Acta Scientific Agriculture (ISSN: 2581-365X)

Volume 2 Issue 3 March 2018

Conceptual Paper

Synthesis of Nanoparticles and their Application in Agriculture

Ashish Khandelwal[1]* and Ritika Joshi[2]

[1]Scientist, Division of Agricultural Chemicals, ICAR-Indian Agricultural Research Institute, New Delhi, India

[2]Research Scholar, Soil Science and Agricultural Chemistry, Punjab Agricultural University, Ludhiana, India

***Corresponding Author:** Ashish Khandelwal, Scientist, Division of Agricultural Chemicals, ICAR-Indian Agricultural Research Institute, New Delhi, India.

Received: January 02, 2018; **Published:** February 03, 2018

Abstract

A nanoparticle is a microscopic particle with at least one dimension ranges between 1 - 100 nm. Nanoparticles are different from bulk particles in terms of their physical, chemicals and biological properties. Nanoparticles in their different size acts differently sometime it can be used as crop protectants or sometime it can be used as fluorescent compounds and their application can be used in sensor development. Nanotechnology has become boon and its wide application in the field of agriculture increasing day by day. Still, guidelines for application of it's in environment is in the pipeline.

Keywords: Nanoparticles; Nanotechnology; Agriculture

Introduction

One of the first and most natural questions asked when starting to deal with nanoparticles is "Why are nanoparticles so interesting? Why work with these extremely small structures that are challenging to handle and synthesize especially when compared with their macroscopic counterparts?" The answer lies in the unique properties possessed by these nanoparticles. The term nano is adapted from the Greek word meaning "dwarf." When used as a prefix, it implies 10-9. A nanometer (nm) is one billionth of a meter, or roughly the length of three atoms side by side. Nanoparticles are of great scientific interest as they bridge the gap between bulk materials and atomic or molecular structures. A bulk material has constant physical properties regardless of its size, but at the nanoscale this is often not the case. Several well characterized bulk materials have been found to possess most interesting properties when studied in the nanoscale. There are many reasons for this including the fact that nanoparticles possess a very high aspect ratio [1]. Nanoscale systems like encapsulation and entrapment of agrochemicals such as fertilizers, pesticides, herbicides, plant growth regulators and other active substances by using polymers, dendrimers, surface ionic attachments and other mechanisms may be used in controlled and slow release of agrochemicals, which allow the slow uptake of active ingredients and in turn reduces the amount of agrochemical application by minimizing the input and waste. Importance of nanoscale delivery system in agriculture is because of its improved solubility and stability to degradation in the environmental factors. The nanoscale delivery vehicles increase effectiveness by binding firmly to the plant surface and reduces the amount of agrochemicals by preventing runoff into the environment. Nanomaterials also play an important role in promoting sustain able agriculture and provide better foods globally. In developing countries, nanotechnology has got important application for enhancing agricultural productivity, along with other emerging technologies such as biotechnology including genetics, plant breeding, disease control, fertilizer technology, precision agriculture, and other allied fields. Nanotechnology can be used for combating the plant diseases either by controlled delivery of functional molecules or as diagnostic tool for disease detection. Nanosensors and other field sensing devices can be used in detection and measurement of crop nutrient status, insects, pathogens, weeds, moisture level, soil fertility, temperature etc. which helps in real time monitoring of the crop growth and provide essential data for precision farming practices leading to minimize agricultural inputs and maximizing resource output and yield.

Methods for synthesis of nanoparticles

There are two alternative approaches for synthesis of metallic nanoparticles: the "bottom-up" approach and the "top-down" approach.

Bottom-up approach: It refers to the construction of a structure atom-by-atom, molecule-by-molecule, or cluster by cluster. In this approach, initially the nanostructures building blocks (i.e. nanoparticles) are formed and, subsequently, assembled into the final material using chemical or biological procedure(s) for synthesis. The traditional and most widely used methods for synthesis of metallic nanoparticles use wet-chemical procedures. A typical procedure involves growing nanoparticles in a liquid medium containing various reactants, in particular reducing agents (e.g. sodium borohydride or potassium bitartrate or methoxypolyethylene glycol or hydrazine). To prevent the agglomeration of metallic nanoparticles, a stabilizing agent such as sodium dodecyl benzyl sulfate or polyvinyl pyrrolidone is also added to the reaction mixture. Generally, the chemical methods are; however, include advantage as well as drawbacks.

Advantage

1. Enhanced possibility of obtaining metallic nanoparticles with comparatively lesser defects and more homogeneous chemical composition(s).
2. Low-cost for high volume.

Drawback

1. Contamination from precursor chemicals,
2. Use of toxic solvents and
3. Generation of hazardous by-products.

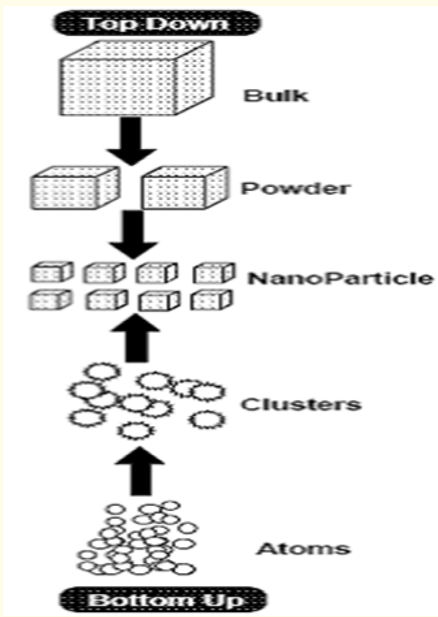

Figure 1: Methods for synthesis of nanoparticles.

Top-down approach: In this method, suitable starting material is reduced in size using physical (e.g. mechanical) or chemical means. Several methods including the commonly used attrition and pyrolysis can be used for physical synthesis of metallic nanoparticles. In attrition, macroscale or microscale particles are ground by a size-reducing mechanism (e.g. an ordinary or a planetary ball mill). The resulting particles are subsequently air classified to recover oxidized nanoparticles. The factors that critically affect the properties of the resultant nanoparticles include the material and time of milling and also the atmospheric medium. In pyrolysis, an organic precursor (either a liquid or a gas) is forced through an orifice at high pressure and burned. The resulting ash is air classified to recover oxidized nanoparticles.

Advantage

1. Production rate is average.

Drawback

1. Imperfection of the surface structure. Such defects in the surface structure can have a significant impact on physical properties and surface chemistry of the metallic nanoparticles due to the high aspect ratio (Major drawback).
2. Expense is very high and
3. Enormous consumption of energy to maintain the high pressure and temperature used in the synthesis procedures.

Nanotechnology in crop protection: Through the ever growing global food demand due to changing climate, urbanization and environmental issues such as run-off and accumulation of agrochemicals, there is an increasing need to feed an estimated population growth from the 6 billion to 9 billion by 2050. With the limited natural resources such as land, water and soil fertility, demand for food has increased tremendously. The cost of chemical fertilizers, pesticides and other production inputs has been drastically increased due to limited reserves of natural gas and petroleum. There is a need to overcome these constraints with the help of precision farming practices and effective application of nanotechnology to agriculture [2].

With the global efforts to reduce generated hazardous waste and the growing demand for synthesis of safe nanomaterials, researchers adopted green synthesis methods. The synthesis of nanoparticles from the plant extracts and microbes is a boon for advance research in nanotechnology. Among the recent advancement in agricultural sciences, nanomaterials play a significant role in crop protection because of its unique physical and chemical properties. Nanoparticles remain bound to the cell wall of pathogen and causes deformity due to high energy transfer leading to its death. Nanotechnological application in plant pathology targets specific agricultural problems in plant pathogen interactions and provide new perceptions for crop protection.

Nanoparticles in plant growth enhancement

Nanomaterials (NM) can be effectively used in plant germination and growth. The carbon nanotubes can be used as regulators of seed germination and plant growth. Multiwalled carbon nanotubes (MWCNTs) have the ability to enhance the growth of tobacco cell culture by 55 - 64% when compared to control at a wide range of concentrations from 5 - 500 µg/ml [3]. At low concentrations, activated carbon enhanced cell growth while at higher concentrations it intensely inhibited the cellular growth.

Nanotechnology: scope in pathogen control

Potential applications of nanotechnology in crop protection include controlled release of encapsulated pesticide, fertilizer and other agrochemicals in protection against pests and pathogens, early detection of plant disease and pollutants including pesticide residues by using nanosensors [4]. The potential applications of nanomaterials in crop protection, helps in the development of efficient and potential approaches for the management of plant pathogens.

Nanoparticles in disease management

Chitosan: In search of natural antimicrobials to avoid harmful synthetic chemicals, chitosan and chitosan nanoparticles are found to be more effective against plant pathogens like *Fusarium solan*i. Inhibitory effect was also influenced by particle size and zeta potential of chitosan nanoparticles. The chitosan therefore could be formulated and applied as a natural antifungal agent in nanoparticles form to enhance its antifungal activity.

Silver nanoparticles: The application of silver nanoparticles as antimicrobial agents is because of its economical production and multiple modes of inhibitory action to microorganisms. Silver nanoparticles are the most studied and utilized nanoparticles in bio-system because of its strong inhibitory and antimicrobial activities [5]. Nano silver colloid is more adhesive on bacterial and fungal cell surface; hence act as better fungicide because of its well dispersed and stabilized silver nanoparticles solution.

Copper nanoparticle: The growth of phytopathogenic fungus *Fusarium graminearum* inhibited due to strong synergistic effect between chitosan and copper which results due to Complexation of copper with chitosan nanogels. These nanohydrogels due to its biodegradable natures are included as a new generation of copper-based bio-pesticides and it could also be developed into an efficient input based delivery system particularly for copper based fungicides as plant protectant [6].

Zinc nanoparticle: The nano-ZnO derived from zinc nitrate showed fungal cell wall deformity due to synthesis of hydroxyl and superoxide radicals and death due to high energy transfer in fungal pathogen *Aspergillus fumigatus* [7]. ZnO nanoparticles prevent the conidiophores and conidial development and cause deformation of fungal hyphae which ultimately leads to the death of fungal hyphae.

Nanotechnology in pest management

Nanopesticide formulations increase the solubility of poorly soluble active ingredient and helps in releasing the active ingredient slowly. The bioavailability of poorly water-soluble agrochemicals can be increased through the use of additives or by nanoparticulate formation of agrochemicals. Rotenone, its effective utilization has limited due to its poor water solubility, stability, degradation and isomerization when exposed to sunlight. It is very effective and used to control aphids, thrips from decades. Chitosan derivatized nanoparticles synthesized by embedding octadecanol-1- glycidyl ether to amino groups and sulphate to hydroxyl groups with novel amphiphilic chitosan derivatives N-(octadecanol-1-glycidyl ether)-O sulphate chitosan (NOSCS) and it was found that loading of insecticide rotenone into a nanoparticles was increased up to 13000 times compared to free rotenone in water and solubility in NOSCS micelles aqueous solution was increased and it showed a way to encapsulate and slow release of water insoluble agrochemicals in pant protection [8].

Conclusion

Nanotechnology provides an opportunity for controlled delivery of agrochemicals to break disease resistance and improve plant growth enhancement and nutrient utilization. Nanoencapsulation shows the benefit of more efficient and targeted use of pesticides, herbicides and insecticides in environment friendly greener way. The increase in solubility of active ingredient due to nanotechnology increase effectiveness of the drug/pesticide many fold and it becomes possible to use inherent property of active ingredient in terms of activity in targeted area. Nanotechnology in coordination with green chemistry and biotechnology provide an opportunity for synthesis of nanomaterials by using plant extracts and living cells and it leads to reduced use of toxic solvents and provide an eco-friendly environment and it extended the scope of nanotechnology. Even though the toxicity of nanomaterials has not yet clearly understood but due to introduction of several cosmetic and medical product based on nanotechnology appears in the market. These things open an opportunity to bring crop protectant very soon in the market with introduction of proper guidelines. The application of nanomaterials is relatively new in the field of agriculture and it needs further research investigations.

Bibliography

1. Rajput N. "Methods of preparation of nanoparticles-A Review". *International Journal of Advances in Engineering and Technology* 7.4 (2015): 1806-1811.

2. Chowdappa P and Gowda S. "Nanotechnology in crop protection: Status and Scope". *Pest Management in Horticultural Ecosystems* 19.2 (2013): 131-151.

3. Khodakovskaya MV., *et al*. "Carbon nanotubes induce growth enhancement of tobacco cells". *ACS Nano* 6 (2012): 2128-2135.

4. Ghormade V., *et al*. "Perspectives for nano-biotechnology enabled protection and nutrition of plants". *Biotechnology Advances* 29.6 (2011): 792-803.

5. Jo YK., *et al*. "Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi". *Plant Disease* 93.10 (2009): 1037-1043.

6. Brunel F., *et al*. "Complexation of copper (II) with chitosan nanogels: Toward control of microbial growth". *Carbohydrate Polymers* 92.2 (2013): 1348-1356.

7. Patra P and Goswami A. "Zinc nitrate derived nano ZnO: Fungicide for disease management of horticultural crops". *International Journal of Innovative Horticulture* 1 (2012): 79-84.

8. Lao SB., *et al*. "Novel amphiphilic chitosan derivatives: Synthesis, characterization and micellar solubilization of rotenone". *Carbohydrate Polymers* 82.4 (2010): 1136-1142.

Volume 2 Issue 3 March 2018