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APPLICATIONS OF NANOMATERIALS IN AGRICULTURE

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Introduction:

Agriculture is the backbone of developing countries, with more than 60% of the population depending on it for their livelihood. Nanotechnology has the potential to revolutionize the agricultural and food industry with novel tools for the molecular management of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients, among others. On the other hand, nanobiotechnology can improve our understanding of the biology of various crops and thus can potentially enhance yields or nutritional values, as well as developing improved systems for monitoring environmental conditions and enhancing the ability of plants to absorb nutrients or pesticides. Agricultural and food systems security, disease management delivery systems, new techniques for molecular and cellular biology, new materials for pathogen detection and protection of the environment are examples of the important links of nanotechnology to the science and engineering of agriculture and food systems.

There are new challenges in this sector including a growing demand for healthy, food safety, an increasing risk of disease and threats to agricultural production from changing weather patterns Nanobiotechnology operates at the same level with virus or disease infecting particle, and thus holds the potential for primordial detection and eradication. It also holds out the possibility that smart sensors and delivery systems will help the agricultural industry combat viruses and other crop pathogens. Long before the symptoms develop, the integrated sensing, monitoring and controlling system could detect the presence of disease and notify the farmer and activate bioactive systems such as drugs, pesticides, nutrients, probiotics, nutraceuticals and implantable cell bioreactors. In the near future, nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used.

Currently, the main thrust of research in nanotechnology focuses on applications in the field of electronics, energy, medicine and life sciences, as agriculture is not considered as potent industry. While nano-chemical pesticides are already in use, other applications are still in their early stages, and it may take many years before they are commercialized or reach the common man. 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 micromanagement 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. Nanotechnology will leave no field untouched by its ground breaking scientific innovations. 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 impact in the main areas of 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. This review is focused on modern strategies used for the management of water, pesticides, sensors, fertilizers, limitations in the use of chemical pesticides and potential of nanomaterials in sustainable agriculture management as modern approaches of nanotechnology.

Applications of Nanomaterials in Agriculture:

Nanomaterials are used in agricultural products across the supply chain including in chemicals and fertilizers, feed and supplements for farm animals, machinery and storage facilities.

Nano-pesticides :

Nanoparticles are also effective against insects and pests. Nanoparticles can be used in the preparation of new formulations like pesticides, insecticides and insect repellants. Nanotechnology has promising applications in nanoparticle gene mediated DNA transfer. It can be used to deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests. Porous hollow silica nanoparticles (PHSNs) loaded with validamycin (pesticide) can be used as efficient delivery system of water-soluble pesticide for its controlled release. Such controlled release behaviour of PHSNs makes it a promising carrier in agriculture, especially for pesticide controlled delivery whose immediate as well as prolonged release is needed for plants.

All of the leading producers of agricultural chemical, including BASF, Monsanto and Syngenta are actively researching nanotechnology for use in agriculture and pesticides and nanoscale ingredients are already on the market. In the last ten years, over 3000 patents have been filed for pesticides with nanoscale ingredients. These are mainly reformulations of existing pesticides at the nanoscale. These products are generally intended to be more targeted in delivery, more toxic, to have greater persistence on leaves and to allow reduced quantities of chemicals to be used with greater effect.

Nanoencapsulation and microemulsions :

Microencapsulations are designed to improve delivery to the target pest, enhance herbicide transport through stubble, reduce adsorption and increase herbicide longevity in soil due to the gradual release and diffusion of active ingredients from the capsule. Products such as Subdue MAXX, a fungicide for turf available in Australia, are characterised as microemulsions, however, scientists at the University of Vienna have determined that they are actually nanoscale emulsions. It appears the term microemulsion is commonly being used as a term for formulations containing organic nanoparticles.

Nanotechnology in irrigation water filtration:

The emerging technologies that will benefit farmers all over world, especially in developing countries include several nanomaterials which are considered economically effective in purification of irrigation water. Nano-enabled water treatment techniques based on membranes filters derived from carbon nanotubes, nanoporous ceramics, and magnetic nanoparticles inspite using chemicals and UV light are common in traditional water treatment. Filters made from carbon nanotube could be employed in removing contaminants and toxicants from potable water. Carbon nanotube fused mesh that can remove water-borne pathogens, heavy metals like lead, uranium and arsenic has been suggested by researchers. Employing nanoceram filter with positive charge can trap bacteria and viruses with negative charge. This sophisticated filtering machine removes microbial endotoxins, genetic materials, pathogenic viruses, and micro-sized particles.

Detoxification or remediation of harmful pollutants:

Using synthetic clay nanomineral does not require expensive laboratory equipment for arsenic removal. The water to be filtered is percolated through a column of hydrotalcite (synthetic clay mineral). This technology can be coupled with leaching through porous pots or filter candles, the technology available in many developing countries to filter organisms from drinking water. Zinc oxide nanoparticles can be used to remove arsenic using a point-of-source purification device. Nanoscale zero-valent iron is the most widely used the set of nanomaterials that could be deployed to remediate pollutants in soil or groundwater. Other nanomaterials that could be used in remediation include nanoscale zeolites, metal oxides, carbon nanotubes and fibers, enzymes, various noble metals (mainly as bimetallic nanoparticles) and titanium dioxide. Nanoparticle filters can be used to remove organic particles and pesticides (for example, dichorodiphenyltrichloroethane (DDT), endosulfan, malathion and chlorpyrifos) from water. A variety of nanoparticle filters have been used in remediation of waste sites in developed countries.

Nanotechnology in organic farming :

Organic farming has been a long-desired goal to increase productivity (that is, crop yields) with low input (that is, fertilizers, pesticides, herbicides among others) through monitoring environmental variables and applying targeted action. Organic farming makes use of computers, GPS systems, and remote sensing devices to measure highly localized environmental conditions, thus determining whether crops are growing at maximum efficiency or precisely identifying the nature and location of problems. By using centralised data to determine soil conditions and plant development, seeding, fertilizer, chemical and water use can be fine-tuned to lower production costs and potentially increase production all benefiting the farmer. Precision farming can also help to reduce agricultural waste and thus keep environmental pollution to a minimum.

Nanoparticles and plant disease control:

Some of the nano particles that have entered into the arena of controlling plant diseases are nanoforms of carbon, silver, silica and alumino-silicates. At such a situation, nanotechnology has astonished scientific community because at nano-level, material shows different properties. The use of nano size silver particles as antimicrobial agents has become more common as technology advances, making their production more economical. Since silver displays different modes of inhibitory action to microorganisms, it may be used for controlling various plant pathogens in a relatively safer way compared to commercially used fungicides. Silver is known to affect many biochemical processes in the microorganisms including the changes in routine functions and plasma membrane. The silver nanoparticles also prevent the expression of ATP production associated proteins. In a nutshell, the precise mechanism of bio molecules inhibition is yet to be understood.

Potential Benefits of Nanotechnology Applications:

Currently the research and development pipeline has the potential to make agriculture more efficient, increase yields and product quality, and thereby increasing nutriational benefits. Developed countries are using or testing nanosensors and nanoagricultural 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 nanosensors, 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; as well as nanocoatings and films, nanoparticles, and quantum dots. There are several reports on the great potential of agricultural and food nanotechnology in developing countries. Promising nanotechnology applications address low use efficiency of agricultural production inputs and stress of drought and high soil temperature. Nanoscale agrichemical formulations can increase efficiency use and decrease environmental losses. Nanoporous materials capable of storing water and slowly releasing it during times of water scarcity could also increase yields and save water. Researchers have shown that applying nanotechnology to reduce the effects of aflatoxin (a fungal toxin) increases the weight of food animals. The potential for nanotechnology in agriculture continues to grow that 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 presented 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. Carbamate pesticides used in a variety of field crops are completely mineralized in the presence of ZnO and TiO_2, dichloropyrifos being an example of an often used pesticide. Apart from nanoparticles, there are reports on the use of nanotubes and nanostructures thin films for degrading pesticides.

Conclusions:

Nanotechnology applications have the potential to change agricultural production by allowing better management and conservation of inputs to plant production. Researchers in nanotechnology can do a lot to benefit society through applications in agriculture and food systems. Introduction of any new technology always has an ethical responsibility associated with it to be apprehensive to the unforeseen risks that may come along with the tremendous positive potential. Public awareness about the advantages and challenges of nanotechnology will lead to better acceptance of this emerging technology. Rapid testing technologies and biosensors related to the control of pests and cross contamination of agriculture and food products will lead to applications of nanotechnology in the near future. Nanotechnology application in agriculture and food systems is still at the nascent stage and a lot more applications can be expected in the years to come. Nanoparticles present an extremely gorgeous platform for a diverse range of biological applications. As it provides the single step process for biosynthesis of nanoparticles, it attracts more researchers to go for future developments in the area of electrochemical sensor, biosensors, medicine, healthcare and agriculture. New research also aims to make plants use water, pesticides and fertilizers more efficiently, to reduce pollution and to make agriculture more environmental friendly. 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. All over the world, this technology has become the future of any country.

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