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A GENERAL REVIEW ON "NANOTECHNOLOGY"- A TREMENDOUS MYSTERY FOR GREEN AGRICULTURE

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ABSTRACT

The application of nanomaterials in agriculture aims in particular to reduce applications of plant protection products, minimize nutrient losses in fertilization, and increase yields through optimized nutrient management. Nanotechnology devices and tools, like Nano capsules, nanoparticles and even viral capsids, are examples of uses for the detection and treatment of diseases, the enhancement of nutrients absorption by plants, the delivery of active ingredients to specific sites and water treatment processes. The use of target-specific nanoparticles can reduce the damage to non-target plant tissues and the amount of chemicals released into the environment. Nanotechnology derived devices are also explored in the field of plant breeding and genetic transformation. Nanomaterials and nanostructures with unique chemical, physical, and mechanical properties like electrochemically active carbon nanotubes, nanofibers and fullerenes have been recently developed and applied for highly sensitive bio-chemical sensors. The present article review and reveals the need, importance over nanotechnology, Nano sensors, Over the upliftment of agriculture. Nanotechnology in agriculture has gained momentum in the last decade with an abundance of public funding, but the pace of development is modest, even though many disciplines come under the umbrella of agriculture. Nanotechnology intervention in farming has bright prospects for improving the efficiency of nutrient use through Nano formulations of fertilizers, breaking yield barriers through bio nanotechnology, surveillance and control of pests and diseases, understanding mechanisms of host-parasite interactions at the molecular level, development of new-generation pesticides and their carriers, preservation and packaging of food and food additives, strengthening of natural fibres, removal of contaminants from soil and water, improving the shelf-life of vegetables and flowers, clay-based Nano resources for precision water management, reclamation of salt-affected soils, and stabilization of erosion-prone surfaces. Nanotechnology. Scientists have been working towards exploring new applications of nanotechnology in agriculture and the food industry – if these discoveries are applied sensibly, the environment, the agricultural sector and the food industry will indeed see tremendous changes for the better in the coming years.

KEYWORDS: Agriculture, Nanotechnology, environment, fertilizers, pesticides.

INTRODUCTION

Agriculture is the backbone of most of the developing countries in which a major part of their income comes from agriculture sector and more than half of the population depends on it for their livelihood. The current global population is nearly 6 billion with 50% living in Asia. A large proportion of those livings in developing countries face daily food shortages as a result of environmental impacts or political instability, while in the developed world there is a food surplus. For developing countries, the drive is to develop drought and pest resistant crops which also maximize yield. In developed countries, the food industry is driven by consumer demand which is currently for fresher and healthier foodstuffs (Anonymous, 2009). Nanotechnology helps agricultural sciences and reduce environmental pollution by production of pesticides and chemical fertilizers by using the Nano particles and Nano capsules with the ability to control or delayed delivery, absorption and more effective and environmentally friendly and production of Nano-crystals to increase the efficiency of pesticides for application of pesticides with lower dose. They can also be used to alter the kinetic profiles of drug release, leading to more sustained release of drugs with a reduced requirement for frequent dosing (Sharon *et al*., 2010). Among the different diseases, the viral diseases are the most difficult to control, as one has to stop the spread of the disease by the vectors. These nano-based diagnostic kits not only increase the speed of detection but also increase the power of the detection (Prasanna, 2007). 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. There are new challenges in this sector including a growing demand for healthy, safe food, an increasing risk of disease and threats to agricultural and fishery production from changing weather patterns (Hager, 2011). However, creating a bio economy is a challenging and complex process involving the convergence of different branches of science.

Defining nanotechnology in agriculture

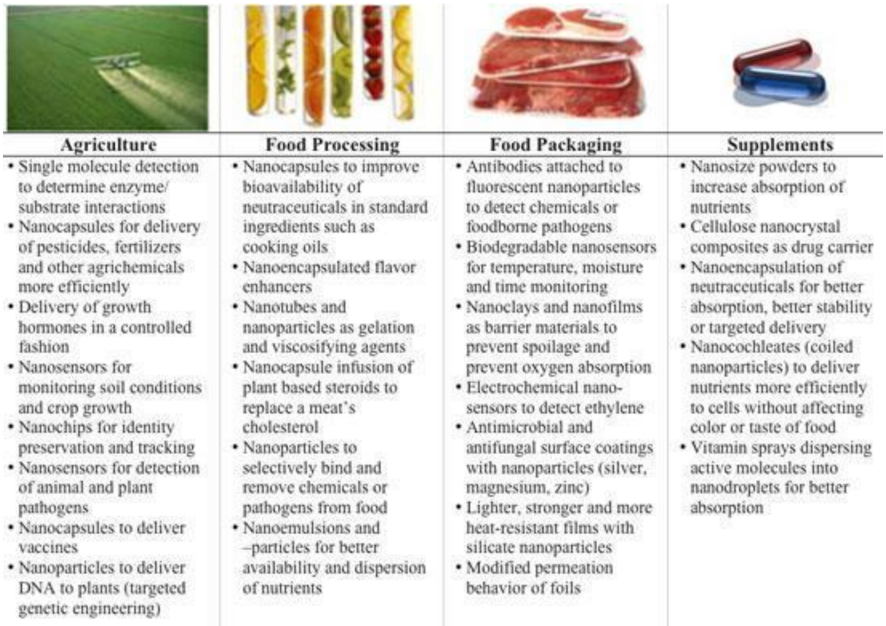
Nanotechnology is defined by the US Environmental Protection Agency, as the science of understanding and control of matter at dimensions of roughly 1–100 nm, where unique physical properties make novel applications possible. This definition is slightly rigid with regard to size dimensions. Greater emphasis could have been placed on the problem-solving capability of the materials. Other attempts to define nanoparticles from the point of view of agriculture include "particulate between 10 and 1,000 nm in size dimensions that are simultaneously colloidal particulate".

Ultimately, nanotechnology could be described as the science of designing and building machines in which every atom and chemical bond is precisely specified. It is not a set of particular techniques, devices, or products, but the set of capabilities that we will have when our technology comes near the limits set by atomic physics. Nanotechnology aims at achieving for control of matter what computers did for our control of information. For Drexler, the ultimate goal of nanomachine technology is the production of the "assembler". The assembler is a nanomachine designed to manipulate matter at the atomic level. The burgeoning applications of nanotechnology in agriculture will continue to rely on the problem-solving ability of the material and are unlikely to adhere very rigidly to the upper limit of 100 nm. This is because nanotechnology for agricultural applications will have to address the large-scale inherent imperfections and complexities of farm production systems (eg, extremely low input use efficiency), that might require nanomaterials with flexible dimensions, which nevertheless perform tasks efficiently in agricultural production systems. This is in contrast with nanomaterials that might be working well in well-knit factory-based production systems.

THIS PRESENT PAPER REVIEW AND REVEALS THE IMPORTANCE OF NANOSCIENCE RESEARCH IN AGRICULTURE AND FOOD SCIENCE

Contribution of nanoscience research in agriculture will be in the following areas:

- Food safety and bio security
- Material science
- Food processing and product development



NANO-PARTICLES CONTROLLING THE PLANT DISEASES

Some of the Nano particles that have entered into the arena of controlling plant diseases are nanoforms of carbon, silver, silica and alumina-silicates.

NANOPARTICLES FOR THE CONTROL OF DISEASE AND PEST INCIDENCES IN PLANTS

Nanoparticles of defined concentrations could be successfully used for the control of various plant diseases caused by several phytopathogens.

Nano silver

Nano silver is the most studied and utilized Nano particle for bio-system. It has long been known to have strong inhibitory and bactericidal effects as well as a broad spectrum of antimicrobial activities. Silver nanoparticles, which have high surface area and high fraction of surface atoms, have high antimicrobial effect as compared to the bulk silver. Antifungal effectiveness of colloidal Nano silver (1.5 nm average diameter) solution, against rose powdery mildew caused by *Sphaerotheca pannosa* Var *rosae*. It is a very wide spread and common disease of both green house and outdoor grown roses. It causes leaf distortion, leaf curling, early defoliation and reduced flowering. Double capsulized Nano silver was prepared by chemical reaction of silver ion with aid of physical method, reducing agent and stabilizers. They were highly stable and very well dispersive in aqueous solution. It eliminates unwanted microorganisms in planter soils and hydroponics systems. It is being used as foliar spray to stop fungi, moulds, rot and several other plant diseases. Moreover, silver is an excellent plant-growth stimulator.

Nano alumni-silicate

Leading chemical companies are now formulating efficient pesticides at Nano scale. One of such effort is use of alumni-silicate Nano tubes with active ingredients. The advantage is that alumni-silicate nanotubes sprayed on plant surfaces are easily picked up in insect hairs. Insects actively groom and consume pesticide-filled nanotubes. They are biologically more active and relatively more environmentally-safe pesticides. Silica nanoparticles have shown that mesoporous silica Nano particles can deliver DNA and chemicals into plants thus, creating a powerful new tool for targeted delivery into plant cells.

Titanium dioxide (TiO2) nanoparticles

Titanium dioxide (TiO2) is a non-toxic white pigment widely used in the manufacture of paints, study, ink, cosmetics, ceramics, leather, etc. and is a very strong disinfectant as compared to chlorine and ozone. Since TiO2 is harmless, it is approved for use in food products up to 1% of product final weight. TiO2 photocatalyst technique has great potential in various agricultural applications, including plant protection since it does not form toxic and dangerous compounds and possesses great pathogen disinfection efficiency. Scientists have been trying to improve the phytopathogenic disinfection efficiency of TiO2 thin films by dye doping and other suitable methods (Yao *et al*., 2009).

Carbon nanomaterials

Among the various engineered nanomaterials, carbon based nanomaterials (such as single walled **carbon nanotubes** (SWCNTs), multi walled **carbon nanotubes** (MWCNTs), Bucky balls, graphene, etc.), occupy a prominent position in various Nano-biotechnology applications. Increased use and exposure to carbon nanomaterials could cause environmental concerns. Hence, it is extremely important to systematically study the effects that carbon nanomaterials in plants occupy a major component of the food chain.

Magnetic nanoparticles

The scope of magnetic nanoparticles for site-targeted delivery of drugs has been exploited widely in biomedicine for the treatment of various diseases (Mornet *et al*., 2004; Jurgons *et al*., 2006). However, in plant biology, such an application is still in its budding stage. Magnetic-based nanomaterials could be utilized for site-targeted delivery of systemic plant protection chemicals for the treatment of diseases that affect only specific regions of plants. If the movement of internalized magnetic nanomaterials could be tracked externally using high power external magnets, then it would be possible to direct them to specific areas where the chemicals need to be released. The advantage of using carbon-based nanomaterials (such as SWCNTs and MWCNTs) functionalized with magnetic Nano particles is that the internal space allows filling of suitable plant protecting chemicals and the functionalized magnetic Nano particles allow external control of the movement of Nano carriers inside the plant system.

NANOFORMULATIONS FOR THE CONTROL OF PLANT DISEASES

Nanotechnology provides new ways for improving and modifying existing crop management techniques. Plant nutrients and plant protecting chemicals are conventionally applied to crops either by spraying or broadcasting. Due to problems such as leaching of chemicals, degradation by photolysis, hydrolysis and microbial degradation, only a very low concentration of chemicals which is much below the required minimal effective concentration, reach the target site of crops.

NANOTECHNOLOGY FOR DETECTING PLANT DISEASES

A need for detecting plant disease at an early stage so that tons of food can be protected from the possible outbreak, has tempted nanotechnologists to look for a Nano solution for protecting the food and agriculture from bacteria, fungus and viral agents. A detection technique that takes less time and that can give results within a few hours, that are simple, portable and accurate and does not require any complicated technique for operation so that even a simple farmer can use the portable system. If an autonomous Nano-sensors linked into a GPS system for real-time monitoring can be distributed throughout the field to monitor soil conditions and crop, it would be of great help. The union of biotechnology and nanotechnology in sensors will create equipment of increased sensitivity, allowing an earlier response to environmental changes and diseases.

PLANT PATHOGENS IN BIOSYNTHESIS OF NANOPARTICLES

The research on nanoscience and nanotechnology essentially involves preparation and use of nanoparticles of various elements and compounds. Among various uses, nanoparticles are also being used as antimicrobial agents for plant disease management. Formation of nanoparticles can be achieved via several processes which may be either physical or chemical.

Fungi

Fungi are relatively recent in their use in synthesis of nanoparticles. There has been a shift from bacteria to fungi to be used as natural 'Nano factories' owing to easy downstream processing, easy handling (Mandal *et al*., 2006) and their ability to secrete a large amount of enzymes. However, fungi being eukaryotes are less amenable to genetic manipulation compared to prokaryotes. Therefore, any alteration of fungi at genetic level for synthesis of more nanoparticles would not be so easy. It is important to know the mechanism of synthesis of nanoparticles in microbial systems to get better control over shape, size and other desired properties of the synthesized nanomaterials.

Bacteria

Among microbes, prokaryotes have received the most attention for biosynthesis of nanoparticles (Mandal *et al*., 2006). Bacteria have been used to biosynthesize mostly silver, gold, FeS and magnetite nanoparticles and quantum dots of cadmium sulphide (CdS), zinc sulphide (ZnS) and lead sulphide (PbS).

Plant virus

Plant virus especially spherical/icosahedra viruses represent the examples of naturally occurring nanomaterials or nanoparticles. The smallest plant viruses known till date is satellite tobacco necrosis virus measuring only 18 nm in diameter (Hoglund, 1968). Plant viruses are made up of single or double stranded RNA/DNA as genome which is encapsulated by a protein coat. The protein coat/shell structurally and functionally appears like a container carrying the nucleic acid molecule as cargo from one host to another. Their ability to infect, deliver nucleic acid genome to a specific site in host cell, replicate, package nucleic acid and come out of host cell precisely in an orderly manner have necessitated them to be used in nanotechnology. A complete review on use of plant viruses as bio templates for nanomaterials and their application has been done recently by Young *et al*. (2008).

Overview of nanotechnology research activities in the agricultural sector

The application of nanomaterials in agriculture aims in particular to reduce applications of plant protection products, minimize nutrient losses in fertilization, and increase yields through optimized nutrient management.

Despite these potential advantages, the agricultural sector is still comparably marginal and has not yet made it to the market to any larger extent in comparison with other sectors of nanotechnology application.

Nanotechnology devices and tools, like Nano capsules, nanoparticles and even viral capsids, are examples of uses for the detection and treatment of diseases, the enhancement of nutrients absorption by plants, the delivery of active ingredients to specific sites and water treatment processes. The use of target-specific nanoparticles can reduce the damage to non-target plant tissues and the amount of chemicals released into the environment.

Nanotechnology derived devices are also explored in the field of plant breeding and genetic transformation.

The potential of nanotechnology in agriculture is large, but a few issues are still to be addressed, such as increasing the scale of production processes and lowering costs, as well as risk assessment issues. In this respect, particularly attractive are nanoparticles derived from biopolymers such as proteins and carbohydrates with low impact on human health and the environment. For instance, the potential of starch-based nanoparticles as nontoxic and sustainable delivery systems for agrochemicals and bio stimulants is being extensively investigated.

Nanomaterials and nanostructures with unique chemical, physical, and mechanical properties – e.g. electrochemically active carbon nanotubes, nanofibers and fullerenes – have been recently developed and applied for highly sensitive bio-chemical sensors. These Nano sensors have also relevant implications for application in agriculture, in particular for soil analysis, easy bio-chemical sensing and control, water management and delivery, pesticide and nutrient delivery.

In recent years, agricultural waste products have attracted attention as source of renewable raw materials to be processed in substitution of fossil resources for several different applications as well as a raw material for nanomaterial production. "Nano composites based on biomaterials have beneficial properties compared to traditional micro and macro composite materials and, additionally, their production is more sustainable. Many production processes are being developed nowadays to obtain useful nanocomposites from traditionally harvested materials.

Commercial applications of nanotechnology in the agricultural sector

From a commercial perspective, existing agro-chemical companies are investigating the potential of nanotechnologies and, in particular, whether intentionally manufactured Nano-size active ingredients can give increased efficacy or greater penetration of useful components in plants.

The definition of nanomaterials that is adopted by the EU. One crucial point related to the EU definition is the possibility that non-active substances already used for many decades in commercial products formulations will fall within the scope of the Nano definition, although not intentionally developed as nanoparticles or having specific Nano-scale properties. Nanoscale formulants (e.g. clay, silica, polymers, pigments, macromolecules) have been used for many decades and are also ubiquitous in many daily household products.

Public acceptance of nanotechnology

Application of nanotechnology is essential, given the millions of people worldwide who continue to lack access to safe water, reliable sources of energy, health care, education, and other basic human development needs. Since 2000, the United Nations Millennium Development Goals have set targets for meeting these needs. In recent years, an increasing number of government, scientific, and institutional reports have concluded that nanotechnology could make a significant contribution to alleviating poverty and achieving the Millennium Development Goals, but with a caution on the potential risks of nanotechnology for developing countries. In a public opinion survey, respondents in the USA did not consider the risks and benefits of nanotechnology independently, and perceived nanotechnology as relatively neutral, less risky, and more beneficial than a number of other technologies, such as genetically modified organisms, pesticides, chemical disinfectants, and human genetic engineering. On the other hand, it was seen as more risky and less beneficial than solar power, vaccination, hydroelectric power, and computer display screens.

Human resource requirements

To be successful in the novel emerging field of agricultural nanotechnology, human resources must be well trained to experiment, innovate, assess, interpret, and successfully assimilate the theory, tools, and techniques of nanotechnology for its application in agriculture. Presently, nanotechnology is taught in several engineering and traditional institutions at both the undergraduate and postgraduate levels. Their curricula and degree programs cater to the needs of industry and industry-oriented institutions. Nanotechnology teaching programs in engineering and traditional institutions do not train their students to handle the issues critical to agriculture. For example, the intricate relationships that interplay in the components of life (i.e., soil, plants, animals, and humans) and the effect of nanomaterials on the food chains, the food web, and farm wastes do not get sufficient coverage in the courses run by technical institutions. There is an urgent need to develop human resources with an understanding of the complexities of the agricultural production system to serve nanotechnology applications in agriculture successfully. By and large, agricultural education has not been able to attract sufficient numbers of brilliant minds the world over, while personnel from kindred disciplines might lack an understanding of agricultural production systems. Instruction programs in agricultural nanotechnology, if initiated, might fill this void by fulfilling the twin goals of attracting brilliant learners and developing a body of skilled farm-focused personnel.

CONCLUSION

The opportunity for application of nanotechnology in agriculture is prodigious. Research on the applications of nanotechnology in agriculture is less than a decade old. Nevertheless, as conventional farming practices become increasingly inadequate, and needs have exceeded the carrying capacity of the terrestrial ecosystem, we have little option but to explore nanotechnology in all sectors of agriculture. It is well recognized that adoption of new technology is crucial in accumulation of national wealth Nanotechnology promises a breakthrough in improving our presently abysmal nutrient use efficiency through nan formulation of fertilizers, breaking yield and nutritional quality barriers through bio nanotechnology, surveillance and control of pests and diseases, understanding the mechanism of host-parasite interactions at the molecular scale, development of new-generation pesticides and safe carriers, preservation and packaging of food and food additives, strengthening of natural fibre, removal of contaminants from soil and water bodies, improving the shelf-life of vegetables and flowers, and use of clay minerals as receptacles for Nano resources involving nutrient ion receptors, precision water management, regenerating soil fertility, reclamation of salt-affected soils, checking acidification of irrigated lands, and stabilization of erosion-prone surfaces, to name a few. Revisiting our understanding of the theoretical foundations of the agricultural production system along the geosphere (pedosphere)-biosphere-atmosphere continuum coupled with application of advanced theories like the theory of chaos and string theory may open up new avenues. Nanotechnology requires a thorough understanding of science, as well as fabrication and material technology, in conjunction with knowledge of the agricultural production system. The rigor of this challenge might attract brilliant minds to choose agriculture as a career. To achieve success in the field, human resources need sophisticated training, for which new instruction programs, especially at the graduate level, are urgently needed.

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