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Review Article

# A Multidisciplinary Role of Nano Particles Focusing Across the Industrial Scale

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## Abstract

Several NPs are being protect plants from various environmental stresses and encourage plant growth. Plant extract-mediated AuNP synthesis has drawn a lot of interest in this field since it can produce AuNPs effective results. AuNPs have better biocompatibility without harboring hazardous chemicals. The physical properties of nanoparticles, such as size, chemical makeup, surface charge, and surface modification, influence the absorption and transportation processes. Applying nanoparticles can assist plants in reducing abiotic stressors. Silver, gold, and other metallic nanoparticles have been produced using a variety of bacterial species. Some strains *Staphylococcus aureus*, *Acinetobacter calcoaceticus* were used to create AgNPs with antibacterial qualities. The exogenous NP administration allows plants to maintain their photosynthetic efficiency under DS while also stabilizing the ultra-structure of the mitochondria and chloroplasts. The application of SiO2 NPs to the leaves enhanced the elasticity and expansion of the cucumber's cell wall during the growth period and increased the accumulation of nitrogen and phosphorus elements in the leaves, thereby reducing the salt stress on cucumber plants. Silver nanoparticles are formed by natural biomolecules present in plants, including proteins, enzymes, amino acids, polysaccharides, alkaloids, alcoholic chemicals, and vitamins. Additionally, nanoparticles have different effects on seed germination and plant growth as they move throughout the plant body.

**Keywords**: AuNP, amino acids, polysaccharides, alkaloids, alcoholic chemicals, and vitamins.



## INTRODUCTION

Materials that fall within the nanometric range and have at least one dimension less than a few hundred nanometers are called nanoparticles. Their physical characteristics differ significantly from those of bulk materials as a result of this size reduction. The majority of these alterations result from the emergence of quantum effects as size lowers, which cause phenomena like surface plasmon resonance, coulomb blockade, and superparamagnetic. The size decrease results in an increase in the surface area to volume ratio. It produces many surface atoms and surface effects with a high specific area which are significant [1, 2]. The reduction in seedling stem length may be due to the down-regulation of subtilisin family protein expression in soybean leaves caused by exposure to Ag NPs. In response to oxidative stress, NiO NPs may raise the transcription level of genes linked to the production of proline, anthocyanins, and antioxidant enzymes in cabbage seedlings. Rice plant increased exposure to plastic nanoparticles (NPs) dramatically changes the production of phytohormones in anti-stress metabolic pathways, indicating that it plays a critical physiological function in plant stress response. According to a transcriptome analysis that demonstrated the phytotoxicity, wheat exposed to plastic nanoparticles had considerable changes in the processes of carbon metabolism, amino acid production, and plant hormone signal transduction [3, 4].

The release of dangerous compounds into exposed media, such metal ions into plants, are causes NPs to be phytotoxic. Despite the lack of knowledge on the mechanism underlying the phytotoxicity produced by NPs, researchers have been increasingly interested in the impacts of NPs on terrestrial plants [4, 5]. Instead, than studying plants over their whole life cycle, most studies focus on their early stages of growth. Therefore, it is essential to conduct long-term exposure studies of NPs, investigate their effects on the environment and human health, and carefully analysed their phytotoxicity mechanism. Many new NP solutions, such as nanopesticides and nanofertilizers, aim to reduce nutritional losses and significantly increase food output. Nanofertilizers and nanoencapsulated nutrients release nutrients on demand, while chemical fertilizers that boost the target plant's activity are also controlled in their release. Several NPs are being tested to protect plants from various environmental stresses and encourage plant growth. This area of research offers new approaches to regulate the expression of the target gene, the plant cell, and its organelles in plant biotechnology. Furthermore, NPs are employed in several biosensors and agents for different purposes [6, 7].

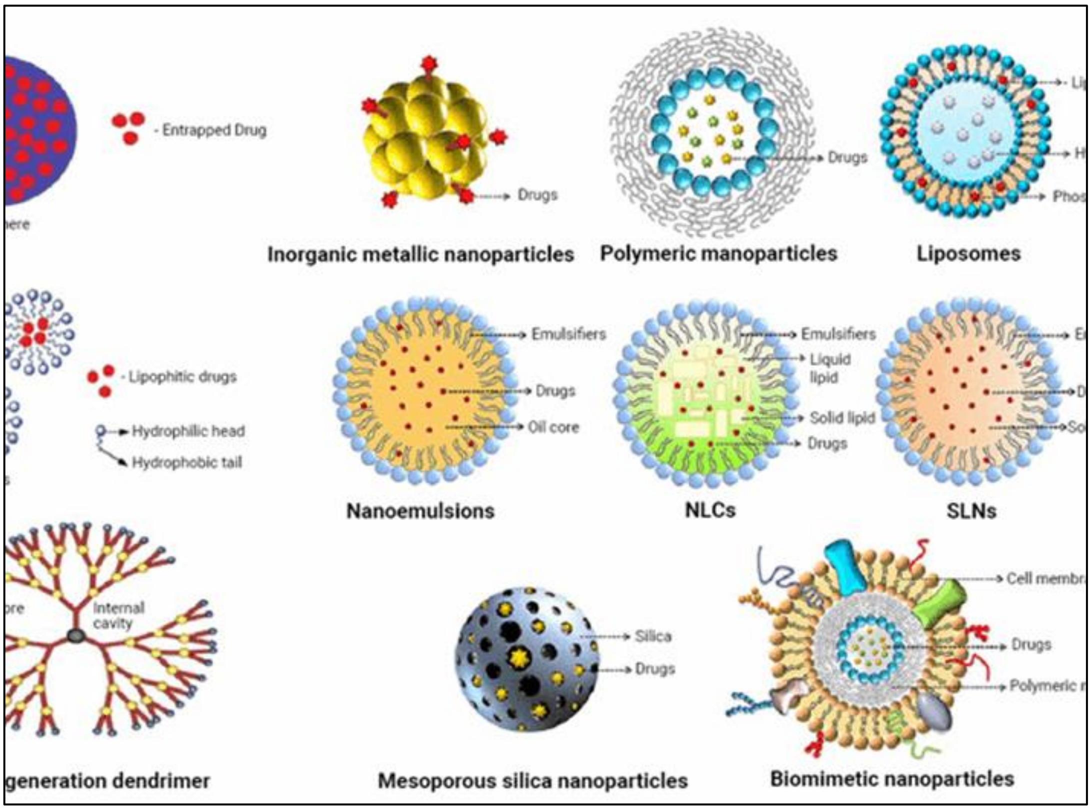


**Fig-1: Shows the numerous types of nanomaterials possessing the structural features**

**Synthetic innovations**

Prior to self-assembling into nuclei, metal ions undergo reduction to metal atoms. Following that, the metal nuclei continue to expand to form MNPs, a process that incorporates the processes of coprecipitation, sol-gel, and atomic condensation and is a component of one of the most widely used bottom-up synthesis procedure [7, 8]. Hazardous chemicals that adsorb on the surface of AuNPs are often used in the current chemical synthesis of AuNPs, which limits their application in the biological and medical fields. Therefore, there is an urgent need for novel, efficient, and environmentally friendly synthetic methods to replace the manufacture of dangerous chemicals. Plant extract-mediated AuNP synthesis has drawn a lot of interest in this field since it can produce AuNPs effective results. AuNPs have better biocompatibility without harboring hazardous chemicals [5, 8]. Silver, gold, and other metallic nanoparticles have been produced using a variety of bacterial species. Some strains *Staphylococcus aureus*, *Acinetobacter calcoaceticus* were used to create AgNPs with antibacterial qualities. To biosynthesize the AgNPs, the researchers utilized the rod-shaped Bacillus bacteria, namely species like *B. subtilis*, *B. amyloliqefaciens*, *B. megaterium*, and *B. flexus*. Additionally, mesophilic and psychrophilic microorganisms were used to produce antibacterial AgNPs. Cuboidal, hexagonal, triangular, spherical, and discoidal are among the several shapes of the generated AgNPs. The *Bacillus subtilis* in a microwave environment with water present to create AgNPs. The generated AgNPs in around five minutes using *Escherichia coli*, and *Enterobacter cloacae* [9, 10].

The SiO2 enhances the nutritional supply to the plant seeds and adds a desirable pH and conductivity to the growth medium is responsible for the higher rate of seed germination that was seen in maize as a result of its application. SiO2 nanoparticles have been demonstrated to improve seedling growth and *Larix olgensis* quality. The root collar diameter, mean height, main root length, chlorophyll content, and number of lateral roots all showed notable improvements. It has been demonstrated that SiO2 nanoparticles perform well in the presence of abiotic stimuli such as salt [11, 12].

**Innovations in agriculture**

Lack of water lowers PS-II efficiency, electron flow rate, and chlorophyll synthesis, all of which negatively impact plants' total photosynthetic efficiency. Application of NPs (ZnO) improved photosynthetic efficiency under DS, increasing chlorophyll synthesis, fluorescence, and activity of enzymes involved in chlorophyll synthesis. The exogenous NP administration allows plants to maintain their photosynthetic efficiency under DS while also stabilizing the ultra-structure of the mitochondria and chloroplasts. Additionally, NPs (TiO2) promote light absorption in the cell chloroplast by increasing the expression of the LHCII-b gene in the thylakoid membrane [13, 14].

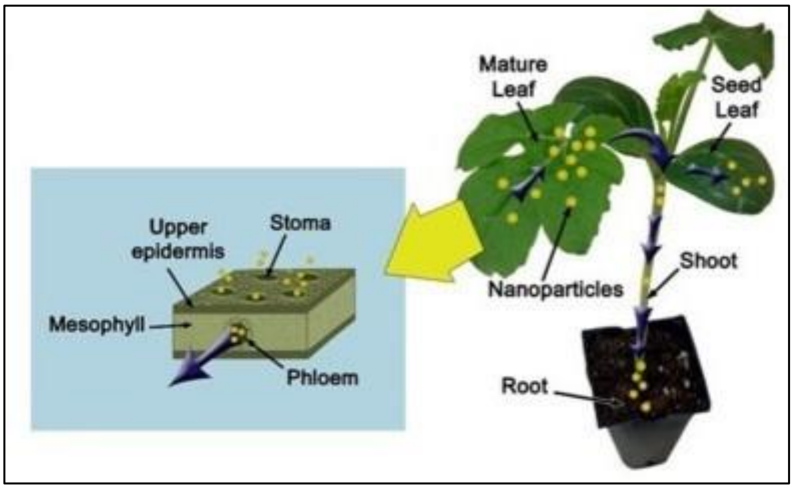


**Fig-2: Shows the delivery of nanomaterials to the plant parts**

The primary issue that plants encounter during growth is abiotic stress, which is caused by dryness, salt, and heavy metals. This results in plant growth retardation, which lowers crop output. Plants have developed several defensive mechanisms through physiological processes to mitigate these pressures. Applying nanoparticles can assist plants in reducing abiotic stressors. In comparison to a typical environment, the yield and biomass of crops in dry regions are greatly decreased due to environmental, climatic, and other reasons. By treating maize with zinc oxide nanoparticles, the nanoparticles have a moderating impact on plant drought stress by increasing the photosynthetic rate and chlorophyll content of plants under drought stress. Inappropriate salinity in plant growth circumstances leads to slow plant development and an imbalance in plant nutrition. Nanoparticles can be used in agriculture to increase the activity of enzymes involved in the mechanism by which plants tolerate salt. The study found that ZnO NPs improved the ability of cotton and wheat to withstand salt stress. The application of SiO2 NPs to the leaves enhanced the elasticity and expansion of the cucumber's cell wall during the growth period and increased the accumulation of nitrogen and phosphorus elements in the leaves, thereby reducing the salt stress on cucumber plants. This was achieved by reducing the loss of leaching process, which lowers the content of Na [15, 16].

The promising results of elevated lipid peroxidation levels and reduced chlorophyll content as indicators of oxidative stress. Lipid peroxidation increased twofold when ZnO NPs were present, whereas the incidence of copper oxide NPs in wheat increased almost fourfold when compared to the same control groups. It has been demonstrated that asparagus lettuce is adversely affected by cerium oxide nanoparticles, which cause lipid peroxidation, cell membrane degradation, membrane breakdown, and suppression of root elongation. When *A. thaliana* plants were exposed to Fe NPs, their chlorophyll content dropped [17]. These application methods are the most effective in terms of delivery, despite the feeding or injection of NPs. This suggests that have practical potential e.g., for pesticide administration. On the other hand, most of the NPs that are administered by foliar spraying or soil soaking are not absorbed by the plants. NPs that do enter the plant, however, show effective movement from leaf to root and the other way around. When it comes to NP delivery and transport, foliar application seems to be more efficient than soil drenching among these two treatment techniques. To investigate the interactions of NPs with the surfaces in order to better understand the data presented in the literature and to investigate the transport pathways of NPs throughout the plant [18].

Because of their special qualities, nanoparticles are being employed more and more in various industrial sectors; yet, their introduction into ecosystems raises concerns about food security and human health. Specifically, the buildup of nanoparticles in soils can disrupt the plant and soil relationship, thus posing a threat to agricultural output and current developments about nanoparticles in the soil-plant relationship [18,19]. It reflects the concentrate nanoparticle sources, emission, transformation, bioavailability, interactions, phytotoxicity, and plant uptake. It highlights nanoparticles modify plants' genomes, metabolomes, and proteomes. The advantages of nanoparticles for plant development are examined in addition to their drawbacks. In addition, a standard tube furnace requires several kilowatts of power and several minutes of pre-heating time to reach a consistent operating temperature. Because of their superior stability and minimal chemical reactivity when compared to other metals, silver nanoparticles are among the most researched nanomaterials. Toxic chemical reducing agents that convert metal ions into uncharged nanoparticles are frequently used in their synthesis. To avoid using hazardous ingredients, however, a number of attempts have been made in the past several decades to create green synthesis techniques. Silver nanoparticles are formed by natural biomolecules present in plants, including proteins/enzymes, amino acids, polysaccharides, alkaloids, alcoholic chemicals, and vitamins. An environmentally beneficial method for producing silver nanoparticles is green synthesis, which need to be investigated further in light of the possibility of producing nanoparticles from various plants, the environmentally friendly production of nanoparticles utilizing bacteria, plants [20].

There is a lot of interest in the use of bio-based nanoparticles in agriculture because of their potential to enhance plant growth, differentiation, and development to provide a comprehensive overview of the effects of bio-based nanoparticles on plant physiology [21]. The various types of bio-based nanoparticles, including cellulose, chitosan, and lignin nanoparticles, as well as their effects on plant growth and development. The investigated the molecular and cellular effects of these nanoparticles on plants. Furthermore highlighted are the potential applications of bio-based nanoparticles in agriculture, such as enhancing nutrient absorption, promoting sustainable crop production, and increasing stress tolerance. Overall, it provides useful details on the potential benefits of using bio-based nanoparticles to encourage plant development. A potential technique in agriculture, bio-based nanoparticles (NPs) offer a sustainable and environmentally friendly way to improve plant growth, differentiation, and development. Bio-based NPs are useful in plant biotechnology because of their special qualities, which include targeted distribution, biodegradability, and biocompatibility. In order to control differentiation processes and enhance root growth, shoot proliferation, and flower and fruit output, they can affect gene expression, hormone signalling, and signal transduction pathways. Furthermore, bio-based NPs improve the absorption and transport of nutrients, providing vital components for plant development. Additionally, by lessening the detrimental effects on differentiation and other physiological processes, they increase plant resistance to abiotic stressors such drought, salt, and nutritional deficiencies [22]. Bio-based NPs have benefits over synthetic ones, including less toxicity, less environmental buildup, and improved. SeNPs derived from plants enter cells by endocytosis mediated by receptors. The cancer cells have a particular redox imbalance and acidic pH condition. Because of their biocompatibility, environmental friendliness, and in vivo activities, phyto-synthesis of SeNPs produces nanomaterials of different sizes, shapes, and biochemical properties. It also offers benefits over other standard physical and chemical processes. To investigate the therapeutic potential of SeNPs against different cancer cells, microbial pathogens, viral infections, hepatoprotective activities, diabetic management, and antioxidant methods, a few research were conducted. Furthermore, in order to deliver medications to the intended places, several selenium-based drug delivery systems are created by designing SeNPs with functional ligands. SeNPs induce more free radicals to develop, which damages the mitochondrial membrane and allows mitochondrial proteins to leak out while also causing endoplasmic reticulum stress. When the mitochondrial membrane is disrupted, different proteins seep out and caspases are activated, which causes apoptosis. Numerous biochemical pathways, such as the NF-κB, Wnt/β-catenin, MAPK/Erk, PI3K/Akt/mTOR, and apoptotic pathways, are activated by this cellular stress state. Through the oxidative and inflammatory stress signalling systems, the NF-κB disturbs cellular homeostasis. Conversely, carcinogenic signalling depends on the MAPK/Erk, VEGF, PI3K/Akt/mTOR, and Wnt/β-catenin pathways [21, 22].

Furthermore, removing harmful toxins from agriculture and water requires the identification of pathogens in the soil and water. As a result, detectors based on nanotechnology may be able to identify a portion of the infection. For increased sensitivity, nano biosensors integrate cutting-edge technologies including molecular biology, microfluidics, and nanomaterials. A certain concentration of analytics with increased sensitivity may be specifically detected by nanoparticles in a nano biosensor. Furthermore, pesticide detection is accomplished by the use of enzyme-based nanobiosensors, which are created by utilizing metal nanoparticles and altering their surface with proteins and nucleotides to enhance the biosensors' useful biorecognition and other characteristics [23]. Because any excess might obstruct the flow of vital nutrients, not all Ag-NP concentrations are beneficial for a particular plant. Ag-NPs applied in a controlled manner to plants may improve their general growth and development. Ag-NPs have been found to reduce the bulk of vegetables and edible plants (Cucurbita pepo, Allium cepa, cabbage, and lettuce), however they frequently also cause seeds to germinate. NPs affect the overall biomass, root, and shoot development of plants by their interactions with proteins, enzymes, and carbohydrates. Ag-NPs also activate onions' antioxidants and function as an ethylene inhibitor. Onion leaves and bulbs accumulate a significant amount of them. The two main variables influencing the development and biomass of plants are size and concentration [24].

When soybeans are exposed to super paramagnetic iron-oxide nanoparticles through the soil, growth and chlorophyll content are also seen to rise [25]. Applying Fe2O3 particles, to watermelon plants through soil has also been shown to enhance germination, seedling growth, and the activity of antioxidant enzymes (catalase, superoxidedismutase, and peroxidase). An increased photosynthetic activity is attained by introducing nano copper through soil to mungbean, which modifies fluorescence emission and photophosphorylation, which increases nitrogen assimilation and root and shoot lengt. When nano Fe2O3 is exposed to peanuts, the protein concentration increases. Applying NanoFe results in a higher yield with concentrations of seed protein and chlorophyll [26]. Reactive nanomaterials are applied in nano-remediation techniques to convert and detoxify contaminants. When nanoparticles enter a cell, they disrupt the mitochondrial and chloroplast electron transport system (ETS) cycle, which causes an oxidative burst because the quantity of reactive oxygen species rises. Thus, oxidative stress may be induced in a variety of plant species using metal-based nanoparticles. In plants, sulphur metabolism is crucial for stress tolerance, particularly in metal detoxification. Excessive use of pesticides damages subsequent crops and leaves residue in the soil. This herbicide-resistant weed species evolve as a result of ongoing use of a single herbicide. Due to its strong persistence and mobility in certain soil types, atrazine herbicide is used worldwide to suppress pre- and postemergence broadleaf and grassland weeds [26, 27].

In the face of changing environmental difficulties, the application of nanotechnology in agriculture offers a sustainable strategy and a foundation for resilient and resource-efficient agricultural production. In terms of encouraging plant growth and resistance, nano-enabled technologies from the genetic engineering to the nanofertilizers [28]. Nanoparticles' (NPs') outstanding qualities set them apart from traditional fertilizers, including as their high surface-area-to-volume ratio and effective nutrient delivery. Research shows that NPs, such iron oxide (Fe3O4) NPs and nano-silicon (Si), can improve crop development in a variety of stressful situations, including drought stress and soil polluted by heavy metals. Interestingly, *Tephrosia apollinea* under drought stress has enhanced antimicrobial activity when exposed to green-synthesised silver nanoparticl, reducing membrane damage and increasing the amount of hydrogen peroxide (H2O2) in plant roots. Given climate change and population growth, nanobiotechnology holds great promise for future agricultural technology revolutions, but it also comes with a number of hazards and obstacles. Since the behavior of nanoparticles differs greatly from that of their bulk counterparts, further investigation into their characteristics is necessary. Because of important yet unidentified hazardous traits associated with their distinct physiochemical characteristics, several materials are suspected of being poisonous at the nanoscale. Manufacturers, formulators, handlers, applicators, and consumers may be at increased risk as a result. Because they can have hazardous effects on non-target creatures upon touch that is, when nanoparticles come into direct contact with people, they can have deleterious effects on them nanoparticles can thus have a variety of impacts. Dermal absorption of nanoparticles is one of the harmful consequences of nanoparticles on non-target species [29, 30].

## CONCLUSION

The growth, development, and metabolism of plants are sometimes disrupted by unfavourable environmental circumstances. Both biotic (insects, viruses, or microbes) and abiotic (drought, temperature, pH, salt, and environmental changes) stressors seriously impair plant physiology. Without a question, nanotechnology is essential to many aspects of the food industry. It is nearly hard to understand the practical application without understanding its impact on environmental toxicity. Additionally, the lack of rules, standards, and similar organizations hinders the commercialization of novel NP-based agrochemicals. Thus, it is essential to carry out comprehensive research in order to develop and produce futuristic. Additionally, these nanoparticles may be employed for the exact delivery of agricultural chemicals, which offer a novel technique to increase crop protection and minimize environmental damage, by targeting and regulating the dispersion of pesticides and nutrients. Second, nano-biosensors in precision farming integrate biology and nanotechnology to detect issues and measure environmental variables in real time the two crucial components of ecologically responsible farming methods. Thirdly, the continuous green production of nanomaterials by microorganisms like bacteria and fungi enables the ecologically favourable synthesis of nanoparticles, such as silver nanoparticles created by endophytic fungus. Fourth, nanodevices in plant genetic engineering employ nanotechnology to transfer DNA and change genes through breeding and genetic modification, increasing traits like insect resistance in plants.

Although NPs' role in osmolyte and hormone accumulation has been well studied, more investigation is needed to look NPs affect osmolyte and hormone accumulation in plants. The effects of NPs on proline, ethylene, gibberellic acid, cytokinin, salicylic acid, and glycine-betaine should be examined at the transcriptome level. Additionally, it's critical to look at how NPs impact the enzymes and gene expression that produce these osmolytes. It would also be interesting to ascertain how NPs contribute to the crosstalk of different hormones and osmolytes. Additionally, the identification and characterization of NP-mediated can be accelerated. The physical properties of nanoparticles, such as size, chemical makeup, surface charge, and surface modification, influence the absorption and transportation processes. Additionally, nanoparticles have different effects on seed germination and plant growth as they move throughout the plant body. It has been shown that while certain nanoparticles promote plant growth at low concentrations, they can cause damage to plants at large concentrations. The detrimental impacts of nanoparticles can result in genotoxicity, which includes chromosomal abnormalities and the development of micronuclei, which changes the expression of plant genes, in addition to changing the levels of plant hormones. Although the effects of nanoparticles on plants have been widely confirmed, the mechanism by which they produce plant toxicity remains poorly understood.

A rapidly expanding field of study, nanotheranostics has great promise for enhancing the detection and treatment of illness. Green nanoparticle synthesis is a new and developing area that offers benefits over chemical and physical nanoparticle synthesis techniques, including lower operating costs and capital requirements, less pollution, and enhanced biocompatibility and stability. Gene delivery, medication delivery, biosensors, and bioimaging are just a few of the biomedical applications in this field that are expanding daily. The knowledge on the chemical components involved in the synthesis and stabilization of MNPs continues to be a significant issue, and the pertinent synthetic pathways need to be better clarified. Furthermore, more research is required to determine the actual molecular active groups in the molecules and the way in which the extracts' active molecules bind to the MNP surface. The buildup of MNPs in the environment due to the exponential rise of MNP applications; thus, attention must be paid to the MNPs' in vivo toxicity as well as their long-term impacts on people, animals, and the environment.

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