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Applications of Nanotechnology in Agricultural and their Role in Disease Management

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ABSTRACT

Agriculture provides food for humans, directly and indirectly. As world population is increasing, it is necessary to use the modern technologies such as bio and nanotechnologies in agricultural sciences. Nanotechnology has been defined as relating to materials, systems and processes which operate at a scale of 100 nm or less. Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural products. Nanotechnology will revolutionize agriculture and food industry by innovation new techniques such as: Precision farming techniques, enhancing the ability of plants to absorb nutrients, more efficient and targeted use of inputs, disease detection and control diseases, withstand environmental pressures and effective systems for processing, storage and packaging.

Key words: Nanotechnology, agricultural, crop protection, disease, particle

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.

NANOTECHNOLOGY SCIENCE

Nanotechnology is an interdisciplinary field that has been entered in different range of applied sciences such as chemists, physicists, biologists, medical doctors and engineers. Nanotechnology has been provisionally defined as relating to materials, systems and processes which operate at a scale of 100 nm or less. A nanometer is one billionth of a meter. Overall nano refers to a size scale between 1 and 100 nm. For comparison, the wavelength of visible light is between 400 and 700 nm. A leukocyte has the size of 10000 nm, a bacteria 1000-10000 nm, virus 75-100 nm, protein 5-50 nm, deoxyribonucleic acid (DNA) ~2 nm (width) and an atom ~0.1 nm. Nanotechnology considers the topics with viruses and other pathogens scale. So, has high potential for identify and eliminate pathogens (Predicala, 2009; Prasanna, 2007).

AGRICULTURE AND NANOTECHNOLOGY

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. 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 (Joseph and Morrison, 2006). The effects on society as a whole will be dramatic. Recent advances in materials science and chemistry have produced mastery in nano particle technology, with wide ramifications in the field of agriculture. One area in particular is that of the cotton industry where current techniques of spinning cotton are quite wasteful. From harvesting the cotton to finalizing the fabric it's made into, over 25% of the cotton fibre is lost to scrap or waste (Kumar, 2009).

AREAS OF NANOSCIENCE RESEARCH IN AGRICULTURE AND FOOD SCIENCE

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

- Food safety and biosecurity
- 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 alumino-silicate: Leading chemical companies are now formulating efficient pesticides at nano scale. One of such effort is use of alumino-silicate nano tubes with active ingredients. The advantage is that alumino-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 (TiO_2) nanoparticles: Titanium dioxide (TiO_2) 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 TiO_2 is harmless, it is approved for use in food products upto 1% of product final weight. TiO_2 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 TiO_2 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), buckyballs, 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 'nanofactories' 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).

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