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Review Article; Scope of Nanoscience and Nanotechnology in Agriculture

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ABSTRACT

Nanotechnology is the engineering of functional systems at the molecular scale, deals with particles sizes between 1 and 100 nanometer at least one dimension. Particle size reduced to nanometer length scale exhibit high surface area to volume size ratio thus showing unusual properties makes them enable for systematic applications in engineering, biomedical, agricultural and allied sectors. Nanomaterial can create from bottom up or top down approaches using physical, chemical and biological mode of synthesis. Intentionally created nanoparticles are much useful to mitigate the chronic problem of moisture retention in arid soils and enhance crop production by increasing the availability of nutrients in rhizosphere.

1.INTRODUCTION

Nanotechnology is the creation and utilization of materials, device, system, through the control of the properties and structure of the matter at the nanomatric scale [1, 2]. Nanotechnology is a novel and innovative science that attracts researchers and scientists from different disciplines, including physicists, chemists, engineers, and biologists [3-5] across the globe. Owing to its high surface area to volume size ratio, exhibit significantly novel and improved physical, chemical, and biological properties, phenomena, and functions [6], which are used in various fields such as optical devices, catalytic, bactericidal [7], electronic, sensor technology, biological labeling, cosmetics, clothing and numerous consumer products, and treatment of some cancers [8]. Nanobiotechnology may increase agriculture's potential to harvest feedstocks for industrial processes. Agro-Nano connects the dots in the industrial food chain and goes one step further down. With new nano-scale techniques of mixing and harnessing genes, genetically modified plants become atomically modified plants. Pesticides may be more precisely packaged to knock-out unwanted pests, and artificial flavorings and natural nutrients engineered to please the palate. Visions of an automated, centrally-controlled industrial agriculture can now be implemented using molecular sensors, molecular delivery. The agricultural industry is no exception. So far, the use of nanotechnology in agriculture has been mostly theoretical, but it has begun and will continue to have a significant effect in the main areas of the food industry: development of new functional materials, product development, and design of methods and instrumentation for food safety and bio-security. The effects on society as a whole will be dramatic. Nanotechnology can be used for combating the plant diseases either by controlled delivery of functional molecules or as diagnostic tool for disease detection [9].

Whenever a new technology has emerged, it has opened many vistas to be explored. The new nanotechnology with materials having unique properties than their macroscopic or bulk counter parts, has promised applications in various fields. The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. The aim is to exploit these properties by gaining control of structures and devices at atomic, molecular, and supra-molecular levels and to learn to efficiently manufacture and use these devices [10]. Nanotechnology has provided new solutions to problems in plants and food science (post-harvest products) and offers new approaches to the rational selection of raw materials, or the processing of such materials to enhance the quality of plant products. The heart of nanotechnology lies in the ability to compress the tools and devices to the nanometer range, and to accumulate atoms and molecules in to bulkier structures while the size remains very small.

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2. NANO-STRUCTURED MATERIAL CREATION

Synthesis of nanoparticles involves a number of chemical, physical, aerosol and biological methods including chemical reduction in aqueous or non-aqueous solution, micro emulsion [11], template [12], sonochemical [13], microwave-assisted [14] and fungal mediated biosynthesis of nano-particles [15]. In recent biological methods for nanoparticle synthesis is preferred over the physical and chemical owing to ecofriendly environment concern and reduced agglomeration.

3. GLOBAL FUNDING

The global nanotechnology market had been touched, approximately US$ 29 billion by 2010. The exponential growth of global investments in nanotechnology research can be directly corresponding with the number of patents filing related to technology and products developed from nanotechnology and nanoscience [16]. Global market forecasts is indicating investments of more than US$ 1880 billion in nanotechnology industries by 2015 [17].

4. APPLICATION IN AGRICULTURAL

Nanotechnology may transform the entire food industry, changing the way food is produced, processed, packaged, transported, and consumed. Nanotechnology has the prospective to modernize the agricultural research and development with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients etc. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens [18]. In the near future nano structured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants. Technology may address the challenges of growing demands for healthy and nutritionally balanced food.

However, creating a bio economy is a challenging and complex process involving the convergence of different branches of science. In the agricultural sector, nanotech research and development is likely to facilitate and frame the next stage of development of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques. While nano-chemical pesticides are already in use, other applications are still in their early stages, and it may be many years before they are commercialized. These applications are largely intended to address some of the limitations and challenges facing large-scale, chemical and capital intensive farming systems.

Zinc, magnesium and Titanium are playing direct or indirect role in the photosynthesis process [15]. The photosynthate leaches in the soil through plant root. In the rhizosphere, root exudation is a key process for carbon transfer into the soil, influencing the role of soil microbial communities in the decomposition of organic matter and in native nutrient cycling [19]. Root exudates are the substances released by roots and may affect growth and activity of soil microorganisms in the rhizosphere [20]. Root exudates act as a chemo-attractants to attract microbes towards root and have been shown to increase the mass and activity of soil microbes and fauna found in the rhizosphere [21]. Nanotechnology is one of the most important tools in modern science yet only a few attempts have been made to apply these advances for increasing crop productivity. It is possible to develop microorganisms as bionanofactories for synthesis of agriculturally important particles. These nanoparticles offer an excellent scope in developing efficient source of plant nutrients, for enhancing biomass production through increased plant metabolic activities, utilization of native nutrients by promoting microbial activities.

5. NANOTECHNOLOGY FOR MOISTURE RETENTION AND NUTRIENT MOBILIZATION

In the arid region where there is low water holding capacity of soil and low nutrient mobilization is a chronic problem. To solve this problem researcher group of Central Arid Zone Research Institute (CAZRI) undertaken to study about the effect of ZnO nanoparticles on polysaccharide and phosphatases and phytase secretion by two most important phosphatases and phytase producing organisms *Aspergillus terreus* CZR1 and *Aspergillus flavus* CZR2 [22]. Organic polymers can play important role in ecosystems by accumulating biologically important elements and also by retaining soil moisture after aggregating soil particles. Extracellular polymeric substances (EPS) play an important role in cell aggregation, cell adhesion, and biofilm formation that subsequently protect cells from a hostile environment. Furthermore, certain polysaccharides from microbial sources are surface active, and thus attempts have been made to use them as metal chelaters, emulsifiers and flocculants in industrial and environmental fields/domain. Such use of microbial polysaccharides has infused renewed interest in its production and characteristics. Worldwide efforts are being done in this direction. As Zn is the structural component of phosphatases and phytase enzymes as well as polysaccharides, it can be hypothesized that application of nano–Zn may help more secretion of polysaccharides for better soil aggregation, higher moisture retention as well as phosphatases and phytase enzymes secretion, which may be involved in phosphorous mobilizing for plant nutrition from mainly unavailable organic sources.

6.NANO-NUTRIENT

Fertilizer play pivotal role in the agriculture production up to 35 to 40% of the productivity. To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nanofertilizer might be a best alternative. Attempts have been made to synthesize nanofertilizer particulary for zinc in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nanonutrients are more efficient than ordinary fertilizer [15]. Nano-fertilizer technology is very innovative and scanty reported literature is available in the scientific journals. However, some of the reports and patented products strongly suggest that there is a vast scope for the formulation of nano-fertilizers. An enhanced production has been observed by foliar application of nano particles as fertilizer [23].

7. PRECISION FARMING

Nanotechnology supports the application of information technologies applied to the management of commercial agriculture. Precision farming's enabling technologies include satellite-positioning systems, geographic information systems, and remote sensing devices. By connecting global positioning systems with satellite imaging of fields, farm managers could remotely detect crop pests or evidence of drought. Information about these conditions would trigger an automatic adjustment of pesticide applications or irrigation levels. Dispersed throughout fields, a network of sensors would relay detailed data about crops and the soil.

These sensors would need to have nanoscale sensitivity to monitor conditions, such as the presence of plant viruses or the level of soil nutrients. Other forms of nanotechnology may directly alter agricultural practices. Nanoparticles or nanocapsules could provide a more efficient means to distribute pesticides and fertilizers, reducing the quantities of these chemicals introduced into the environment [15]. Livestock may be identified and tracked through commerce using implanted nanochips. Nanoparticles may deliver growth hormone or vaccines to livestock, or DNA for genetic engineering of plants.

8. FOOD PROCESSING

Nanotechnology may be used in agriculture and food production in the form of nanosensors for monitoring crop growth and pest control by early identification of animal or plant diseases. These nanosensors can help enhance production and improve food safety. The sensors function as external monitoring devices and do not end up in the food itself. Nanomaterials can also be introduced in or on the food itself. The effectiveness of pesticides may be improved if very small amounts are enclosed in hollow capsules with a diameter in the nanometer range which can be designed to open only when triggered by the presence of the pest to be controlled [9]. Nanopesticide residues on the food and from animal feed and veterinary medicine may end up inside the stomach but what happens then is not clear.

9. CONCLUSIONS

Nanotechnology will have large impact on rural development. Synthetic biology can revolutionize food production threatening traditional methods of agriculture. It is necessary to create international standards for nanotechnology and in addition special international organizations in the area of nanotechnologies to reduce national differences in assessing of nanotechnologies and risk governance practices. Nanotechnology can pose significant risks to food production, food distribution and healthcare systems that are poorly understood that are particularly important to a small country that can ill afford to mount the research effort required to manage the risks that are likely to emerge with the accelerating global development of nanotechnology. For these purposes it is necessary to create the research infrastructure for toxicology and risk assessment. In aspects of nanotechnology study courses it is necessary to define what kind of skills and knowledge are needed in a small, agricultural country to take advantage of nanotechnology and to manage risks that are likely to emerge with increasing commercialization of nanotechnology. Ultimately, nanotechnology innovations may enable the agricultural industry to precisely control and improve production by reducing the disease incidence and increasing the nutrient availability.

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