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Nanotechnology in Agriculture and Food Production

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ABSTRACT

Agriculture provides food for humans, directly and indirectly. Given the increasing world population, 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 nanometers (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 novation 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. Efficiency of medicine increases by use of nano particle in animal sciences. Silver and iron nano particle are used in the treatment and disinfection of livestock and poultry. Levels of environment pollution can be evaluation quickly by nano smart dust and gas sensors.

Keywords: Nanotechnology, agriculture, food, quality, precision farming.

INTRODUCTION

Importance of agriculture to all human societies is characterized more than ever with increasing world population. The first and most important need of every human is needs to food, and food supply for humans associated with agriculture directly and indirectly. Growth of the agricultural sector as a context for development objectives is seen as essential in developing countries. Now, after years of green revolution and decline in the agricultural products ratio to world population growth, it is obvious the necessity of employing new technologies in the agriculture industry more than ever. Modern technologies such as bio and nanotechnologies can play an important role in increasing production and improving the quality of food produced by farmers. Many believe that modern technologies will secure growing world food needs as well as deliver a huge range of environmental, health and economic advantages (Wheeler, 2005). Food security has always been the biggest concern of the mankind. Nations, communities and governments have been struggling with the issue since long. Recent decades have seen even bigger challenges on this front. The future looks even bleaker with food shortage issue looming large. The challenge is how to feed the growing population by producing more on a stagnant or shrinking landscape; with lesser input costs and with lesser hazards to the eco-system. (Anonymous, 2009).

In between, nanotechnology has proved its place in agricultural sciences and related industries, as an interdisciplinary technology and a pioneer in solve problems and lacks. Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural products. The use of nanotechnology in agriculture and forestry will likely have environmental benefits (Froggett, 2009). Farm applications of nanotechnology are also commanding attention. Nano materials are being developed that offer the opportunity to more efficiently and safely administer pesticides, herbicides, and fertilizers by controlling precisely when and where they are released (Kuzma and VerHage, 2006). Nanotechnology as a new powerful technology has the ability to create massive changes in food and agricultural systems. Nanotechnology is able to introduce new tools for use in cellular and molecular biology and new materials to identify plant pathogens. Hitherto numerous applications of nanotechnology in agriculture, food and animal sciences, has been proposed. Use of nanotechnology in agriculture and food industry can revolutionize the sector with new tools for disease detection, targeted treatment, enhancing the ability of plants to absorb nutrients, fight diseases and withstand environmental pressures and effective systems for processing, storage and packaging. 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 (Sharon *et al.*, 2010). Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. In the near future nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides,

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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 (Joseph and Morrison, 2006).Nanotechnology as a powerful technology allows us to have a look at the atomic and molecular level, and able to create nanometer-scale structures. Nanotechnology in agriculture and food production, causing the agricultural land returned to its normal position, greenhouse construction with high performance and productivity, prevent extinction and destruction of plants and animals species, and overall nanotechnology provides the efficiency of the agricultural for higher population. In the agricultural sector, nanotechnology 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. Precision agriculture means that there is a system controller for each growth factor such as nutrition, light, temperature, etc. Available Information for planting and harvest time are controlled by satellite systems. This system allows the farmer to know, when is the best time for planting and harvesting to avoid of encountering bad weather conditions. Best time to achieve the highest yield, best use of fertilizers, irrigation, lighting and temperature are all controlled by these systems. An important nanotechnology role is the use of sensitive nuclear links in GPS systems controller. 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. This includes the fine-tuning and more precise micro-management of soils; the more efficient and targeted use of inputs; new toxin formulations for pest control; new crop and animal traits; and the diversification and differentiation of farming practices and products within the context of large-scale and highly uniform systems of production (Kumar, 2009). The relationship between nanotechnology and agricultural sciences can be investigated in the following fields: Need for security in agricultural and nutritional systems; intelligent systems for preventing and treating of plant diseases; creating new tools for progress in cellular and biological research; recycling waste obtained from agricultural. By using nanotechnology, plant growth ability increases and the best harvest time is determined to achieve the highest performance.

In recent decades, agricultural land and soil pollution with hazardous elements and compounds present in industrial and urban wastewater are the most important factors that limiting crop and food production in the world. Nanostructured catalysts are able to eliminate the harmful components of agricultural ecosystems as a safe. This topic is importance in point of view of physiological plant diseases; eliminate food poisoning, organic products and finally production of healthier products. This nanotechnology application will help to reduce pollution and to make agriculture more environmentally friendly with use of nano filters for industrial waste water treatment, nano powders for gas pollutants treatment, and nano tubes for storage clean hydrogen fuel (Anonymous, 2009).

What is 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. Targeted research and development, for understand, manipulate and measure at the materials with atomic, molecular and super molecules dimensions is called nanotechnology. Nanotechnology has been provisionally defined as relating to materials, systems and processes which operate at a scale of 100 nanometers (nm) or less. A nanometer is one billionth of a meter. Overall nano refers to a size scale between 1 nanometer (nm) and 100 nm. For comparison, the wavelength of visible light is between 400 nm 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 In this scale, physical, biological and chemical characteristics of materials have fundamentally different from each other and often unexpected actions are seen from them. Nanotechnology considers the topics with viruses and other pathogens scale. So has high potential for identify and eliminate pathogens. (Predicala, 2009; Prasanna, 2007).

Recently nano molecules obtained by nanotechnology; there is possibility manipulation on nano scale level, regulate and catalyzed on chemical reactions by these structures. Nano materials are composed of components with very small size, and these components have impacts on the properties of materials at the macro level. Nan particles can serve as ‘magic bullets’, containing herbicides, chemicals, or genes, which target particular plant parts to release their content. Nan capsules can enable effective penetration of herbicides through cuticles and tissues, allowing slow and constant release of the active substances (Perea-de-Lugue and Rubiales, 2009). This convergence of technology with biology at the nano level is called nano biotechnology. Nan biotechnology is a highly interdisciplinary field of research and is based on the cooperative work of chemists, physicists, biologists, medical doctors and engineers (Prasanna, 2007). Nano polymers and nano shells are the most important nano compounds that have many applications in different sciences. Nano polymers are three-dimensional molecules that are achieved through nano synthesis, and nano shell is a nano particle with dielectric core and very thin coating of gold.

Applications of nanotechnology in Animal Science

Nanotechnology will have a potential and ability on future approaches in veterinary and treatment of domesticated animals. Nanotechnology has the ability to provide appropriate solutions for providing food items, veterinary care and prescription medicines and vaccines for domesticated animals. Use of nano capsules for cap and protect of some particular enzymes and proteins would be effective in the livestock and poultry food rations in order to increase yield and effectiveness in the specific context. Taking certain medications such as antibiotics, vaccines, and probiotics, would be more effective in the treating infections, nutritional and metabolic disorders, when use in the nano level. Medicine use is in the nano level has multilateral properties to remove biological barriers for increase efficiency of medicine. Appropriate timing for the release of drug, self-regulatory capabilities and capacity planned are the main advantages use of nanotechnology in the drug treatment. Silver nano particles have been considered as a strong antiseptic (antibacterial and antimicrobial), and it's widely used for disinfection in the livestock and poultry places. In the cancer treatment, nano particles are connected to the membrane receptors cancer cells, and cancer cells are destroyed with increasing their temperature to 55 °C by infrared waves generated by the nano particles. Also iron nano particles destroy cancer cells by creating magnetic radiation. Breeding suitable time and cross management in livestock, requires to cost and long time in dairy cattle farms. Use of nano-tubes inside the skin of the livestock shows peak real-time of estrus and estrogen hormone, and the exact and actual time insemination (Chakravarthi and Balaji, 2010; Patil, *et al*., 2009; Scott, 2005).

Applications of nanotechnology in pests and plant diseases management

Today use of chemicals such as pesticides, fungicides and herbicides is the fastest and cheapest way to control pests and diseases. Also biological control methods are very expensive currently. Uncontrolled use of pesticides has caused many problems such as: adverse effects on human health, adverse effects on pollinating insects and domestic animals, and entering this material into the soil and water and its direct and indirect effect on ecosystems. Intelligent use of chemicals on the nano scale can be a suitable solution for this problem. These materials are used into the part of plant that was attacked by disease or pest. Also these carriers in nano scale has self-regulation, this means that the medication on the required amount only be delivered into plant tissue. Nanotechnology helps to agricultural sciences and reduce environmental pollution by production 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. Nano particles for delivery of active ingredients or drug molecules will be at its helm in near future for therapy of all pathological sufferings of plants. There are myriad of nano materials including polymeric nano particles, iron oxide nano particles and gold nano particles which can be easily synthesized and exploited as pesticide or drug delivery piggybacks. The pharmacokinetic parameters of these nano particles may be altered according to size, shape, and surface functionalization. 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). Diseases are one of the major factors limiting crop productivity. The problem with the disease management lies with the detection of the exact stage of prevention. Most of the times pesticides are applied as a precautionary manner leading to the residual toxicity and environmental hazards and on the other hand application of pesticides after the appearance of disease leads to some amount of crop losses. 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. But, once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of exact stage such as stage of viral DNA replication or the production of initial viral protein is the key to the success of control of diseases particularly viral diseases. Nano-based viral diagnostics, including multiplexed diagnostic kit development, have taken momentum in order to detect the exact strain of virus and stage of application of some therapeutic to stop the disease. Detection and utilization of biomarkers that accurately indicate disease stages is also a new area of research. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. These nano-based diagnostic kits not only increase the speed of detection but also increase the power of the detection (Prasanna, 2007). In the future, nano scale devices with novel properties could be used to make agricultural systems “smart”. For example, devices could be used to identify plant health issues before these become visible to the farmer. Such devices may be capable of responding to different situations by taking appropriate remedial action. If not, they will alert the farmer to the problem. In this way, smart devices will act as both a preventive and an early warning system. Such devices could be used to deliver chemicals in a controlled and targeted manner in the same way as nano medicine has implications for drug delivery in humans. Nano medicine developments are now beginning to allow us to treat different diseases such as cancer in animals

with high precision, and targeted delivery (to specific tissues and organs) has become highly successful (Joseph and Morrison, 2006).

Applications of nanotechnology in food industry

Oxygen is a problematic factor in food packaging, because it can cause food spoilage and discoloration. One of the applications of nanotechnology in the food industry is developing new plastic for food packaging industry. The nano particles are used in the production of these plastics. Nano particles have been found to zigzag in the new plastic, and preventing the penetration of oxygen as a barrier. In other words, the oxygen for entry into package should during longer route, and hence with the long route for oxygen molecules, food can be spoiled later. Recently, nano-coatings are produced for fruit that covering the fruits completely, and prevent of fruit weight loss and shrinkage. (Predicala, 2009). Developing smart packaging to optimize product shelf-life has been the goal of many companies. Such packaging systems would be able to repair small holes/tears, respond to environmental conditions (e.g. temperature and moisture changes), and alert the customer if the food is contaminated. Nanotechnology can provide solutions for these, for example modifying the permeation behavior of foils, increasing barrier properties (mechanical, thermal, chemical, and microbial), improving mechanical and heat-resistance properties, developing active antimicrobic and antifungal surfaces, and sensing as well as signaling microbiological and biochemical changes (Joseph and Morrison, 2006; Moraru *et al*., 2003). With coated the enzymes by nanotechnology, we can keep them away of environment and prevent of working them. Thus, the nutrients corruption will be postponed and their longevity increases. Ethylene absorbent is the most important material that is produced by nanotechnology. Absorbent ethylene nano materials, absorbs ethylene gas that is produced by fruits (fruit decay increases by ethylene gas) and increases persistence of fruit for long periods. Nano barcodes and nano processing could also be used to monitor the quality of agricultural produce. Scientists at Cornell University used the concept of grocery barcodes for cheap, efficient, rapid and easy decoding and detection of diseases. They produced microscopic probes or nano barcodes that could tag multiple pathogens in a farm which can easily be detected using any fluorescent-based equipment. This on-going project generally aims to develop a portable on-site detector which can be used by non-trained individuals (Li *et al*., 2005). With the advent of nano technology, nano based bar codes are also available which can do the same function as that of conventional bar codes, thereby helping in tracking and controlling the quality of food product and give all relevant details in minute (Prasanna, 2007). Biosensor is composed of a biological component, such as a cell, enzyme or antibody, linked to a tiny transducer, a device powered by one system that then supplies power (usually in another form) to a second system. The biosensors detect changes in cells and molecules that are then used to measure and identify the test substance, even if there is a very low concentration of the tested material. When the substance binds with the biological component, the transducer produces a signal proportional to the quantity of the substance. So if there is a large concentration of bacteria in a particular food, the biosensor will produce a strong signal indicating that the food is unsafe to eat. With this technology, mass amounts of food can be readily checked for their safety of consumption (Johnson, 2005).

Nano-fibers

Nanotechnology with use of biological, chemical and physical processes plays a role in recycling the residual materials of agricultural products to energy and industrial chemicals. For example when cotton is processed into fabric or garment, some of the cellulose or the fibers are discarded as waste or used for low-value products such as cotton balls, yarns and cotton batting. With the use of newly-developed solvents and a technique called electro spinning, scientists produce 100 nanometer-diameter fibers that can be used as a fertilizer or pesticide absorbent. These high-performance absorbents allow targeted application at desired time and location (Lang, 2003). Nano-fibers are also used for encapsulating chemical pesticides, to prevention of scattering of chemical pesticides in the environment and water and soil pollution. This technology increases the chemical pesticides durability and security applications. When the fibers are degraded through biological, chemical materials are released slowly in the soil. When hydrophobic organic pollutants are enters to the soil through water, easily absorbed by the water insoluble solids. Porous nano-polymers have a very similar to the pollutants molecules, and considered the most suitable means for separating organic pollutants of soil and water. Similar nano fiber-based fabrics are being used as a detection technology platform to capture and isolate pathogens. The nano fibers in this fabric are embedded with antibodies against specific pathogens. The fabric can be wiped across a surface and tested to determine whether the pathogens are present, perhaps indicating their presence by a change in colour (Hager, 2011).

Nano filtration

Due to big demand for freshwater in the world, developing new methods is essential for producing freshwater. The use of nano particles and nano-filtration provides possibility of refining and improving water with

speed and accuracy. Also, nano-filter has a widespread application in eliminate microbial contaminants of water. In the new method for water desalination, hot saltwater are pass on thin sheets of carbon nano tube membranes, that have small holes (nano-holes). Only the steam passes through of this holes and liquid of water, salts and other minerals remain in the membrane. Cold water containers are located in the other side of membrane, that steam is converted to liquid again with passing through it. The most important features of carbon nano tubes can be include: smaller and denser holes; allowing high flow rate passing each hole (Thorsen and Flogstad 2006).

In the processing of dairy products are also used of nano-filters. Nano-filters, provides a selective passing particles. Also nano-filtration is used to detect metabolites quality control in food industry and pathogenic factors, and is a major change in food packaging and storage (Yacubowicz and Yacubowicz, 2007).

Nanotech sensor

Smart sensors, which are obtained by nanotechnology, are the powerful tools for track detect and control with animal and plant pathogen. Detection of very small amounts of a chemical contaminant, virus, or bacteria in agricultural and food systems is envisioned from the integration of chemical, physical and biological devices working together as an integrated sensor at the nano scale. The bio analytical nano sensors either use biology as a part of the sensor, or are used for biological samples (Scott and Chen, 2003). At the University of Manitoba in Winnipeg, microelectronics and nanotechnology have been combined to create a tiny sensor that can help farmers in the early detection of grain spoilage during storage. The sensor was developed by Suresh Neethirajan, research and development engineer in the Department of Bio systems and Engineering, along with colleagues from electrical engineering, entomology and chemistry. The stand-alone sensor is the size of a dime and can detect parts per billion levels of carbon dioxide and odour-causing chemicals to determine the level and cause of spoilage. "There are two or three major insects in grain," says Neethirajan. "Each insect produces a specific chemical inside the grain bin. Similarly, if the grain is being infested with fungus, it produces different chemicals. Our particular sensor has seven chips in it and will identify which insect or fungus is causing the spoilage." The sensor also measures changes in carbon dioxide to detect incipient and ongoing deterioration of stored grains. Once the cause of spoilage is identified, a specific treatment can be used to correct the problem. "We are also looking at building the sensor to be wireless," says Neethirajan. He envisions that multiple sensors would be distributed throughout the grain to pinpoint problem areas and would communicate with a central hub. The central hub would automatically update a household computer, website, or personal mobile device such as a cellphone so that a farmer could monitor the grain on a daily basis without having to visit the grain bin. By catching and treating spoilage before it becomes severe, additional benefits might include reduced chemical usage and better grain quality (Hager, 2011).

One of the major roles for nanotechnology-enabled devices will be the increased use of autonomous sensors linked into a GPS system for real-time monitoring. These nano sensors could be distributed throughout the field where they can monitor soil conditions and crop growth. Ultimately, precision farming, with the help of smart sensors, will allow enhanced productivity in agriculture by providing accurate information, thus helping farmers to make better decisions (Joseph and Morrison, 2006).

Nano smart dust and gas sensors are used in determining the amount of pollutants and dust in the air. It is possible evaluation the presence of pollutants in the environment by these sensors (that are made by nano technology) in the few minutes (Scott and Chen, 2003).

Application of nanotechnology in agronomy

In general, precision agriculture is a new attitude in farm management. With use of nano sensors will be determined every small part of farm how much needs to fertilizer and chemical pesticides. Therefore, use of inputs will be optimal and safe products and economic efficiency is increased. Nano-sensors help to farmers in maintaining farm with precise control and report timely needs of plants. Nano sensors and nano-based smart delivery systems could help in the efficient use of agricultural natural resources like water, nutrients and chemicals through precision farming. Through the use of nano materials and global positioning systems with satellite imaging of fields, farm managers could remotely detect crop pests or evidence of stress such as drought. Once pest or drought is detected, there would be automatic adjustment of pesticide applications or irrigation levels. Nano sensors dispersed in the field can also detect the presence of plant viruses and the level of soil nutrients. Nano fertilizers will be absorbed by plants rapidly and completely. Nano encapsulated slow release fertilizers have also become a trend to save fertilizer consumption and to minimize environmental pollution. Super water adsorbents made by nanotechnology, has an important role in storage and protecting water in arid and semiarid regions. Nanotechnology has many applications in the field of agricultural machinery such as: application in machines structure and agriculture tools to increase their resistance against wear and corrosion and ultraviolet rays; producing strong mechanical components with use of nano-coating and use of bio-sensors in smart machines for mechanical-chemical weed control; production nano-

cover for bearings to reduce friction; The use of nanotechnology in production of alternative fuels and reduce environmental pollution. Nanotechnology has also shown its ability in modifying the genetic constitution of the crop plants thereby helping in further improvement of crop plants (DeRosa *et al*., 2010; Jones, 2006).

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