGPSYCH.2009.12.001.
[19] A. Nath Yadav, "Plant Growth Promoting Bacteria: Biodiversity and Multifunctional Attributes for Sustainable Agriculture," *Adv. Biotechnol. Microbiol.*, vol. 5, no. 5, Aug. 2017, doi: 10.19080/AIBM.2017.05.555671.
[20] Y. S. Ku, H. M. Rehman, and H. M. Lam, "Possible Roles of Rhizospheric and Endophytic Microbes to Provide a Safe and Affordable Means of Crop Biofortification," *Agron. 2019, Vol. 9, Page 764*, vol. 9, no. 11, p. 764, Nov. 2019, doi: 10.3390/AGRONOMY9110764.
[21] S. Zhang, T. L. White, M. C. Martinez, J. A. McInroy, J. W. Kloepper, and W. Klassen, "Evaluation of plant growth-promoting rhizobacteria for control of Phytophthora blight on squash under greenhouse conditions," *Biol. Control*, vol. 53, no. 1, pp. 129–135, Apr. 2010, doi: 10.1016/J.BIOCONTROL.2009.10.015.
[22] A. V. Sturz, "The role of endophytic bacteria during seed piece decay and potato tuberization," *Plant Soil 1995 1752*, vol. 175, no. 2, pp. 257–263, Aug. 1995, doi: 10.1007/BF00011362.
[23] C. O. Ogunkunle *et al.*, "Effect of Low-Dose Nano Titanium Dioxide Intervention on Cd Uptake and Stress Enzymes Activity in Cd-Stressed Cowpea [Vigna unguiculata (L.) Walp] Plants," *Bull. Environ. Contam. Toxicol. 2020 1045*, vol. 104, no. 5, pp. 619–626, Mar. 2020, doi: 10.1007/S00128-020-02824-X.
[24] P. Christian, F. Von Der Kammer, M. Baalousha, and T. Hofmann, "Nanoparticles: Structure, properties, preparation and behaviour in environmental media," *Ecotoxicology*, vol. 17, no. 5, pp. 326–343, 2008, doi: 10.1007/s10646-008-0213-1.
[25] A. Moudgil, A. S. Deval, M. S. Dharne, D. M. Sarkar, A. S. Choudhari, and B. P. Chaudhari, "Eichhornia crassipes Mediated Bioinspired Synthesis of Crystalline Nano Silver as an Integrated Medicinal Material: A Waste to Value Approach," *J. Clust. Sci. 2020 322*, vol. 32, no. 2, pp. 391–404, Apr. 2020, doi: 10.1007/S10876-020-01797-5.
[26] B. Mehdaoui *et al.*, "Optimal Size of Nanoparticles for Magnetic Hyperthermia: A Combined Theoretical and Experimental Study," *Adv. Funct. Mater.*, vol. 21, no. 23, pp. 4573–4581, Dec. 2011, doi: 10.1002/ADFM.201101243.
[27] C. A. Ottoni *et al.*, "Screening of filamentous fungi for antimicrobial silver nanoparticles synthesis," *AMB Express*, vol. 7, no. 1, pp. 1–10, Dec. 2017, doi: 10.1186/S13568-017-0332-2/FIGURES/6.
[28] R. Prasad, B. Siddhardha, and M. Dyavaiah, Eds., "Nanostructures for Antimicrobial and Antibiofilm Applications," 2020, doi: 10.1007/978-3-030-40337-9.
[29] J. Li *et al.*, "Green synthesis of silver nanoparticles–graphene oxide nanocomposite and its application in electrochemical sensing oftryptophan," *Biosens. Bioelectron.*, vol. 42, no. 1, pp. 198–206, Apr. 2013, doi: 10.1016/J.BIOS.2012.10.029.
[30] N. Padmavathy and R. Vijayaraghavan, "Interaction of ZnO nanoparticles with microbes--a physio and biochemical assay," *J. Biomed. Nanotechnol.*, vol. 7, no. 6, pp. 813–822, Dec. 2011, doi: 10.1166/JBN.2011.1343.
[31] K. D. Leuba, N. G. Durmus, E. N. Taylor, and T. J. Webster, "Short communication: Carboxylate functionalized superparamagnetic iron oxide nanoparticles (SPION) for the reduction of S. aureus growth post biofilm formation," *Int. J. Nanomedicine*, vol. 8, pp. 731–736, Feb. 2013, doi: 10.2147/IJN.S38256.

[32] A. M. Awwad, N. M. Salem, M. M. Aqarbeh, and F. M. Abdulaziz, "Green synthesis , characterization of silver sulfide nanoparticles and antibacterial activity evaluation," vol. 6, no. 1, pp. 42–48, 2020, doi: 10.5281/zenodo.3243157.

[33] L. Wang and J. Lin, "Phenylalanine-Rich Peptide Mediated Binding with Graphene Oxide and Bioinspired Synthesis of Silver Nanoparticles for Electrochemical Sensing," *Appl. Sci. 2017, Vol. 7, Page 160*, vol. 7, no. 2, p. 160, Feb. 2017, doi: 10.3390/APP7020160.

[34] S. Gurunathan, J. W. Han, D. N. Kwon, and J. H. Kim, "Enhanced antibacterial and anti-biofilm activities of silver nanoparticles against Gram-negative and Gram-positive bacteria," *Nanoscale Res. Lett.*, vol. 9, no. 1, pp. 1–17, 2014, doi: 10.1186/1556-276X-9-373.

[35] S. Gurunathan *et al.*, "Biosynthesis, purification and characterization of silver nanoparticles using Escherichia coli," *Colloids Surfaces B Biointerfaces*, vol. 74, no. 1, pp. 328–335, Nov. 2009, doi: 10.1016/J.COLSURFB.2009.07.048.

[36] G. R. Bhimanapati *et al.*, "Recent Advances in Two-Dimensional Materials beyond Graphene," *ACS Nano*, vol. 9, no. 12, pp. 11509–11539, Nov. 2015, doi: 10.1021/ACSNANO.5B05556/ASSET/IMAGES/MEDIUM/NN-2015-055569_0014.GIF.

[37] L. Actis, A. Srinivasan, J. L. Lopez-Ribot, A. K. Ramasubramanian, and J. L. Ong, "Effect of silver nanoparticle geometry on methicillin susceptible and resistant Staphylococcus aureus, and osteoblast viability," *J. Mater. Sci. Mater. Med.*, vol. 26, no. 7, Jul. 2015, doi: 10.1007/S10856-015-5538-8.

[38] I. V. Sukhorukova *et al.*, "Toward bioactive yet antibacterial surfaces," *Colloids Surf. B. Biointerfaces*, vol. 135, pp. 158–165, Nov. 2015, doi: 10.1016/J.COLSURFB.2015.06.059.

[39] M. Arakha *et al.*, "Antimicrobial activity of iron oxide nanoparticle upon modulation of nanoparticle-bacteria interface," *Sci. Reports 2015 51*, vol. 5, no. 1, pp. 1–12, Oct. 2015, doi: 10.1038/srep14813.

[40] H. Guo, J. B. Callaway, and J. P. Y. Ting, "Inflammasomes: mechanism of action, role in disease, and therapeutics," *Nat. Med. 2015 217*, vol. 21, no. 7, pp. 677–687, Jun. 2015, doi: 10.1038/nm.3893.

[41] S. Basharat, S. Mazhar, R. Yasmeen, and W. Hamid, "Evaluation of Microbial Contamination via Wastewater Collected from Different Oil Industries and its Treatment Using Various Coagulants," *Int. J. Innov. Sci. Technol.*, vol. 4, no. 2, pp. 392–403, 2022.

[42] M. Saliani, R. Jalal, and E. K. Goharshadi, "Effects of pH and Temperature on Antibacterial Activity of Zinc Oxide Nanofluid Against Escherichia coli O157: H7 and Staphylococcus aureus," *Jundishapur J. Microbiol.*, vol. 8, no. 2, pp. 1–6, Feb. 2015, doi: 10.5812/JJM.17115.

[43] E. Bayroodi and R. Jalal, "Modulation of antibiotic resistance in Pseudomonas aeruginosa by ZnO nanoparticles," *Iran. J. Microbiol.*, vol. 8, no. 2, p. 85, 2016.

[44] K. S. Siddiqi and A. Husen, "Fabrication of Metal Nanoparticles from Fungi and Metal Salts: Scope and Application," *Nanoscale Res. Lett. 2016 111*, vol. 11, no. 1, pp. 1–15, Feb. 2016, doi: 10.1186/S11671-016-1311-2.

[45] G. Benelli, "Plant-mediated biosynthesis of nanoparticles as an emerging tool against

mosquitoes of medical and veterinary importance: a review," *Parasitol. Res.*, vol. 115, no. 1, pp. 23–34, Jan. 2016, doi: 10.1007/S00436-015-4800-9.

[46] K. Bahrami, P. Nazari, Z. Sepehrizadeh, B. Zarea, and A. R. Shahverdi, "Microbial synthesis of antimony sulfide nanoparticles and their characterization," *Ann. Microbiol.*, vol. 62, no. 4, pp. 1419–1425, Dec. 2012, doi: 10.1007/S13213-011-0392-5/FIGURES/5.

[47] S. Baker and S. Shreedharmurthy, "Antimicrobial activity and biosynthesis of nanoparticles by endophytic bacterium inhabiting Coffee arabica L .," *Sci. J. Biol. Sci.*, vol. 1, no. 5, pp. 107–113, 2012.

[48] "Endophytes: Toward a vision in synthesis of nanoparticlefor future therapeutic agents - uomeprints." .

[49] A. Fariq, T. Khan, and A. Yasmin, "Microbial synthesis of nanoparticles and their potential applications in biomedicine," *J. Appl. Biomed.*, vol. 15, no. 4, pp. 241–248, Nov. 2017, doi: 10.1016/J.JAB.2017.03.004.

[50] I. R. Imran, "Environmental Factors as Diabetogenic Agent in Type 2 Diabetes Mellitus," *Int. J. Innov. Sci. Technol.*, vol. 4, no. April, pp. 288–299, 2022.

[51] Y.-C. Lee and J.-Y. Moon, "Bionanotechnology in Agriculture, Food, Cosmetic and Cosmeceutical," *Introd. to Bionanotechnol.*, pp. 199–217, 2020, doi: 10.1007/978-981-15-1293-3_11.

[52] H. H. Amin, "Biosynthesized silver nanoparticles using Ulva lactuca as a safe synthetic pesticide (in vitro)," *Open Agric.*, vol. 5, no. 1, pp. 291–299, Jan. 2020, doi: 10.1515/OPAG-2020-0032/MACHINEREADABLECITATION/RIS.

[53] L. Hajji-Hedfi and H. Chhipa, "Nano-based pesticides: challenges for pest and disease management," *Euro-Mediterranean J. Environ. Integr. 2021 63*, vol. 6, no. 3, pp. 1–8, Sep. 2021, doi: 10.1007/S41207-021-00279-Y.

[54] J. Bhattacharya, R. Nitnavare, A. Shankhapal, and S. Ghosh, "Microbially synthesized nanoparticles: aspect in plant disease management," *Biocontrol Mech. Endophytic Microorg.*, pp. 303–325, Jan. 2022, doi: 10.1016/B978-0-323-88478-5.00007-9.

[55] H. Chopra *et al.*, "Green Metallic Nanoparticles: Biosynthesis to Applications," *Front. Bioeng. Biotechnol.*, vol. 10, p. 548, Apr. 2022, doi: 10.3389/FBIOE.2022.874742/BIBTEX.