Biological Synthesis of Nanoparticles and Their Applications in Sustainable Agriculture Production

Naeem Khan[1], **Shahid Ali**[2], **Sadia Latif**[3], **Asif Mehmood**[4]

[1]Department of Agronomy, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL, USA; [2]College of Life Sciences and Oceangraphy, Shenzhen University, Shenzhen, China; [3]Department of Biology and Environmental Science, Allama Iqabal Open University, Islamabad, Pakistan; [4]Institute of Biological Sciences, Sarhad University of Science and Information Technology, Peshawar, Pakistan

Correspondence to: Naeem Khan, naeemkhan@ufl.edu; Asif Mehmood, asif.ibs@suit.edu.pk
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ABSTRACT

Nanotechnology is a developing field in biotechnology. The synthesis of nanoparticles is an important step in the field of nanotechnology. Overcoming the limitations of traditional methods, a green scheme for synthesizing nanoparticles has emerged. Plants and microorganisms are mainly used for the green synthesis of metal nanoparticles. Some of the nanoparticles showed strong antimicrobial effects against different plant pathogens. Compared with microorganisms, the use of plants to synthesize nanoparticles is on the rise, and has advantages compared with microorganisms, because plants have a wide range of bio-molecular variability, which can act as blocking/stabilizing agents and reducing agents, thereby increasing reduction rate and stability of synthetic nanoparticles. Of all living things, plants seem to have the best potential for nanoparticle biosynthesis and are suitable for large-scale biosynthesis. Compared with microorganisms, the synthesis of plant-derived nanoparticles is faster and more stable. Therefore, this review focuses on the use of microbial and plant sources to synthesize nanoparticles and their applications in agriculture.

1. INTRODUCTION

Nanotechnology is an emerging field in the area of interdisciplinary research, especially in biotechnology [1]. Nowadays, nanoparticle research is unavoidable not because of its importance but also by the way of synthesis [2]. In nanotechnology, the construction, management and use of materials range in nanometers. In the field of herbal medicine and medicinal plant biology, with the cross-development of nanotechnology, scientific knowledge has been improved and technology has been advanced. Nanotechnology has many applications in different fields including medicine and agriculture. In agriculture, nanotechnology can be developed by using natural resources to protect, produce and protect crops and livestock [3]. In recent years, due to the biocompatibility, low toxicity and eco-friendliness of the process and NP products, the biosynthesis of nanoparticles (NPs) or the green synthesis of NPs has received worldwide attention [4]. Using biological materials such as bacteria, yeasts, molds, microalgae and plant extracts to synthesize NP has some advantages, such as low energy consumption, moderate technology, and no toxic chemicals [5, 6]. Controlling plant disease with nano-technological products is an emerging application of nanotechnology [7]. Nanoparticles can be disposed of directly or individually as a carrier of various pesticides for industrial protection [8].

Various methods can be used to easily synthesize nanoparticles through various methods including chemical [9], electrochemistry [10], radiation [11], and photochemical methods [12] and langmuir-blodgett [13, 14] and biological techniques [15].

However, most of the chemical methods used to synthesize nanoparticles involve the use of toxic and harmful chemicals, which can create biological risks, and sometimes these chemical processes are not good for the ecological environment. It increases demand for environmentally friendly developments through green synthesis and other biological techniques. Sometimes, the use of various plant materials and their extracts to synthesize nanoparticles may be more beneficial than other biosynthetic processes that involve very complex procedures for maintaining microbial culture [16]. Based on the above aforementioned facts, the current review was undertaken to explore the methods of synthesis of nanoparticles from different sources and their applications in different fields.

2. METHODS OF SYNTHESIS OF NANOPARTICLES

In the past few decades, the synthesis and research of nanoparticles has attracted great attention from scientists in the field of basic and applied research. Metal nanoparticles (MNP) mainly belong to the engineering type of nanoparticles. Eye-catching attraction have been received by these nanoparticles (MNPs) (such as silver, gold, and copper) due to its electronic, catalytic and unique optical properties, it is very attractive in the field of special sensing, bio conjugation and surface enhanced raman spectroscopy. Recently, a complete set of synthetic methods for the preparation of MNP have been developed such as chemical, photochemical and thermal methods. Amongst various procedures, more and more attention is paid to the use of biological and green technologies to produce various MNPs [17]. In MNP, silver nanoparticles play an important role in the fields of biology and medicine. In addition, silver nanoparticles have recently attracted great interest due to their surface plasmon resonance [12], optical properties [18], catalytic action [19], excellent antimicrobial activity [20-22], etc. In the past few years, researchers have proved that silver nanoparticles have significant antimicrobial effects against infections and diseases [16, 23]. Although many methods are suitable for synthesizing metal nanoparticles, the most commonly used method is to chemically reduce metal ions into nanoparticles and then stabilize them [24]. Most of these methods are very expensive and involve the use of toxic and hazardous chemicals, which may pose environmental potential and biological risks. Therefore, materials scientists and nanochemists look forward to using eco-friendly substances to obtain metal nanoparticles. Nano biotechnology is dedicated to the synthesis of nanostructures from living organisms. In the biological use of nanoparticle synthesis, plants have found applications especially in the synthesis of metal nanoparticles. Using plants to synthesize nanoparticles may be superior to other biological processes that are not harmful to the environment because it eliminates the complex process of maintaining cell culture. If plants or their extracts are used to produce nanoparticles in an extracellular manner, in a controlled manner according to their size, dispersion, and shape, the biosynthesis process of nanoparticles will be more helpful. Plant use can also be appropriately scaled up to synthesize nanoparticles on a large scale [25-28].

2.1. Synthesis of Nanoparticles from Microbes

In material chemistry nanoparticles, have important role. It can be used in the control of microorganisms such as bacteria and fungi (**Figure 1**). Biosynthetic methods can be chemical or physical. On the bases of location where nanostructures are formed for example *stutzeri* which is a pseudomonas can be isolated from silver ores can reduce Ag ions and accumulate silver particles and these nanoparticles are 16 to 40 nm and its diameter is 27 nm. Another example is magneto tactic bacteria, which produce magnetite Fe3o4 or reignite Fe3s4. The antibacterial agent silver can kill around 650 kinds of pathogenic microbes and silver have electrical, optical and biological properties and can be used in drug delivery, imaging, catalysis and bio sensing [29, 30].

The biosynthetic metal such as silver, gold, copper and zinc can fight against Gram-positive bacteria and Gram-negative bacteria such as *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus*. Silver nanoparticles have received more attention due to green synthesis of plants, bacteria, fungi and yeasts [31]. The green synthesis of AgNps of Streptomyces endophytes was observed to have antimicrobial activity against four plant pathogenic fungi such as *Alternaria*, *Streptomyces*, *Pythium* and *Aspergillus niger*. Chamomile flower were used to synthesize Mgo and Mno2 NPs. Green synthetic znOPs and TiO2NPs and lemon fruit extract showed antibacterial activity against *Dickeya dadantii* at room temperature, which is the pathogen of sweet potato stem, and root rot [32-34].

2.2. Synthesis of Nanoparticles from Plants

For the synthesis of nanoparticles, plant extracts are used as a reducing agents and it has great advantage over biological processes because of the fact that they eliminate complex cell culture and maintain processes (**Figure 2**). The plant nanoparticles synthesis is cost effective and environmentally friendly and it is safe for humans. Different size and shapes of silver, gold, platinum and titanium nanoparticles are synthesized from different parts of plant materials such as extracts from fruits, bark, pericarp and roots [35]. The synthesis of various nanoparticle includes collecting required plant parts and then washing it with distilled water to remove epiphytes and necrotic after than dry and clean plant source in the dark for 10 to 15 days and then use a household mixer to pulverize it then 10 gram of dried powder is boiled with deionized distilled water of 100 ml. Then filter the resulting solution thoroughly until there are no insoluble in broth. Shortly thereafter, collect the filtrate and add AGNo3 solution with a final concentration of 1mM to the filtrate [36, 37]. Then after adding, the mixture will sometimes oscillate in shaking incubator, and the color of the mixture will soon change due to the reduction of pure silver ions to Ago and it is necessary to regularly monitor the obtained samples in uv-visible spectrum of the solution to identify the characteristic absorption characteristics of the nanoparticles, which indicates the formation of nanoparticles [38].

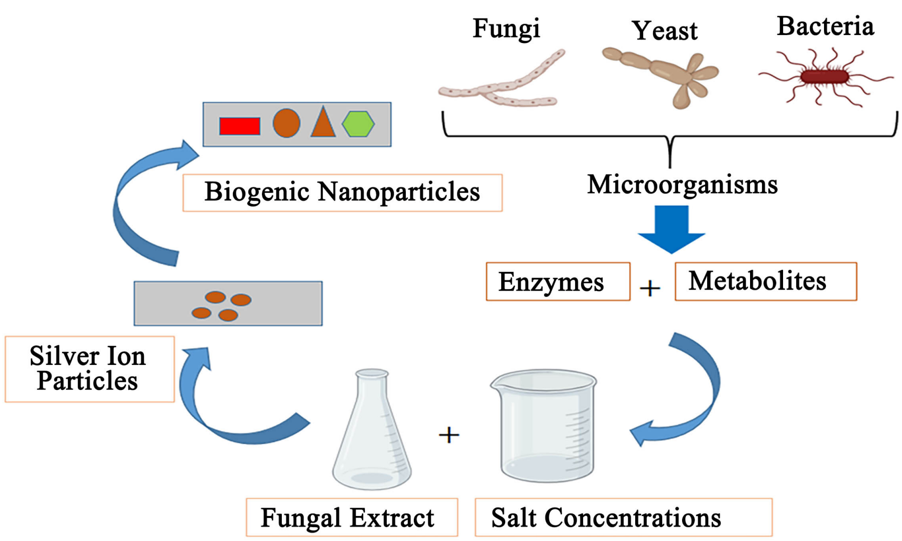

Figure 1. Methods of synthesizing nanoparticles form microbes.

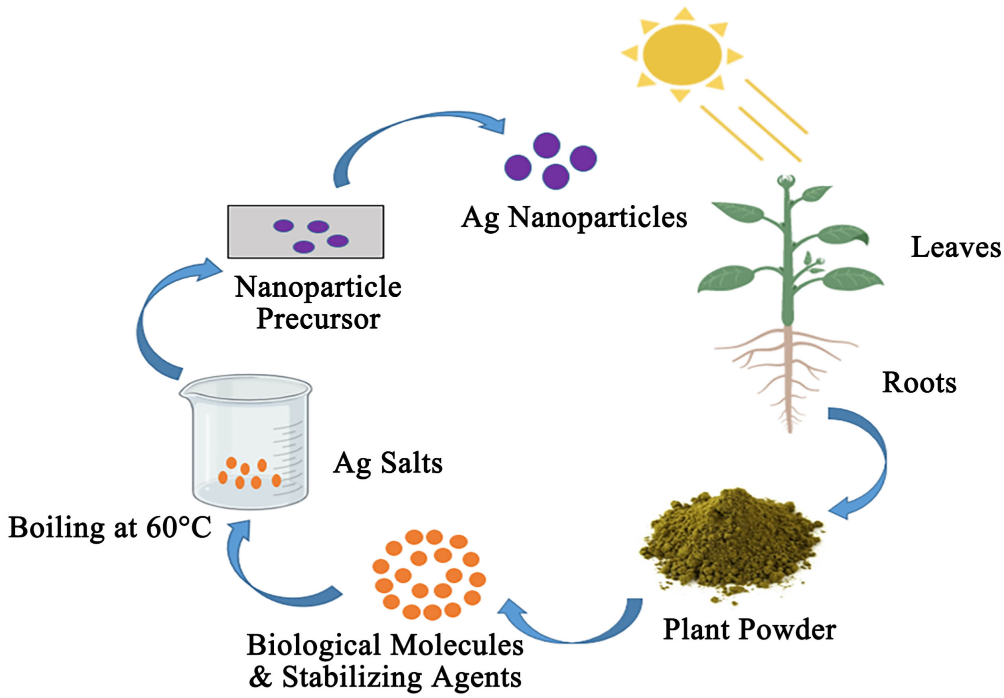

Figure 2. Synthesis of Nanoparticles from plant extracts.

Green nanoparticles from different plant species have also identified for example root extract of *Morinda citrifolia*, *Phoenix dactylifera* inflorescence extract of Mangifera, aloe vera extract, latex of *Jatropha gossypifolia*, fruit extract *Phyllanthus emblica*, Aqueous rosemary extract was used to synthesize the Mg-flowers having antibacterial potentials [39]. The quality, size and shape of these green synthetic NPs depend on many factors, such as plant extract concentration and its composition, metal salt concentration, reaction pH, reaction temperature., titanium dioxide Nps synthesized from fresh lemon fruit extract have antibacterial activity within 8 minutes of reaction time. *O. sanctum* leaf extract can reduce silver ions to nano-silver particles and it has bacterial activity and size range from 4 - 30 nm [40].

2.3. Applications of Nanoparticles in Agriculture

In today's world the use of chemicals such as pesticides, fungicides and herbicides are used to control pests and diseases. It has caused many harms such antagonistic effects on human health, adverse effect on pollinating insects and livestock, and the entry of substance into soil and water and its effects on ecosystem. Nano-scale chemicals may be a suitable solution to these problems [41]. Through the production of pesticides and chemical fertilizers by using nanoparticles and Nano capsules environmental pollution can be reduced. Nanomaterials including polymer, nanoparticles, iron oxide nanoparticles and gold nanoparticles, which can be easily synthesized and used as carriers for pesticides or drugs. The pharmacokinetic parameters of these nanoparticles may change to kinetic characteristics of drug release resulting in sustained drug release, reducing the need for frequent drug delivery. The pesticides are used as preventive measures leading to remaining toxicity and environmental risk. One of the most important factors is disease which is restraining crop production but the use of pesticides after the occurrence of diseases will cause certain crop losses [42]. Detecting the stage of DNA replication or production of initial viral protein is the key to control the disease. The use and recognition of biomarkers that exactly specify the stage of the disease is also a new field of research. The nano-scale equipment with new properties can be used to smart agriculture system. Nano-based diagnostic kits can not only increase detection speed, but also increase detection capabilities (**Figure 3**).

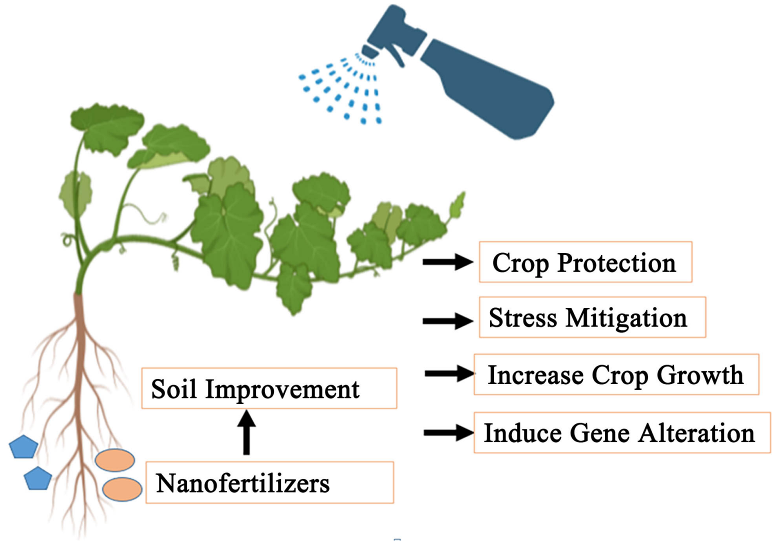

Figure 3. **Impacts of biologically synthesized nanoparticles on plant growth and stress tolerance.**

2.4. Applications of Nanotechnology in Food Industry

Oxygen tends to act as one of the key factors in the food industry that can cause food spoilage and discoloration. One of the main implementations of Nanotechnology within the food industry is the creation of fresh plastics for food packaging. These Nanoparticles in return are processed to produce plastics that are used for packaging of foods. In the new plastic, the Nanoparticles are known to be spiked, acting as a barricade used for blockage in order to prevent oxygen diffusion. Other than that, the pathway for the oxygen to enter the package should be long, the result of that is, and the food deterioration is imminent in the future. According to "Predicala 2009", Nano-coatings are produced to prevent fruits from weight loss and shrinkage, thus covering them completely [43]. It has been the goal of many production companies to develop smart packaging to optimize the shelf life of the product. A packaging system developed with such technology will be in itself enough to repair minor gaps within packaging, as well as responding to environmental conditions when climate change occurs and alert the customers regarding the contamination of food. None other than Nanotechnology can provide the solutions for these problems. Here are some of the examples: the changing of permeability of foils, enhancing the properties of the barrier (mechanical, thermal, chemical and microbiological), ameliorate the mechanical and heat resistance of the packaging, evolving the already developed active antimicrobial and antifungal surfaces with sensing and protection. The top example regarding the production of Nanotechnology is the Ethylene absorbent [44-46]. Ethylene, a gas that is produced by fruits in order to increase the probability of food decay, is absorbed by the Nanomaterials in the absorbent ethylene, thus increasing the tenacity of fruits for an extended period. In order to monitor the agricultural products, Nano barcodes and Nano processing can also be used as a measure. According to "Prasanna, 2007" As new discoveries are made in the world of Nanotechnology, in the same manner that normal barcodes operate, Nano-based barcodes can also perform the similar function like helping to track the food products and keeping a check on the quality of food products, thus producing an entire record in a matter of minutes, or less. The biosensor is another example of the advanced Nano-technology, that comprises of a biological element, that is the same as a cell, an enzyme or an antibody, linked to a small transducer, a device powered by one system that in return supplies the same power to a different system in another form, a form that is required by that other system. Biosensors detect and record every change occurring in every cell and molecule that is used to measure, identify and test the test substance, even at the lowest concentrations of the substance about to be tested. When a substance hitches to a biological component, the transducer then produces a signal that is proportional to the number of components. In case of a high concentration of bacteria in a certain food product, the biosensor will perform the duty of producing a strong signal that would indicate that the food is not sanitary and hence, not safe to be consumed. With a technology so sharp and so cutting edge, it is easy to check the amount of food for their safety in consumption [47].

2.5. Applications of Nanotechnology in Pests and Plant Diseases Management

Nowadays, the fastest and economical way to control pests and diseases are the use of chemicals such as pesticides, fungicides and herbicides. In addition, biological control methods are currently very costly. The abandoned use of pesticides has triggered several harms, such as antagonistic effects on human health, adverse effects on pollinating insects and livestock, and the entry of the substance into soil and water and its direct and indirect effects on the ecosystem. The smart use of nano-scale chemicals may be a suitable solution to this problem. Pests and diseases use these materials for plant parts that are attacked.

Similarly, these nano-scale carriers have a self-regulating function, which means that the required amount of drugs can only be delivered to plant tissues. Nanotechnology contributes to agricultural science and reduces environmental pollution through the production of pesticides and chemical fertilizers by using nanoparticles and nanocapsules that have the ability to control or delay delivery. Nanoparticles used to deliver active ingredients or drug molecules will control all pathological diseases of plants in the near future. There are a variety of nanomaterials, including polymer nanoparticles, iron oxide nanoparticles and gold nanoparticles, which can be easily synthesized and used as carriers for pesticides or drugs. The pharmacokinetic parameters of these nanoparticles may change according to size, shape and surface functionalization. They can also be used to change the kinetic characteristics of drug release, resulting in sustained drug release, reducing the need for frequent drug delivery [48]. Disease is one of the most important factors restraining crop production. In case of disease management, the issue is the discovery of the particular phase of prevention. In most cases, pesticides are used as preventive measures, leading to remaining toxicity and environmental risks. On the other hand, the use of pesticides after the occurrence of diseases will cause certain crop losses. Of the various diseases, viral infections are the most difficult to control, because the spread of the disease must be prevented by the carrier. Therefore, detecting the exact stage, such as the stage of viral DNA replication or the production of initial viral protein, is the key to successful disease control, especially viral diseases. Nano-based virus diagnosis, including the development of multiple diagnostic kits, has gained momentum in order to detect the exact virus strain and the application stage of certain treatments for the disease. The recognition and use of biomarkers that exactly specify the stage of the disease is also a new field of research. Determining the production of differential proteins in vigorous and unhealthy situations can lead to determining the development of several proteins in the infection cycle. These nano-based diagnostic kits can not only increase detection speed, but also increase detection capabilities [49]. Forthcoming, nano-scale equipment with new properties can be used to "smart" agricultural systems [50].

3. CONCLUSION

It is beneficial to synthesize nanoparticles from plant and microbial sources, because it is an economical, energy-saving, low-cost product. It can protect human health and the environment, thereby reducing waste and safe products. Plant-synthesized nanoparticles have important aspects of nanotechnology through unparalleled applications, and the use of plant-synthesized nanoparticles may be superior to other biological entities, which can overcome the time-consuming process of using microorganisms and maintaining their culture, which may lose its potential in the process of nanoparticle biosynthesis. Therefore, this review demonstrates the importance of plant- and microorganism-mediated nanoparticle synthesis by providing various recently reported literatures.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest regarding the publication of this paper.

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