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Application of Nano-Techniques in Agriculture

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Introduction

The word "nano" encompasses various fields such as biotechnology, nanotechnology, agriculture, material science, physics, chemistry, mathematics, health and environment (Porter and Youtie, 2009). A nanometer is a SI unit of distance of one-billionth of a meter. The term nano arises from the Greek word 'nanos' meaning dwarf. Technology is the making, usage and knowledge of tools, machines and techniques in order to solve a problem or perform a specific function. Thus, Nanotechnology is the art and science of manipulating and rearranging individual atoms and molecules at nanoscale to create useful materials, devices and systems. Nature is the master of nanotechnology, transforming atoms of various elements into building blocks and power plants that result in a living, functional person. Nanotechnology draws knowledge from all diverse knowledge sources. The major evolution of nanotechnology is system of nano systems and molecular nano systems. It is a promising field of interdisciplinary research. The potential uses and benefits of nanotechnology are enormous. Agriculture is the backbone of most developing countries, with more than 60% of the population reliant on it for their livelihood. As well as developing improved systems for monitoring environmental conditions and delivering nutrients or pesticides as appropriate, nanotechnology can improve our understanding of the biology of different crops and thus potentially enhance yields or nutritional values.

Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural products. The reduced use of herbicides, pesticides and fertilizers with increased efficiency, controlled release and targeted delivery will lead to precision farming. Modern agriculture is need of hour because conventional agriculture will not be able to feed an ever-increasing population with changing climate, depleting resources and shrinking landscape. But at the same time application of nano-materials in agri-food sector has to be evaluated for public acceptance so it does not come across a scenario as faced by GMOs in past. Nanotechnology has great potential in agriculture as it can enhance the quality of life through its applications in fields like sustainable and quality agriculture and the improved and rich food for community.

History of Nanotechnology

The ideas and concepts behind nanoscience and nanotechnology started with a talk entitled "There's Plenty of Room at the Bottom" by Physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology on December 29, 1959 long before the term nanotechnology was used. He described molecular machines building with atomic precision. In 1974, the term "Nanotechnology" was introduced by Norio Taniguchi, professor in Tokyo University of Science. In 1977, Dr K Eric Drexler explained in depth about the nano scale technology and its significance through his speeches and the book *Engines of Creation*: *The coming era of nanotechnology and nanosystems*: *Molecular machinery, Manufacturing and Computation*. In 1993 Feynman won the Nobel Prize for nanotechnology.

Why Nanomaterials?

Nanomaterials are materials possessing distinct properties as compared to their bulk counterpart. It is the property of nanomaterials that earns distinction of 'nano'. Individual nanoparticle is the basic building block of entire nanoscience dictating all unique properties. They have size ranging from one to a few hundred nanometers in all three dimensions. They have unique chemical, physical and electrical properties. For example: Nanotubes are stronger than steel, but lighter than aluminum, they can act as conductive wires or semiconductors, transport heat or electricity with little resistance and can be woven into fabrics.

Nano particles synthesis

Two main approaches are used in nanotechnology, namely Bottom-up approach and Top-down approach. Bottom-up approach represent nanoscale components arranged to microscale or little larger than nano size components by self-assembly or chemical assembly. Top-down approach represents nanoscale objects which are made up of microscale components or larger than nanoscale objects. The nanoscale atoms have important characteristics like wavelength property of electrons, high surface area for reaction etc. (Khalid *et al*., 2010; Peterson, 2004).

Types of Nanomaterials

There are various categories of nanomaterials. They can be carbon based, metal based, dendrimers and composites. Carbon based Carbon nanotubes are allotropes of Carbon with a cylindrical nanostructure. Nanotubes have been constructed with length-to-diameter ratio of upto 132,000,000:1 (Collier *et al*., 2011) which is significantly larger than any other material. A nanocomposite is as a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm while a Quantum dot is a semi conductors whose conducting characteristics are closely related to the size and shape of the individual crystal (Naher *et al*., 1993). Cationic polyamidoamine (PAMAM) dendrimers are nanoparticles with a tunable number of branches and unique molecular features, making them one of the most promising nanocarriers for gene delivery applications (Teranishi *et al*., 1998).

Potential of Nanotechnology applications

Currently the research and development pipeline have the potential to make agriculture more efficient, increase yields and product quality and thereby increasing nutritional benefits. Developed countries are using or testing nano sensors and nano agricultural chemicals, nanoparticles for soil cleaning and

nanopore filters, nanoceramic devices, and nanoparticles. An increasing number of applications are expected for food and agriculture uses, including nano sensors, potentially capable of detecting chemical contaminants, viruses, and bacteria; nano delivery systems which could precisely deliver drugs or micronutrients at the right time and to the right part of the body. Promising nanotechnology applications address low use efficiency of agricultural production inputs and stress of drought and high soil temperature. Nanoscale agrichemical formulations can increase efficient use and decrease environmental losses. Nano-porous materials capable of storing water and slowly releasing it during times of water scarcity could also increase yields and save water. The potential for nanotechnology in agriculture continues to grow. More ambitious uses of nanoparticles are bio-remediation of contaminated environments, biocides and antifungals on textiles. Photocatalysis in agriculture is another direction in which nanomaterials can play an important role. Different nanostructures of titanium dioxide (TiO_2) and zinc oxide (ZnO) have been widely studied as photocatalysts. Chemicals present in pesticides are transformed in relatively harmless molecules such as CO_2, N_2 and H_2O. Under progress is also the removal of pesticides and herbicides on plants and the soil through photocatalysis (Biswal *et al*., 2012).

Limitations

a) Application of nano agrichemicals for crop production and protection can be realized if the nanoproducts could be economically affordable besides eco-safe as these products have to address the problems and issues of the resource-poor and marginal growers.

b) In general, vegetables are voracious nutrient mining crops and have their specific requirements thus, crop specific nano fertilizer application strategies have to be customized.

c) There is a dilemma for wide-spread embracement of the products of nanotechnology for vegetable cultivation among the growers which need to be shunned through series of tests of imperative risk assessment toolbox.

d) Moreover, a variety of socio-psychological factors are impairing the societal acceptance and stigmatization of the nanotechnology products in agriculture due to analogies drawn with genetically modified food in spite of a positivity for biomedical and environmental applications of nanotechnology.

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