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Modern Approaches of Nanotechnology in Agriculture-A Review

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The development of technology provides a new way in all areas of living. Agriculture is considered as the oldest area which is highly essential for life of earth. Agriculture plays a crucial role in the life of an economy. The importance of agriculture in a country is to provide a Source of Livelihood, Contribution to National Income, Supply of Food and Fodder, Importance in International Trade, Marketable Surplus, Source of Raw Material, Importance in Transport, Contribution to Foreign Exchange Resources, Vast Employment Opportunities, Overall Economic Development, Source of Saving, Source of Government Income and the Basis of Economic Development. As the population growth increases the land area for agriculture is reduced. To obtain the best yield from less space technology is combined with agriculture. Various education institutions for agricultural studies are developing (*Mark Brock -Innovative Farmer of the Year 2012)*. The recent technology which finds a great leap in all the fields is 'nanotechnology'. This leads to the combination of the art of nano with agriculture.

Key words: Fabric sensors, Electrospinning, Photocatalysis, nano-fungicides, nano-pesticides.

The term 'nano' is referred as 'dwarf' in Greek language. It is of the magnitude of the order of 10^{-9}. The first level of organisms starts from a nano size. Nature evokes bioorganic molecules that form living cells which self-assemble to form human, animals. The concept of self-assembly with nano technology has a great impact in various fields ranging from biology to material science. It is commonly referred as generic technology. The experience gained from various applications could be used to revolutionize the food and agriculture technology. The usage of the nanotechnology in agriculture is no different than those in any other industry. Through the rapid distribution of nanoparticles to food products, nanoparticles will come in direct contact with virtually everyone. Scientists are finding way to improve upon current methods in every possible field. In the field of agriculture, there are still many possibilities to explore. There are various techniques used in agriculture with the application of nanotechnology. Some of them are been discussed below.

A need to increase agricultural production with limited arable land and water supply, there are several white spaces where nanotechnology may have significant impact:

1. Reduction of spray drift with aerodynamic nanoparticles for optimized deposition.
2. Controlled release for season-long treatment.
3. More efficient formulations with reduction in dose required to achieve the desired effect.
4. Combinations of multiple previously incompatible actives into a single treatment.
5. Advanced delivery systems of pesticides, herbicides, antimicrobials, fertilizers etc.,
6. Seed treatments to improve plant health and

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stress resistance

7. Encapsulation of the toxic compounds to minimize occupational exposures.
8. Improved rain fastness, photo-protection and reduced run-off.

Challenges in nanotechnology

Every new technology that arises should overcome various challenges for its better implementation. The main factor required is to create value to the customer which depends on the rate of adoption and speed of commercialization. This is likely meant to be the investment capital and the cost of processing. Care should be taken that there is no environmental and health issues during implementation.

Implementations

Precision Farming

In order to increase the yield of crops it is necessary to monitor its growth effectively. Any changes in environment will be taken care manually with the traditional techniques that are followed. The development in technology supports farmers in such a way that these factors could be predicted earlier and precautions will be made. These are done with the help of computers, global satellite positioning 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. The sensors that are been used makes use of GPS system for real time monitoring. 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.

Grain spoilage detection sensor

Grain spoilage is the major problem experienced by the farmers. This spoilage is due to the variation in the atmospheric climate and pathogens. The combination of microelectronics and nanotechnology created a sensor. This sensor helps the farmer for the detection of crop spoilage. It has the capacity to detect parts per billion levels of carbon dioxide and odour causing chemicals to determine the level and cause of spoilage. It has an inbuilt seven chips which have the ability to detect the insect or fungus causing the spoilage and can also measures the changes in carbon dioxide level. Fabric sensor is a special sensor which indicates the arrival of pathogens alone. These sensors alert the farmers about the grain spoilage via mobile phone, and begin specific remediation[1]. This method is largely helpful for avoiding the grain damage by providing preventive measures in advance.

Electrospinning

Electrospinning is a process of drawing thin fibres of nano scale by the use of electrical charge. When a sufficiently high voltage is applied, the particles gets charged and stretched. The molecular cohesion should be high to avoid a breakup. The stretching and thinning of the fiber caused by this action results in the formation of thin fibers with nanometer scale diameters[2].

For pathogen removal

Nanofibres are drawn from droplets of liquid polymer. This type of nanofibres provides a platform for controlled-release technology. These nanofibres are used to capture and isolate pathogens. Electrospinning provides an electrostatic repulsion which counteracts the surface tension. Thus the liquid droplet is stretched forming a charged liquid jet. As the jet dries a thin nanofiber is obtained which is used for pathogen removal

In cotton industry

In cotton industry current techniques of spinning cotton are quite wasteful will leads to a loss of 25% of the cotton fiber. However, electrospinning makes use of the scrap material which would be otherwise used to make products like cotton balls, yarn, and cotton batting[3]. This technique of electrospinning to spin nanofibers from cellulose makes up to 90% of the cotton material. The technique of electrospinning cellulose on the nanoscale was successfully used for the first time about two years ago.

Nano-bioprocessing

The use of natural biological process to get a compound from plant and animal waste is termed as bio-processing. Nano-bio-processing will involve in the usage of nano technology to obtain a greater efficiency[4]. The microbes in the feedstock are identified with the help of molecular probes or devices which is the application of the nanotechnology that can increase the efficiency of bioprocessing. Other applications include the combination of nanoscale devices with catalytic domains to achieve in-vitro catalysis.

Bioanalytical nanosensor

Bio analytical nanosensor uses biology as a part of the sensor or used for biological samples. Detection of very small amounts of a chemical contaminant, virus, or bacteria in agriculture is a tedious process. The integration of chemical, physical and biological devices working together as an integrated sensor at the nanoscale is used to make this detection easier[5]. The Integrated Pest Management (IPM) approach is used widely which reduces the pesticide usage. This technique informs the farming to apply the pesticides only when the plants are in need. It is determined based on the scouting for pests. Timing and extent of irrigation or fertilization for various areas of the plant crop are determined by scouting. Many of these tasks could be simplified through nanotechnology.

Photocatalysis

Organic pesticides can be degraded through a process called photocatalysis. It is the process of changing in the rate of chemical reactions or their generation under the action of light in the presence of substances that absorb light energy. When a semiconductor surface is exposed with energy greater than its band gap, it excites electron from valence band to the conduction band. This produces electron hole pair which has very short life span. It depends a lot on the effective surface area of the photocatalyst and for reaction with the dissociated organic contaminant. Nanotechnology can be used for the removal the harmful toxic pesticides and increases the fertility of the soil. Nanoparticles and nanowires provide a large surface which makes them available for photocatalysis[6]. The end product of photocatalysis is carbon dioxide which escapes into the atmosphere, water and mineral salt which add fertility to the soil.

Nano-fungicide

Sliver nano-particles are used as fungicides. Silver nano-particles have been known as a kind of antibiotic. When seeds are coated with silver nano-particles of about 50nm, they provide a good germination like other untreated seeds. Since no significant difference has been observed by the use of silver nano-particles when compared to other fungicides it can be an alternative to conventional fungicides for protecting seeds against fungi[7]. Nano-treated seeds reduce the cost of agricultural production and the environmental impacts of fungicides. The nano-particles generally used are biogenic silver which it is not unsafe for human consumption.

Nano pesticides

The usage of pesticides causes:

- Reduction of beneficial species,
- Drift of sprays and vapour,
- Residues in food,
- Ground water contamination,
- Resistance,
- Poisoning hazards,
- Other possible health effects.

Nano pesticides over comes these problems. Nano encapsulated pesticides contains smaller quantities of the pesticides to be used. It is effectively used without causing much damage to the environment. Several nano pesticides are developed which are biosafety and has a molecular interaction with plant, soil and environment with very limited dosage. When the nano pesticides are applied as spray or in the soil, the carrier and pesticide interact with the soil, insect, plant and atmosphere[8]. It is expected that large number of nano pesticide formulations will be introduced commercially. The environmental problems caused by overuse of the pesticides have attracted a lot of farmers to shift for the usage of nano pesticides.

Water management

As plants require limited water, timing delivery of water is essential. More water decays the roots and less water dries the roots[9]. Sensors are made by the application of nanotechnology which timely monitors what crops need more water and nutrients. These nanosensors can measure water stress on plants in an individualised and localised manner. Each plant, root system or plot of land can then be given the exact amount of water it needs, thus reducing the use of water.

Nano plant growth regulator

Nano plant growth regulator and immunity enhancer employs chemical concentrations in the order of one part per billion. It increases yields by an average of 20%, and even more for some crops. There are various plant growth regulators available which provides growth in leaf, biomass, fruit and grain separately. It increases of about 10% in both protein and sugar content of treated plant for most types of crops. Overall health of the plant is improved, making it more resistant varying

atmospheric conditions. Immunological response is increased allowing the plant to fight disease and prevent infections.

Smart delivery system

Smart Delivery Systems possess the combination of the any of the following characteristics: time-controlled, spatially targeted, self-regulated, remotely regulated, preprogrammed, or multifunctional characteristics. This system is used to avoid biological barriers to successful targeting. Smart delivery system has the capacity to monitor the delivery of insecticides, fungicides, vaccinations to animals, plants, insects, soils and the environment[10].

The following area covers the usage of smart delivery system as said by the research at the national research program for agriculture and food systems on the "smart treatment delivery systems research"

→ Develop delivery systems for biological and bioactive systems (drugs, pesticides, nutrients, probiotics, nutraceuticals and implantable cell bioreactors).

→ Develop integrated sensing, monitoring and controlling capabilities with onboard intelligence for self-regulation or remote activation for food production, storage and packaging applications.

→ Develop targeted site delivery capability from implants in animals and plants that are activated only as needed.

→ Design food nanostructure, oral delivery matrices, particulates, emulsions and nanodevices for enhanced food flavor and digestibility.

Smart system integration

Smart system integration involves a large systems integrated together to function as a single system. The technologies that are integrated are the sensing systems, reporting systems, localization systems and control systems. The logic to control the subsystems must be developed and eventually translated into a computer language.

→ The following topics are recommended as Smart Systems Integration research priorities for Agriculture and Food Systems.

→ Integrate Nano-Electromechanical Systems (NEMS) with remote receive/transmit systems (embedded on the chip, satellite interaction, global positioning systems, remote powering and biopowering).

→ Develop integrated sensing, monitoring and controlling capabilities with on board intelligence for self-regulation and remote activation for food production, storage and packaging applications.

→ Design and develop automated integrated networks for monitoring and control of animal and plant production systems, food safety and security, biochemical/biomass processing or environmental monitoring applications.

Nano barcodes

Barcodes are referred as a small symbol which is used for fast and easy identification. It is combined with nano technology to perform disease detection on a nano scale. It has the ability to tag pathogens. Nano-barcode system is a platform, multiplexed detection technology that has found applications in a variety of fields including agriculture, ecology, and hydrology, along with medicine. It contains a portable device which is powered by batteries and interfaced with laptop or computers. It is multiplexed with various pathogen detectors and has the potential to detect different pathogens simultaneously[11]. The first time demonstration of nano-barcodes is done by multiplexed detection scheme using color ratio intensity and branched DNA molecules. A portable detecting device has been developed and will enable both researchers and end farmers to detect and track multiple species in the field. The combined technology can also be used to monitor composter environment, food safety, environment pollutions etc.,

The applications of nanobarcodes include

→ DNA nanobarcoding for pathogen detection (such as Ebola and SARS)

→ Monitoring of bacterial systems

→ Can be used as a "nano-sensor" to detect water levels, soil nutrient information, and chemical levels

→ Tagging food packages (Pathogens, Temperature changes, Leaks)

→ Biomolecular tracing

→ Maximizes productivity

Impacts of nanotechnology

The success of nanotechnology is achieved in satisfying certain conditions that includes reduction of plant protection products, minimizing nutrient losses in fertilization and increasing the yield through optimized nutrient management. Its emergence gives rise to socio economic issues in terms of health and

environmental safety, consumer perception and intellectual property rights. Developing countries involves in taking the technology through various applications. But the main factors limiting the development of these applications are low investments in manpower training and in research infrastructure.

Other applications

Some of the nano application for agriculture available in market

→ Nano-capsules for delivery of pesticides, fertilizers and other agrichemicals more efficiently.

→ Delivery of growth hormones in a controlled manner.

→ Nano-sensors for monitoring soil conditions and crop growth.

→ Nano-chips for identity preservation and tracking.

→ Nano-sensors for detection of animal and plant pathogens and about quarantine purposes.

→ Nano-capsules to deliver vaccines.

→ Nano-particles to deliver DNA to plants in genetic engineering.

→ Nano-sensors for monitoring plant microenvironment and its changes and in green house production of protected cultivation.

CONCLUSION

Nanoscience, nanoengineering, nanotechnology all will have massive impact on the ultimate success of the evolving global industries of agriculture and food, over the long term. Nano technology is a vast area of development in every part of the world. It finds a great a progress in all the fields. As agriculture is the backbone of the economy and the need for crop production increases nano technology has stepped into agricultural activities which results in a leap to the crop production. Nano technology is a powerful tool for the benefits of humankind. Effective use of this valuable technology in a right path would create a new world with the best place to live in. Great opportunities exist for invention and application in global agricultural enterprise.

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