Journal of Phytonanotechnology and Pharmaceutical Sciences 2(1): 11-14, 2022

Online ISSN:2583-0376

http://jpps.ukaazpublications.com

DOI: http://dx.doi.org/10.54085/jpps.2022.2.1.3

Journal of Phytonanotechnology and Pharmaceutical Sciences

Review Article : Open Access

# Nanotechnology applications in agriculture: An overview

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**Article Info**

**Article history**
Received 10 February 2022
Revised 12 March 2022
Accepted 13 March 2022
Published Online 30 March 2022

**Keywords**
Nanotechnology
Applications
Agriculture
Pesticides
Nanosensors
Nanoparticles

**Abstract**

Nanosized particles are used for various applications. Nanotechnology is emerged as a promising cutting edge technology with its applications as a powerful tool for agriculture food security, nutritional security, and control of abiotic, biotic stresses and in pesticide, sensor and newer particle delivery as well. In future, strategic researches are required to develop the potential technology use in agriculture for enhancing productivity, biosafety and over all agriculture sustainability.

## 1. Introduction

Nanotechnology introduces smart agricultural products which may be a milestone in solving many common economic and ecological issues. Nanofertilizers show unique characters which do not exist in their conventional counterparts. Nanotechnology is one of the new technologies that entered almost all sides of our lives and were used in agriculture production. Nowadays, nanotechnology has expanded horizons in all fields of science. The nanotechnology can takes an important part in the productivity through control of nutrients (Mukhopadhyay, 2014) as well as it can also participate in the monitoring of water quality and pesticides for sustainable development of agriculture (Prasad *et al*., 2014).

Nanotechnology dealing with nanoscale particles of size 1-100 nm, which leads to cost-effective, long-lasting, safer, smart products with applications in all the sectors. In agriculture, its applications are very diverse including fertilizers, herbicides, pesticides, recalcitrant contaminants from water, scale carriers, sensors, animal husbandry, *etc*. As per Salamanca-Buentella *et al*. (2005), the applications of nanotechnology for agricultural production are as follows in Table 1.

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**Table 1:** Application of nanotechnology for agricultural production

| Nanotechnology | Applications in agriculture |
|---|---|
| Nanoforms zeolites | Slow release and efficient dosage of water and fertilizers for plants; drugs for livestock; nanocapsules and herbicide delivery |
| Nanosensors | Soil quality and for plant health monitoring; nanosensors for pests detection |
| Nanomagnets | Removal of soil contaminants |
| Nanoparticles | New pesticides, insecticides, and insect repellents |

As per the recent statistics, 90% of the nano-based patents and products are claimed by China, Germany, France, Japan, Switzerland, South Korea and USA. To harnese the potential of nanoscience, the Government of India has invested one crore through the Nano Mission Project during 11th Five Year Plan with the aim of training of manpower, development of products and processes such as safe drinking water, materials development, drug delivery linkages between educational and research institutions and industry; setting up a dedicated Institute of Nanoscience and Technology, Post Graduate Programmes (M.Sc/M.Tech.) in 16 Institutions/ Universities across the country (Source: Planning Commission, 2011 (http://planningcommission.gov.in/aboutus/committee/wrkgrp12/sandt/wg_dst2905.pdf).

## 2. Applications of nanotechnology

Presently, in India, research is mainly concentrated on nanoparticle synthesis, smart release of nutrients from nanofertilizers, nanoinduced polysaccharide powder for moisture retention/soil aggregation and

C build up, regulated release of active ingredients from nano-encapsulated herbicides, nano-seed invigoration, and slow and steady release of pesticides, nanofilm for extended shelf-life of perishables and nano-remediation of soil and aquatic pollutants (Figure1) (NAAS, 2013).

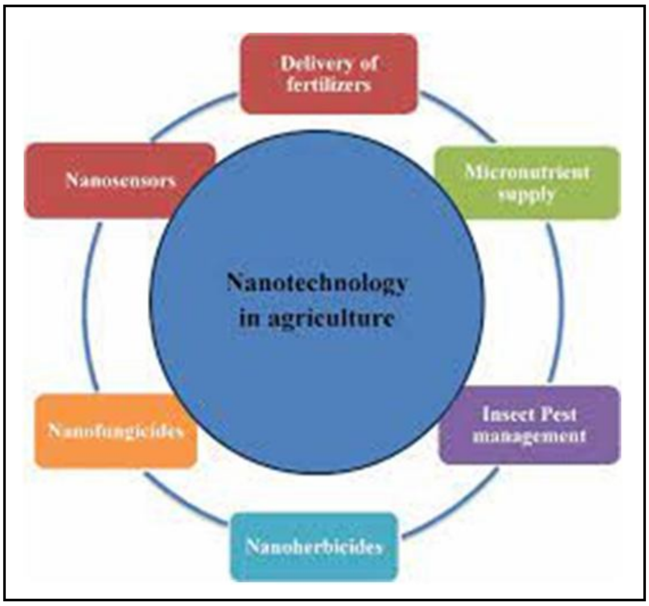


**Figure1: Applications of nanotechnology in agriculture.**

In the sector of agriculture, which is a backbone of Indian economy. It had various applications with nanotechnology. The applications in various fields are summarized as below:

**Nanopesticide:** Several pesticide manufacturers are developing pesticides encapsulated in nanoparticles (OECD and Allianz, 2008). These pesticides may be time released or released upon the occurrence of an environmental trigger (temperature, humidity, light). Clay nanotubes (halloysite) have been developed as carriers of pesticides at low cost, for extended release and better contact with plants, and they will reduce the amount of pesticides by 70-80%, thereby reducing the cost of pesticide with minimum impact on water streams. NPs play a key role in the control of insect pests and host pathogens (Khota *et al*., 2012). Formulation of nanoencapsulated pesticides reduces the dosage of pesticides and human beings exposure (Nuruzzaman *et al*., 2016). Development of non-toxic and promising pesticide delivery systems for increasing global food production is possible with NTs. Interestingly, iron (II, III) oxide NPs ($Fe_3O_4$ -NPs) have the ability to accumulate in *Lepidium sativum* and *Pisum sativum* plants leading to the conclusion that they accumulate in natural ecosystem (Abbas *et al*., 2016). Hence, the introduction of engineered NPs in the agricultural field is a way to sustain an eco-friendly in the agricultural field.

**Seed science:** Metal oxide nanoparticles and carbon nanotube to improve the germination of rainfed crops. Khodakovskaya *et al*. (2009) reported the use of carbon nanotube for improving the germination of tomato seeds.

**Biosensors:** Electronic nose (E-nose) is used to identify different types of odors; it uses a pattern of response across an array of gas sensors useful to gas sensors which are composed of nanoparticles, *e.g.*, ZnO nanowires. Biosensors provide high performance capabilities for use in detecting contaminants in food or environmental media. They offer high specificity and sensitivity, rapid response, user-friendly operation, and compact size at a low cost (Amine *et al.*, 2006). Recently, nanosensors are widely applied in the agriculture due to their strengths and fast for environmental monitoring of contamination in the soils and in the water (Ion *et al.*, 2010). Several sensors based on nanodetection technology such as, *viz*., biosensors, electrochemical sensors, optical sensors, and devices will be the main instruments for detecting the heavy metals in trace range. Sagadevan and Periasamy (2014) stated that the sensitivity and performance of biosensors can be improved by using nanomaterials through new signal transduction technologies. At present, the nanotechnology-based biosensors are at the early stage of development as per the Fogel and Limson (2016). The improvement of tools and procedures used to fabricate, measure and image nanoscale objects, has led to the development of sensors. The microcantilever based DNA biosensor that uses AuNPs have been developed and used widely to detect low level DNA concentration during a hybridization reaction (Brolo, 2012).

**Balanced crop nutrition:** Significant yield increase due to foliar application of nanoparticles as fertilizer (Tarafdar, 2012) was recorded. About 640 mg ha-1 foliar application (40 ppm concentration) of nanophosphorus gave 80 kg ha-1 P equivalent yield of cluster bean and pearl millet under arid environment, which suggested that balanced fertilization can be achieved through nanotechnology. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients. Kandasamy and Prema (2015) revealed that application of nanoscale particles results numerous advantages over traditional procedures. When nanoscale particles are put together, biological tests measuring the presence or activity of selected analytics become quicker, more sensitive and flexible.

**Nanofood industry:** There is a strong need to develop nanofood through nanoengineering of food ingredients. Under this, texture, taste, flavour and color of food ingredients can be modified using nanoengineering without losing their nutritional value or with improved nutritional quality. Nanotechnology can extend the shelf-life of perishables like fruits, vegetables, and flowers during transportation, thus preventing the post-harvest losses. Nanoscale biosensors can take part in pathogen detection and diagnosis. Nanotechnology has the ability to supply bioactive ingredients in foodstuffs to hosts while improvement of knowledge of food materials at the nanoscale (Martirosyan and Schneider, 2014). Sensing ability of label and package, *in situ* sensors, food quality monitoring, control and nutraceuticals delivery, portable DNA/protein chips, *etc*., most of the time, nanomaterials produced by bottom-up methods (Siegrist *et al*., 2008). KD Pharma BEXBACH GMBH (Germany) provides encapsulated omega-3 fatty acids in two different forms-suspension and powder. The capsulation technology used the resulted particles in nano- and microscale (Berekaa, 2015). NP-based sensors indicate the color change and information about the nature of the packed foods can be observed, that's why NT technology have been successfully applied in package of milk and meat (Bumbudsan pharoke and Ko, 2015). The nanotechnology is a forward looking process, it acts as an agricultural biosecurity.

**Nanoparticles for filtration:** The NRC report (2008) on emerging technologies that will benefit farmers in Africa and Asia lists several nanomaterials that are believed to be economical and effective for water purification. Nanoenabled water treatment techniques rely on membranes and filters made of carbon nanotubes, nanoporous ceramics, and magnetic nanoparticles rather than the use of chemicals and ultraviolet light used in conventional water treatment (Hillie and Hlophe, 2007).

**Smart delivery systems:** Quality assurance of agricultural products safety and security through IP at the nanoscale. Nanoscale IP holds the possibility of continuous tracking and recording of the history which a particular agricultural product experiences. The IP system is highly useful to discriminate organic versus conventional agricultural products.

**Photocatalysis:** One of the processes using nanoparticles is photocatalysis. Analogy with n- and p-type semiconductors, *i.e.*, the Group IV elements, *e.g.* Germenium of the Periodic Table, dopted with, respectively, minute quantities of the Group V and Group III impurities, is worth noting. Due to their large surface-to-volume ratio, these have very efficient rates of degradation and disinfection.

The technological application of nanoproducts through the regulatory processes, keeping in view the social, political and cultural implications based on an integrated effort of different subject matter specialists, planners and stake-holders. For providing the desired scientific support to the regulatory process, a "National Institute of Agricultural Nanotechnology and Nanosafety" should be established with the state-of-art infrastructure, human resource and research programmes for conducting frontier research, capacity building in this field and providing policy support and technical advice to the government.

Recently, Mohammad *et al*. (2020) investigated the response of yield and quality of sugar beet cv. Farida to foliar application of nano-microelements mixtures (Fe, Mn, Zn and B) with/without urea and concluded that the application of nanomicroelements 200 mg l-1+urea 1% treatment for significantly produced higher yields associated with improving the quality traits of sugar beet and saving the plants' needs from micronutrient and nitrogen fertilizers, if this fertilizer rate has been added in the form of nanoparticles. Marzouk *et al.* (2019) reported highest values of vegetative growth, fresh pod yield, pod physical quality dry weight, and pod nutritional value content expressed as P, K, Zn, Mn, Fe, Cu, crude protein, total soluble solids, and fiber and concluded that foliar application of zinc nanofertilizer increased the studied characteristics significantly compared with other nanomicronutrients. Also, the combined effect of Flantino cultivar with zinc nanofertilizer treatment recorded the highest values of vegetative growth, fresh pod yield, pods physical quality and nutritional value.

## 3. Conclusion

The ultra-small sizes that make the nanoparticles of immense usefulness are investigated in various fields. At present in India, research is mainly concentrated on nanoparticle synthesis, smart release of nutrients from nanofertilizers, nanoinduced polysaccharide powder for moisture retention/soil aggregation and C build up, regulated release of active ingredients from nanoencapsulated herbicides, nanoseed invigoration, and slow and steady release of pesticides, nanofilm for extended shelf-life of perishables and nanoremediation of soil and aquatic pollutants. These are cutting-edge researchable areas which are expected to expand in the years to come. However, if the nanoproducts and the processes for creating them are not managed judiciously, there could be serious health and environmental risks. Nanopesticides may reduce environmental contamination through the reduction in pesticide application rates. Identification, upgradation of institutions with relevant expertise and facilities and networking them for enhancing their efficiency in biosafety evaluation of nanoparticles for future applications.

## Acknowledgements

The authors sincerely thank original researchers whose work was referred to in this review.

## Conflicts of interest

The authors declare no conflicts of interest relevant to this article.

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**Citation** **Amarapalli Geetha and Saidaiah Pidigam (2022). Nanotechnology applications in agriculture: An overview. J. Phytonanotech. Pharmaceut. Sci., 2(1):11-14. http://dx.doi.org/10.54085/jpps.2022.2.1.3**