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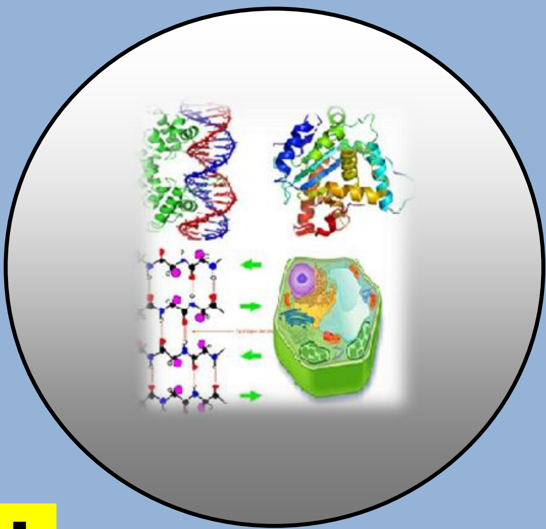

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# Agricultural Applications of Nanotechnology

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## ABSTRACT

***Nanotechnology plays an important role in agriculture by providing new tools for improving the crop production efficacy, processing of food and food safety efficiency. Apart from this, nanotechnology is also helpful in determining and improving environmental consequences on production of food as well as storage and distribution. Nanotechnology is able to permit several advances in research related to agriculture with special reference to reproductive science and technology, agricultural and food wastes conversion to energy and other useful by-products through enzymatic nanobioprocessing as well as prevention of disease and treatment in plants and animals. Materials which are new and possess special characteristics at the nanoscale could offer a tremendous breakthrough for pathogen and contaminant detection.***
***Keywords: Nanotechnology, Pathogen Detection, Agriculture, Disease Prevention and Nanobio processing.***

## INTRODUCTION

Nanos: Greek term for dwarf, Technology: produce, visualize, characterize and manipulate matter of the size of 1 – 100 nm. This technology has been considered as vast field of the 21st century and is making a very significant impact on the world's economy, industry and people's lives (Scott and Chen 2003). Nanotechnology proposes the construction of novel Nano-scale devices possessing extraordinary properties. Nanotechnology is able to eliminate unwanted byproducts.

Materials science and biomass conversion technologies applied in agriculture are the applications of nanotechnology which have been considered as basis of providing food, feed, fiber, fire and fuels. Demand for food will increase day by day but natural resources such as land, water and soil fertility are limited.

Due to limited reserves of fuel such as natural gas and petroleum, the cost of production inputs like chemical fertilizers and pesticides is expected to increase at an alarming rate. Precision farming is a better option to reduce production costs and to maximize output, i.e. agricultural production.

## THE PIONEERS

The term “Nanotechnology” was coined in 1974 by Norio Taniguchi at the University of Tokyo. During the 1950s Arthur von Hippel proposed the term “molecular engineering” and predicted the feasibility of constructing nano molecular devices.

Nanotechnology should not be viewed as a single technique that only affects specific areas. It is more of a ‘catch-all’ term for a science which is benefiting the whole environment which leads to healthcare benefits and ultimately to number of commercial products. Basically, nanotechnology is also reffered as 'tiny science' which does not only related to very small structures and products because incorporation of nanoscale features is also done into bulk materials and large surfaces. Nanotechnology will allow limitations in many existing technologies to be overcome and thus has the potential to be the part of every industry like agriculture industry, food industry, textile industry and medicine industry etc.

Nanotechnology possesses the ability to revolutionize the agricultural and food industry with new tools for molecular treatment and rapid detection of diseases as well as enhancing the ability of plants to absorb nutrients etc. Agricultural industry will be helped by smart treatment delievery system and smart sensors combat viruses and other pathogens associated with crops. Nanostructured catalysts will be available in future which will increase the efficiency of pesticides and herbicides as well as leads to use of lower doses. Nanotechnology will be efficient enough to protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants. Controlled Environment Agriculture (CEA) is an agricultural methodology which is broadly used in USA, Europe and Japan for crop management. CEA is an advanced and intensive form of hydroponically-based agriculture. Plants are grown within a controlled environment so that horticultural practices can be optimized. CEA technology also provides an excellent platform for nanotechnology introduction to agriculture. Various nanotechnological devices for CEA that provide “scouting” capabilities could tremendously improve the grower’s ability to determine the best time of crop harvest, crop vitality and security of food issues involving microbial or chemical contamination (Prasad *et al*. 2014). As a new enabling technology, agriculture nanotechnology has tremendous potential to revolutionize food and agriculture systems. Security of agricultural and food systems, delivery systems for disease treatment, new materials for pathogen detection and protection of the environment are examples of the important links of nanotechnology to the science and engineering of agriculture and food systems. Some overarching examples of nanotechnology as an enabling technology are: food stuffs production, processing, and shipment. Agriculture has long dealt with improving the efficiency of production of crop, processing of food, safety of food and environmental consequences of production of food it’s storage and distribution. Presently if a plant or animal becomes infected with disease, it can be days, weeks, or months before then the disease presence is detected by whole-organism symptoms.

Nanotechnology also has the potential for very early detection of virus or disease infecting particle and their eradication. Nanotechnology enchance the activation possibility of "Smart" treatment delivery systems long before macro symptoms of disease appear. The integrated sensing, monitoring and controlling system could detect the presence of disease in early stages of fever development and notify the farmer and activate a targeted treatment delivery system. In agriculture, the fundamental life processes are explored through research in molecular and cellular biology. Nanotechnology is also helpful in designing new tools for cellular and molecular biology which are needed for individual molecule separation, identification and quantification. Besides this the technology could permit broad advances in research related to agriculture including reproductive science and technology, agricultural and food wastes conversion to energy and other useful by-products through enzymatic nanobioprocessing, prevention as well as treatment of disease in plants and animals. New materials that have special characteristics at the nanoscale could offer a tremendous breakthrough for pathogen and contaminant detection. Materials that have self-assembly and self-healing properties can find a multitude of applications in agriculture. Food packaging in self-healing containers could prevent food microbial contamination and facilitate food preservation, storage and distribution. Protection of the environment through the reduction and conversion of agricultural materials into valuable products can be made easier by nanotechnology. Design and development of new nanocatalysts to convert vegetable oils into biobased fuels and biodegradable industrial solvents is already being examined. Such an approach could be greatly enhanced using capabilities of nanotechnology. Protection of the environment through management of local and environmental emissions is another exciting area of agriculture that could benefit from nanotechnology. Agricultural crops must be protected against the invasions of wild animals, weeds, insect pests, fungal pathogens and the whimsical nature of the weather. Close daily scrutiny, or "scouting" of crops for potential problems is critical to the health of the crop and also reduces the amount of pesticides needed. The Integrated Pest Management (IPM) approach, widely adopted in US agriculture today, reduces pesticide use on plants and animals by only applying pesticides when needed, as determined by scouting for pests. However, scouting is a time consuming task for the farmer, and requires a significant degree of expertise to recognize and diagnose symptoms of problems from insects, fungal, bacterial or viral pathogens, or nutritional stress. Timing and extent of irrigation or fertilization for various areas of the plant crop are determined by scouting. Many of these tasks could be simplified through nanotechnology. Computerized control of the environment over small enclosed parcels of land is known as "Controlled Environment Agriculture" (CEA). Agricultural production is defined as the processes to produce materials from plant cultivation and raising domesticated animals. This material includes foodstuffs, fuel, and raw materials for other industries including the pharmaceutical, textile, and construction industries (Kuzma and VerHage 2006).

Global agriculture today faces several issues: maximising land-use in different environments, sustainable use of resources (in particular fresh water) and ensuring that practices do not have an adverse impact on the environment (e.g. accumulation of pesticides and fertilisers). At the same time there are opportunities for agriculture to expand into new areas, for example the utility of what would previously have been regarded as agricultural waste which now can be used for industrial processes.

On the basis of these details applications of nanotechnology in different sectors of agriculture is discussed below:

## AGRICULTURAL APPLICATIONS OF NANOTECHNOLOGY

- Crop improvement
- Soil management
- Plant disease diagnostics
- Water management
- Nano-pesticide
- Utilization of Nano-fertilizers for balanced crop nutrition

- **Crop improvement**: New tools for molecular and cellular biology are needed in agriculture now a day's which are specifically designed for individual genes and molecules separation, identification and quantification (Warad and Dutta 2005). Nanotechnology has that potential to deliver the genes to specific sites at cellular levels and rearrange the atoms in the DNA of the same organism to get expression of desired character which is helpful in skipping the time consuming process of transferring the gene from foreign organisms. Nanotechnology has the ability in modifying the genetic constitution of the crop plants resulted in improvement of the crop progressively. Instead of using certain chemical compounds like EMS, MMS and physical mutagens like X-ray, gamma ray etc. for conventionally induced mutation studies, a new dimension has been shown by nanotechnology in mutation research. For example in Thailand, Chiang Mai University's Nuclear Physics Laboratory developed a new white-grained rice variety from a traditional purple coloured rice variety called Khao Kam through nanotechnology. Using nanotechnology, the scientists changed the colour of the leaves and stems of Khao Kam from purple to green and the grain became whitish (ETC 2004).

- **Soil Management:** Nanotechnology is considered as an exciting and rapidly emerging technology which allows working, manipulating and creating tools, materials and structures at the molecular level. Management of soil plays an important role in agriculture sector. Nanotechnology paved the way for new opportunities to advance nutrient use efficiency. Nanotechnology has provided the feasibility of exploiting nanoscale or nanostructured materials as fertilizer carriers or controlled-release vectors for building of so-called "smart fertilizer" as new facilities to enhance nutrient use efficiency and reduce costs of environmental protection (Cui *et al*. 2010; Chinnamuthu and Boopathi 2009). Nanofertilizers considered as alternatives to conventional fertilizers, have been used to improve soil management, such as controlled release fertilizers (CRF) which released their nutrient contents gradually to fulfill with the plant nutrient requirement. Significance of nanotechnology involvement in soil improvement emerged in many aspects such as:

- **Regulation aspect**
  - Specific regulations for nanotechnology should be introduced.
  - Mandatory labelling of all nanoproducts in foods is required.
- **Environment aspect**
  - Inclusion of nanomaterials in soil fertilizer may cause potential health risks.
  - Nanofertilizer may create new kinds of contamination in soils and waterways.
- **Economy aspects**
  - Marginalize poorer farmers.

- **Plant disease diagnostics**

In crop productivity, diseases are considered as major problem. Detection of the exact stage of prevention is the main problem lies in disease management. Mostly pesticides are applied as a precautionary measure which ultimately results in residual toxicity and environmental hazards. Hence, application of pesticides after the appearance of disease leads to some amount of crop yield losses. Among diseases, viral diseases are the most difficult to control because spread of the disease can be stopped only by vectors. In this context, nano-based diagnostics of viral diseases including development of multiplexed diagnostic kit have played a major role to detect the exact strain of virus and stage of application. Detection and utilization of biomarkers accurately indicate disease stages with differential protein production in both healthy and diseased states lead to the identification of the development of several proteins during the infection cycle. Besides increasing the speed of detection, nano-based diagnostic kits also increase the power of the detection (Chinnamuthu and Boopathi 2009).

➢ **Water Management**: Since last decade, nano-materials have gained special attention in water pollution mitigation researches. Two vital properties make nanoparticles highly lucrative as sorbents. On the basis of mass, nanoparticles have much larger surface areas as compared to macro particles. Nanofiltration techniques are used for the removal of cations, natural organic matter, biological contaminants, pollutants which are organic in nature, nitrates and arsenic from groundwater and surface water. Apart from this, nano-membranes are used to treat contaminated water by filtration or separation techniques. In addition to this, nanosorbents are widely used as separation media in water purification to remove inorganic and organic pollutants from contaminated water (Bruggen and Vandercasteele 2003). For example, titanium dioxide ($TiO2$) nanoparticles have emerged as promising photocatalysts for water purification during the last decade. Synthesis of some nanostructured mixed oxides used for groundwater treatment has been done by various methods like chemical precipitation, sol–gel, vapour deposition, solvo thermal, solid state reaction etc. Mixed oxides nano-agglomerates such as iron–cerium, iron–manganese, etc. have been synthesized, characterized and successfully employed for water treatment. The environmental fate and toxicity of a material are critical issues in materials selection and design for water purification (Bhattacharya *et al*. 2013).

➢ **Nano-pesticide:** Persistence of pesticides in the initial stage of crop growth helps in bringing down the pest population below the economic threshold level and to have an effective control for a longer period. Utilization oof active ingredients in the applied surface remains one of the most cost-effective and versatile means of controlling insect pests. A nanotechnology approach, namely "nano-encapsulation" protect the active ingredient from the adverse environmental conditions and promote persistence, hence it can be used to improve the insecticidal value. Nanoencapsulation comprises nano-sized particles of the active ingredients being sealed by a thin-walled sac or shell (protective coating). Several workers have published research papers on the encapsulation of insecticides (Owolade *et al*.2008). Nano-encapsulation of various insecticides, fungicides or nematicides will be helpful in producing a formulation which offers effective control of pests while preventing accumulation of residues in soil as well as encapsulated nanoparticles in the form of pesticides allows for proper absorption of the chemicals into the plants (Scrinis and Lyons 2007).

Nano-pesticides will reduce the rate of application because the quantity of product actually being effective is at least 10-15 times smaller than that applied with classical formulations, therefore a much smaller quantity than the normal could be required to have much better and prolonged management.

- **Utilization of Nano-fertilizers for balanced crop nutrition:** Nano-fertilizer technology is very innovative but scantily reported in the literature. However, some of the reports and patents strongly suggest that there is a vast scope for the nanofertilizers formulation. Due to foliar application of nano particles as fertilizer, increase in yields has been observed which was very significant (Tarafdar 2012; Tarafdar *et al*. 2012a). It was shown that under arid environment 640 mg ha-1 foliar application (40 ppm concentration) of nanophosphorus gave 80 kg ha-1 P equivalent yield of clusterbean and pearl millet. Development of nano-composites to supply all the required essential nutrients in suitable proportion through smart delivery system is under process. Research suggests that balanced fertilization may be achieved through nanotechnology (Tarafdar *et al*. 2012b). Indeed the metabolic assimilation within the plant biomass of the metals, e.g., micronutrients, applied as Nano-formulations through soil-borne and foliar application. Currently, efficiency of nitrogen use is low due to the loss of 50-70% of the nitrogen supplied in conventional fertilizers. Nanoparticles encapsulated with nanoparticles will increase the uptake of nutrients. New nutrient delivery systems that exploit the porous nanoscale parts of plants could reduce nitrogen loss by increasing plant uptake. (Tarafdar *et al*. 2012c). Release of the nutrients in next generation of nanofertilizers can be triggered by an environmental condition or simply released at desired specific time.

## CONCLUSIONS

Nanotechnology has great potential of enhancing the quality of life through its applications in various fields from medicine to agriculture (Fakruddin *et al*. 2012). Nanotechnology has become the future of any nation throughout the world. But we must be very careful with any new technology to be introduced about its possible unforeseen related risks that may come through its positive potential. The theme of the paper is based on the provision of basic knowledge about the applications of nanotechnology in agriculture and their prospects in the near future with reference to the current situation around the world. In this review, some of the potential applications of nanotechnology in agriculture for the welfare of humans and for sustainable environment, challenges and opportunities for developing countries have been identified. Finally, for their solution, collaboration among developed and developing countries, public and private sectors and between research institutions and international organizations have been identified and suggested. The future of nanotechnology is uncertain due to many reasons, such as negative reaction of the public towards genetically modified crops, lack of many of the requisite skills in public agricultural research organizations for this type of research and ill-equipped and somewhat hesitant regulatory structures to deal with these new technologies. There is a dire need to tear down the sharp boundary present between the social and natural sciences and if we succeed in discarding this boundary, we will be able in developing a more desirable and more democratic sociotechnical future.

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