

## Bio-Nanotechnology and its Role in Agriculture and Food Industry

Thakur S<sup>1</sup>, Thakur S<sup>2</sup> and Kumar R<sup>1\*</sup>

<sup>1</sup>Department of Biotechnology, Akal College of Agriculture, Eternal University, Himachal Pradesh, India

<sup>2</sup>Department of Physics, University of Aveiro, 3810-193 Aveiro, Portugal

### Abstract

Bulk material is divided into small size particles with one or more dimensions in the nanometer range or even smaller, the individual particles exhibit unexpected properties which are different from those of the bulk material. Due to distinct properties of nanomaterials like improved plant disease resistance, detect the mycotoxins in food, efficient nutrient utilization and enhanced plant growth. Bio-Nanotechnology combines biological principles with physical and chemical approaches to produce nano-size particles with specific functions. It also represents an economic substitute for chemical and physical methods of nanoparticles formation. Metal nanoparticles exhibit good anti-pathogenic, anti-bacterial, and anti-fungal activities due to electrostatic interaction of nanoparticles with bacterial cell membrane and their accumulation in cytoplasm. Nano-fertilizers may contain zinc, silica, iron and titanium dioxide, gold nano-rods, core shell QDs, etc. The carbon nanotubes and nanoparticles of silver, zinc oxide, etc can be really helpful in remediating the plant growth by ensuring that the nutrients are utilized optimally by the plants. Nanoscale biomaterials can take part in pathogen detection as well as helps in nanoscale purification systems for improved food quality. Some important aspects covered such as nano-additives, intelligent packaging, control and nutraceuticals delivery, nano-coding of plastics and paper materials and nano-encapsulation and target delivery. Nanoparticles have been effectively entrenched in the packaging materials for making food storage, thus minimizing pathogenic growth on stored foodstuffs. The bio-nanotechnology is a forward-looking process and acts as an agricultural biosecurity.

**Keywords:** Nano-particles; Nano-pesticides; Nano-fertilizers; Metal nanoparticles

### Introduction

In last few decades nanotechnology has delivered extensive research with emergence in Engineering, Biotechnology, Food-technology, Medical sciences and Agriculture. It also forming impact on all forms of life with significant advances owing to wide range of applications in the field of electronics, optical fibers, sensors, semi-conductors, automobiles, nano-fabrics, bio-medical, catalysts, agriculture, cosmetics, packaging, bio-engineering, medicines, drug delivery, and other areas [1-4]. The arena of nanotechnology is modestly too vast and too rapidly changing to cover exhaustively. In 1959 the concept of nanotechnology was first begun; when Richard Feynman conveyed a visionary and prophetic speech at a meeting of the American Physical Society, where he speculated on the possibility and potential of Nano sized materials [5]. When a bulk material is divided into small size particles with one or more dimensions in the nanometer range or even smaller, the individual particles exhibit unexpected properties which are different from those of the bulk material. It is known that atoms and molecules possess totally different behaviors than those of bulk materials. The fundamentals of nanotechnology lie in the fact that properties of substances dramatically change when their size is reduced to the nanometer range [6,7].

The classic laws of science are different at the nanoscale. Nanoparticles possess large surface areas and essentially no inner mass, i.e., their surface-to-mass ratio is extremely high. Nanoscience is based on the knowledge that particles in the nanometer range, and nanostructures or Nano machines that are developed from these nanoparticles possess special properties and exhibit unique behavior. These special properties, in conjunction with their unique behavior, can significantly impact physical, chemical, electrical, biological, mechanical, and functional properties [8]. The uses of nanomaterials specifically for the agricultural purposes are required for improving the fertilization process, increase in yields through nutrient optimization and minimized the requirements of plant protection products [9].

Many potential benefits such as enrichment of food quality and safety, reduction of agricultural efforts, augmentation of absorbing nanoscale nutrients from the soil, etc. allow the application of nanotechnology to be resonant impediment. The ambition of nanomaterials in agriculture is to diminish the amount of hazard chemicals, minimize nutrient losses in fertilization and increased yield through pest and nutrient management [10]. Chemically synthesize nanomaterials considered as toxic in the nature due to involvement and production of hazard chemicals, to replace this, nanomaterials may synthesized from plant materials and it considered as green nanotechnology or bio nanotechnology [11-13]. The proficiency of plant extracts to reduce metal ions in to nano size due to association of different biomolecules and reducing agents present in plants. It has attracted considerable attention due to cost free, rapid, safe process, energy efficient, reduces waste, natural and safe way of nanomaterial synthesis [14-17]. In few decades in agriculture, viable production and efficacy are unconceivable without the use of pesticides, fertilizers, etc. Which has some prospective issues including contamination of hazard chemicals in water or residues in food chain that threat the human being and environmental wellbeing; thus, the alternative ecofriendly and controlled inputs could allow to reduce these risks [18,19]. The development of smart Nano-tools with high-tech agricultural system make a revolution in agricultural practices; and helpful in enhancing the quality and quantity of crops yield [20,21].

**\*Corresponding author:** Dr. Rahul Kumar, Department of Biotechnology, Akal college of Agriculture, Eternal University, Sirmour, Himachal Pradesh – 173101, India, Tel: +918894130717, Fax: +91-1799-276006; E-mail: [rkdsun@gmail.com](mailto:rkdsun@gmail.com)

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Due to distinct properties of nanomaterials like improved plant disease resistance, detect the mycotoxins in food, efficient nutrient utilization and enhanced plant growth; nanotechnology plays an essential role in agricultural [22,23]. About 40% of all contributions deal with carbon-based nanomaterials, followed by titanium dioxide, silver, silica, and alumina. Nanomaterials come in many diverse forms, from solid doped particles to polymer and oil–water-based structures. Bio-nanomaterials serve equally as additives and active constituents [24]. Green synthesis of Bio-nanoparticles can be done by using five methods [25]. They are a) Polysaccharide method, b) Tollens method, c) Irradiation method, d) biological methods, and e) Polyoxometalates method (Figure 1).

## Materials and Methods

### Polysaccharide method

In Polysaccharide method, nanoparticles (NPs) are synthesized by water and polysaccharides as a capping agent. For instance, synthesis of starch- NPs was carried out with starch as a capping agent and  $\beta$ -D-glucose as a reducing agent in a gently heated system. Such nanoparticles can be easily integrated into systems for biological and pharmaceutical applications.

### Tollens's method

The Tollens synthesis method gives NPs with a controlled size in a one-step process. In the modified Tollens procedure, metal ions are reduced by saccharides in the presence of ammonia, yielding NP films with particle sizes from 50–200 nm, metal hydrosols with particles in the order of 20–50 nm, and metal NPs of different shapes.

### Irradiation method

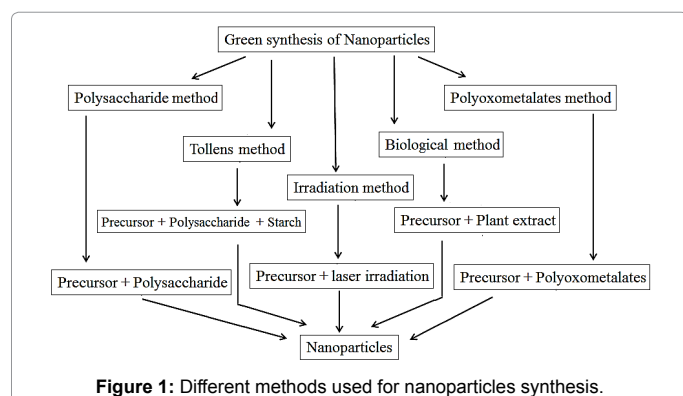
Metal NPs can be successfully synthesized by using a variety of irradiation methods. For example, laser irradiation of an aqueous solution of metal salt and surfactant can fabricate metal NPs with a well-defined shape and size distribution. No reducing agent is required in this method.

### Biological method

Extracts from bio organisms may act both as reducing and capping agents in Ag NPs synthesis. The reduction of metal ions by combinations of biomolecules found in these extracts such as enzymes/proteins, amino acids, polysaccharides, and vitamins is environmentally benign, yet chemically complex. An extensive volume of literature reports successful metal NPs using bio-organic compounds.

### Polyoxometalates method

Polyoxometalates have the potential of synthesizing metal NPs



S. No.	Carrier system	Uses	Reference
1.	Organic-inorganic nanohybrid	Control release	[40]
2.	Polyhydroxybutyrate-co-hydroxyvalerate	Increased biodegradability and decreased genotoxicity	[41]
3.	Alginate/chitosan	Reduced ecological toxicity	[42]
4.	Wheat gluten	Reduce diffusivity	[43]
5.	Surfactants/water	Increase bio-efficacy and decreased ecological toxicity	[44]
6.	Rhodamine B-covered gold nanoparticle	Sensing pesticides in complex samples	[45]
7.	Chitosan/tripolyphosphate, Chitosan-saponin, Chitosan-Cu	<i>In vitro</i> antifungal activity	[46]
8.	Chitosan/tripolyphosphate	Lower cyto & genotoxicity	[47]
9.	Polyacetic acid-polyethylene glycol-polyacetic acid	Decrease the lethal concentration	[48]
10.	Sodium alginate nanoparticles	Cytotoxicity, leafhoppers	[49]
11.	Silica nanoparticles	Central nervous system	[50]
12.	Chitosan	Cytotoxicity assays	[51]
13.	Gold nanoparticles	Pest control	[52]
14.	Red-light-emitting water-soluble semiconducting quantum dots	Detect precoated quartz contamination in dairy product	[53]

**Table 1:** A list of studies on nano-pesticides and its applications.

because they are soluble in water and have the capability of undergoing stepwise, multi electron redox reactions without disturbing their structure.

Bio-Nanotechnology combines biological principles with physical and chemical approaches to produce nano-size particles with specific functions. It also represents an economic substitute for chemical and physical methods of nanoparticles formation [26,27].

## Bio-Nanotechnology and Agricultural Development

Bio-nanotechnology takes a prominent part in agriculture through control of nutrients [8] as well as it can also participate in improved plant disease resistance, detect the mycotoxins in food, monitoring of water quality and pesticides for sustainable development of crops [11]. In the agriculture and food technology relevant applications of controlled delivery systems, nanotubes, fullerenes and biosensors, etc. were observed (Table 1) [28,29].

### Nano-pesticides

Presently, apart from the current synthetic pesticides in the market, bio-pesticides occupies an unique position in controlling target diseases of pests and insect origin. An innovative technology in the field of bio-pesticides is the employment of engineered nanomaterials or bio-nanotechnology. It is well known that insects and pests are the predominant destroyer in the agricultural and also in its products. Nano-pesticides may have key role in the control of pests and insect and host pathogens due to its properties like enhanced solubility, specificity, permeability and stability [30,31]. Thus, synthesis of non-toxic, ecofriendly and promising nano-pesticide delivery systems for increasing agriculture production is mandatory; On the other hand, helps in reducing the destructive environmental impacts to ecosystem [23,32-34]. Metal nanoparticles exhibit good anti-pathogenic, anti-bacterial, and anti-fungal activities due to electrostatic interaction of nanoparticles with bacterial cell membrane and their accumulation in cytoplasm [35-38]. Microorganism shows important role in maintaining soil health, ecosystem, and crop productivity in agriculture. Therefore, it is very indispensable to know the ecotoxicological aspects of the considered nanoparticles in agricultural field. If nanomaterials

containing agricultural plants are devoid of any toxic nanocomposite, then the inimitable prospect of more production of agricultural crops are their [10,21,39].

### Nano-fertilizers

In past few years nano-fertilizers are spontaneously accessible in the market, but particularly the agricultural fertilizers are still not synthesized. Nano-fertilizers may contain zinc, silica, iron and titanium dioxide, gold nano-rods, core shell QDs, etc. [40-53]. Studies on the uptake and toxicity of several metal oxide nanoparticles were carried out regularly in the currently to improve crops production). The carbon nanotubes and nanoparticles of silver, zinc oxide, etc. can be really helpful in remediating the plant growth by ensuring that the nutrients are utilized optimally by the plants [54,55]. However, its success depends on a lot of factors like the susceptibility of plants species and other parameters including the concentration, composition, size and chemical properties of nanomaterials. As well as, nanoparticles uptake and intracellular fate are confirmed by ion beam microscopy, Raman chemical imaging spectroscopy, transmission electron microscopy, and confocal laser scanning microscopy. Size, degree of aggregation and zeta potential of the metal oxide NPs are studied in the presence of proteins and cell media [11,56,57]. In the present century, the smart agriculture is a way to attain significance of long term improvement in the expression of environment and serves as a link to others ecosystem [58,59]. Thus, application of nanoscale particles results abundant benefits over customary procedures.

### Nano-technologies in food industry

Bio-nanotechnology has the capability to resource bioactive constituents in eatables while improvement in foodstuffs at the nanoscale due to anti-pathogenic ability and enhanced properties of nanoparticles [60,61]. Nanoscale biomaterials can take part in pathogen detection, as well as helps in nanoscale purification systems for improved food quality. Some important aspects covered such as nano-additives [62], intelligent packaging, control and nutraceuticals delivery [63,64], nano-coding of plastics and paper materials [65] and nano-encapsulation and target delivery [66]. Currently, some nutrients primarily vitamins are encapsulated and targeted into the bloodstream. Some foods and drinks were exhilarated with nanoparticles without affecting the taste or appearance. Nanoparticles emulsions are being used in ice cream and spreads of this nano-emulsion can improve the texture and uniformity of the ice cream [67,68]. Development of smart food packaging materials that can give information regarding packed foodstuffs is still challenge for researchers. In recent times, some packaging materials integrated with “nano-sensors” to detect the oxidation process in food. In such packaging materials when the oxidation occurs in the foodstuffs, nano-sensors indicate the color change and inform about the contamination of the foodstuffs like milk and meat [69,70]. In precise, nanoparticles have broad-spectrum anti-pathogenic properties against different pathogens causative agents of food borne illness. The antimicrobial mechanism of action of NPs is typically considered as of few prototypes such as oxidative stress and cell damage, metal ion release, or non-oxidative mechanisms [71-73]. This property of metal nanoparticles is very helpful in increasing the shelf-life of foodstuffs. Nanoparticles have been effectively entrenched in the packaging materials for making food storage, thus minimizing pathogenic growth on stored foodstuffs. Therefore, the nanotechnology is a forward-looking process and acts as an agricultural biosecurity.

### Future Perspectives of Bio-Nanotechnology

The new and forthcoming technology is bio-nanotechnology that

possesses very exclusive properties in agriculture via improved crops production and yield using nano-fertilizers, nano-pesticides, etc. As well as precision agriculture skills and techniques, intelligent nourishing stuffs and enhancement of food texture and quality, packaging and labeling, etc. in agriculture field. Some focused areas may need more attention in near future researches in agriculture.

1. New eco-friendly and safety delivery systems for carrying special foodstuffs, plant nutrients etc. These systems also can have pharmaceutical application potentials.

2. The sensors-based bio-nanotechnology have effective role in insect and pest control; as well as food industry.

3. The enhanced properties of nanomaterials such as size, structures, surface chemistry, dose delivery, exposure time to environment, immune response, accumulation in eco-system, retention time, etc., should be accessed carefully.

### Conclusion

Bio-nanotechnology is an emergent field having enormous prospective to certainly impact on the agriculture and food industry. Thus, it is indispensable to take smart bio-nanotechnology awareness in agriculture. Despite a lot of information about individual nanomaterial is available but toxicity level of many nanoparticles is still imperceptible. Due to not as much of facts the application of these nano-materials is limited for risk assessments and effects on human health. Basic appreciative of how nanomaterials, the building blocks of bio-nanotechnology, interact with the cells and their biological consequences are beginning to evolve with lots of scopes and hopes in agriculture.

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