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SUSTAINABLE ECONOMIC DEVELOPMENT - INDIAN PERSPECTIVE

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EDITORIAL MESSAGE

We take great pleasure in welcoming you to our Edited Book. The immediacy of e-based publication makes it possible for us all to be fully connected to each other and to developments in our field and to be directly involved in ongoing knowledge construction.

With several economies gearing towards the end of lockdowns, it's time for organizations to implement Post-COVID-19 business recovery strategies. Although it will let organizations restore balance to an extent, total recovery from the crisis is going to be a long and strategic battle. With these concepts in mind, we invited with scholarly discussions to facilitate new ideas for business sectors. This book also stands as a platform for Students and research scholars to express their innovative business models and solutions.

We are thankful to all academicians, research scholars and students who have contributed for this edited book. We also acknowledge the valuable suggestions and support offered by our colleagues and students. We are delighted that you are joining us as readers and hope you will also join us as contributors.

Dr.K.Sasi Kumar
Editor- in -Chief

NANOTECHNOLOGY FOR A SUSTAINABLE DEVELOPMENT IN AGRICULTURE

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Abstract

Nanotechnology has shown promising potential to promote sustainable agriculture. The significant interests of using nanotechnology in agriculture includes specific applications like nanofertilizers and nanopesticides to trail products and nutrients levels to increase the productivity without decontamination of soils, waters, and protection against several insect pest and microbial diseases. This review covers the sustainability of nanotechnology in the improvement of agriculture.

Nanotechnology in agri-food production

Nanotechnology opportunities include food, agriculture and energy applications. In the food processing industries, a few of the most common usages of nanotechnology in quality monitoring of food products may be enumerated as nanosensors/nanobiosensors and bacteria identification. The nanosensors can be utilized to detect the presence of insects or fungus accurately inside the stored grain bulk in storage rooms. Researchers suggested models for use of nanobiotechnology, either on a standalone basis or through complementarity with the existing technologies. In 2004, the researchers had been able to alter rice color from purple to green. Cellular "injection" with carbon nanofibers containing foreign DNA has been used to genetically modify golden rice. Nanobiotechnology provided industry with new tools to modify genes and even produce new organisms. This is due to the fact that it enables nanoparticles, nanofibers, and nanocapsules to carry foreign DNA and chemicals that modify genes. In addition, novel plant varieties may be developed using synthetic biology (a new branch that draws on the techniques of genetic engineering, nanotechnology, and informatics).

In a recent breakthrough in this area, researchers completely replaced the genetic material of one bacterium with that from anothertransforming it from one species to another. Nanotechnology possesses the potential to augment agricultural productivity through genetic improvement of plants and animals along with cellular level delivery of genes and drug molecules to specific sites in plants and animals.

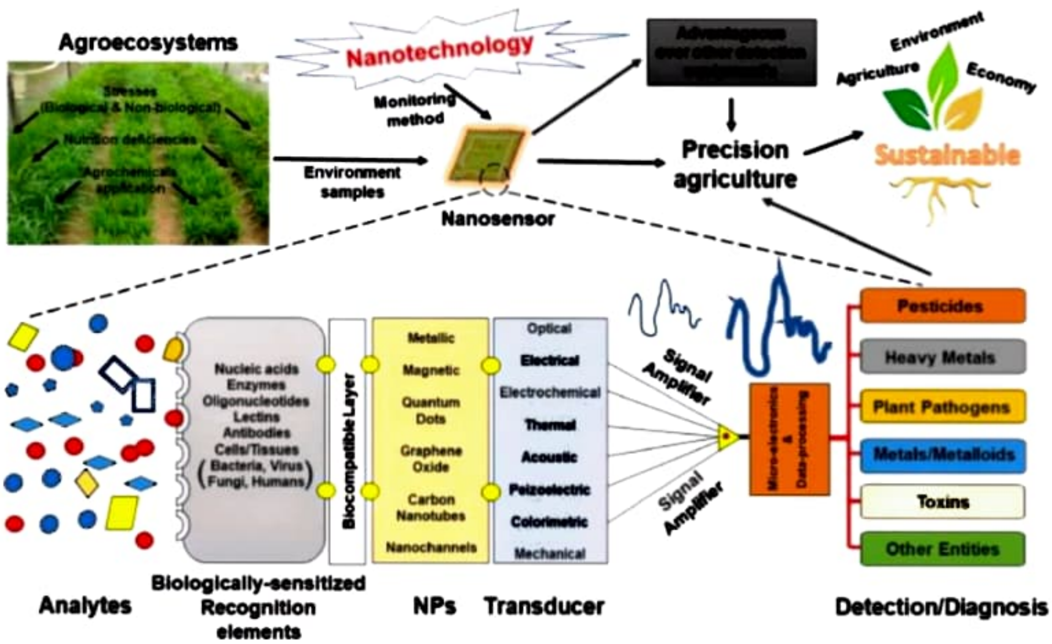
Using a medicinally rich vegetable crop, bitter melon, researchers demonstrated the accumulation of carbon-based nanoparticleFullerol ($C_{60}(OH)_{20}$) in tissues and cells of root, stem, petiole, leaf, flower and fruit at particular concentrations, as the causal factor of increase in biomass yield, fruit yield, and phytomedicine content in fruits. Fullerol treatment resulted in increases of up to 54% in biomass yield and 24% in water content. Increases of up to 20% in fruit length, 59% in fruit number, and 70% in fruit weight led to an improvement of up to 128% in fruit yield. Further, contents of two anticancer phytomedicines, cucurbitacin-B and lycopene, were enhanced up to 74% and 82%, respectively, and contents of two antidiabeticphytomedicines, charantin and insulin, were augmented up to 2 0% and 9 1%, respectively.

Chemists have successfully made DNA crystals by producing synthetic DNA sequences that can self-assemble into a series of three-dimensional triangle-like patterns. When multiple helices are attached through single-stranded sticky ends, a three-dimensional crystal is formed. This technique helps in improving important crops by organizing and linking carbohydrates, lipids, proteins, and nucleic acids to this crystal.Chemically coated mesoporous silica nanoparticles help in delivering DNA and chemicals into isolated plant cells. The coating triggers the plant to take the particles through the cell walls, where the genes are inserted and activated in a precise and controlled manner, without any toxic side or after effects. This technique has been applied to introduce DNA successfully to plants, including tobacco and corn plants.

Nanosensors/nanobiosensors in agri-food production

Nanobiosensors can be effectively used for sensing a wide variety of fertilizers, herbicide, pesticide, insecticide, pathogens, moisture, soil pH and their controlled use can support sustainable agriculture for enhancing crop productivity. Precision farming, with the help of smart sensors, could increase productivity in agriculture, as this technology provides farmers with better fertilization management, reduction of inputs, and better management of time and the environment. Nanosensors and nanobased smart delivery systems could help in the efficient use of agricultural natural resources like water, nutrients, and chemicals through precision farming. Precision farming's enabling technologies include satellite-positioning systems, geographic information systems, and remote sensing devices that could remotely detect crop pests or evidence of stress such as drought. Nanosensors dispersed in the field can also detect the presence of plant viruses and other crop pathogens, and the level of soil nutrients. Levels of environmental pollution can be evaluated quickly by nano-smart dust (the use of tiny wireless sensors and transponders) and gas sensors. Nanobarcodes and nano-processing could also be used to monitor the quality of agricultural produce. Nanotechnology-based plant regulation of hormones such as auxin helps scientists understand how plant roots adapt to their environment, especially to marginal soils.

The development of sensors/biosensors based on specific interactions makes atomic force spectroscopy more effective in detecting enzyme-inhibiting herbicides. A nanobiosensor based on an atomic force microscopy tip functionalized with the acetolactate synthase enzyme was successfully detected for the herbicide metsulfuron-methyl (an acetolactatesynthase inhibitor) through the acquisition of force curves. Bionanosensors also allow the more quantification and rapid detection of bacteria and viruses, thereby increasing the safety of the food for the customer.



Noble metal (palladium, platinum, and gold)/DNA/single-walled carbon nanotube (SWCNT) hybrid nanostructure-based gas sensor arrays were fabricated by means of inkjet printing of metal ion-chelated DNA/SWCNTs on microfabricated electrodes, followed by electroless deposition to reduce metal ions to metal. DNA served as a dispersing agent to effectively solubilize pristine SWCNTs in water and as metal ion-chelating centers for the formation of nanoparticles. The results on the sensitivity and selectivity of the gas sensors toward various gases such as H_2, H_2S, NH_3, and NO_2 indicated the enhancement of the sensitivity and selectivity toward certain analytes by functionalizing with different metal nanoparticles (eg, Pd/DNA/SWCNTs for H_2 and H_2S). The combined responses give a unique pattern or signature for each analyte by which the system can identify and quantify an individual gas.

Nanosensors are expected to impact agricultural, food, and environmental sectors. The Nanotechnology Signature Initiative "Nanotechnology for Sensors and Sensors for Nanotechnology: Improving and Protecting Health, Safety, and the Environment" is the fifth to be launched by agencies of the National Nanotechnology Initiative. Portable nanodevices can rapidly detect insects, diseases, pathogens, chemicals, and contaminants and can result in faster treatments.

Nanosensors based on using electrochemically functionalized SWCNTs with either metal nanoparticles or metal oxide nanoparticles, and metal oxide nanowires and nanotubes for gases such as ammonia, nitrogen oxides, hydrogen sulfide, sulfur dioxide, and volatile organics have potential application in monitoring agricultural pollutants for the assessment of impacts of these pollutants on biological and ecological health and in increase of crop productivity and reducing land burden. Researchers addressed the fabrication, functionalization, assembly/alignment, and sensing applications of field-effect transistors based on carbon nanotubes, silicon nanowires, and conducting polymer nanowires. Further, they evaluated how such sensors have been used for detection of various biological molecules and how such devices have enabled the achievement of high sensitivity and selectivity with low detection limits.

Nanotechnology-enabled devices will increase the use of sensors linked to global positioning systems for real-time monitoring of crops. In the field of sensor research and development, bionanotechnology is poised to make significant contributions and has the potential to radically alter the way sensors are designed, constructed, and implemented. Biomimeticnanosensor designs based on immobilized tyrosinase for determination of toxic compounds and smart biosensors for determination of mycotoxines were reported. Biosensor design showed good compatibility between membranes and enzymes without a change of the conformation of the enzyme molecule, and binding always takes place outside the enzyme active centers.

Carbon–ceramic electrode modified with multi-walled carbon nanotubes–ionic liquid nanocomposite was used for electrochemical determination of the food dyes, sunset yellow and tartrazine, in food and beverage samples.

Nanotechnology and agri-environment

The use of pesticides and fertilizers to improve food production leads to an uncontrolled release of undesired substances into the environment. Today, nanotechnology represents a promising approach to improve agricultural production and remediate contaminated soil and groundwater. Researchers reported the recent applications of nanotechnologies in agro-environmental studies, with particular attention to the fate of nanomaterials once introduced in water and soil. They showed that the use of nanomaterials improved the quality of the environment and helped detect and remediate polluted sites; however, only a small number of nanomaterials demonstrated potential toxic effects. The impact of iron nanoparticles on terrestrial plants revealed that orange–brown complexes/plaques, formed by root systems of all plant species from distinct families tested, were constituted of nanoparticles containing iron. Further, the formation of iron nanoparticles/nanocomplexes was reported as an ideal homeostasis mechanism evolved by plants to modulate uptake of desired levels of ionic iron.

Copper is an essential element in the cellular electron-transport chain, but as a free ion it can catalyze production of damaging radicals. Researchers showed using synchrotron microanalyses that common wetlands plants *Phragmites australis* and *Iris pseudoacorus* transformed copper into metallic nanoparticles in and near roots with evidence of assistance by endomycorrhizal fungi when grown in contaminated soil in the natural environment.

Converting carbon dioxide to useful chemicals in a selective and efficient manner remains a major challenge in renewable and sustainable energy research. Silver electrocatalyst converts carbon dioxide to carbon monoxide at room temperature; however, the traditional polycrystalline silver electrocatalyst requires a large overpotential. A nanoporous silver electrocatalyst enables electrochemical reduction of carbon dioxide to carbon monoxide with approximately 92% selectivity at a rate (that is, current) over 3,000 times higher than its polycrystalline counterpart under moderate overpotentials of <0.50 V. The improved higher activity is a result of a large electrochemical surface area and intrinsically higher activity compared with polycrystalline silver.

Growing and harvesting organic nanoparticles from plants represents an important step in the development of plant-based nanomanufacturing. It is a significant improvement on the exploitation of plant systems for the formation of metallic nanoparticles. An enhanced system for the production of English ivy adventitious roots and their nanoparticles by modifying GA7 Magenta boxes and identifying the optimal concentration of indole-3-butyric acid for adventitious root growth was developed. It represents a pathway for the generation of bulk ivy nanoparticles for translation into biomedical applications.Recent research has demonstrated that the adventitious roots of English ivy are responsible for the production of an adhesive compound composed of polysaccharide and spherical nanoparticles 60–85 nm in diameter. The recent advances brought into methodology for biological and ecofriendly synthesis and characterization of herbal and medicinal plant-mediated nanoparticles were reported.

Nanocomposites/nanobiocomposites

Composites made from particles of nanosize ceramics or metals smaller than 100 nm can suddenly become much stronger than predicted by existing materials-science models. For example, metals with a so-called grain size of around 10 nm are as much as seven times harder and tougher than their ordinary counterparts with grain sizes in the hundreds of nanometers. A nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm, or structures having nanoscale repeat distances between the different phases that make up the material.

Nanocomposites are polymers reinforced with small quantities (up to 5 % by weight) of nanosized particles, which have high aspect ratios and can improve the properties and performance of the polymer. Polymer composites with nanoclay restrict the permeation of gases. Examples of polymer nanocomposites incorporating metal or metal oxide nanoparticles utilized mainly for their antimicrobial action include nanozinc oxide and nanomagnesium oxide.Cellulose nanocrystals are an attractive material to incorporate into composites because they provide highly versatile chemical functionality.

In food packaging, nanocomposites focus on the development of high barrier properties against the diffusion of oxygen, carbon dioxide, flavor compounds, and water vapor. Nanoclay (montmorillonite, a hydrated alumina–silicate-layered clay consisting of an edge-shared octahedral sheet of aluminum hydroxide between two silica tetrahedral layers) minerals are found abundantly in nature and might be incorporated into the packaging films. Bionanocomposites suitable for packaging applications include starch and cellulose derivatives, poly(lactic) acid, polycaprolactone, poly(butylenesuccinate), and polyhydroxybutyrate. The most promising nanoscale fillers are layered silicate nanoclays such as montmorillonite and kaolinite (a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina octahedra).

Nanocomposites have a wide range of applications in various fields including agriculture and food packaging. The use of nanocomposites with new thermal and gas barrier properties can prolong the post-harvest life of food, and this application could facilitate the transportation and storage of food.

In dry land areas, variation in amount and distribution of rainfall mainly influences the crop production. Water sorption capacity is an important characteristic for nanoclay composite super absorbents, especially when used under rainfed condition. In this context, the water-holding capacity, water absorbency, and water-retention capacity of a zinc-coated nanoclay composite cross-linked polyacrylamide polymer developed for promotion of rainfed rice crop was reported. Water-holding capacity of the soil with nanoclay composite was 8.5% more as compared to original soil.

For agricultural applications, polymer nanocomposites are ecofriendly (ie, biodegradable and starch nanocomposites are commonly used). In this direction, the development of mulch films can be useful for farmers to retain moisture and control weeds.

Starch-based nanocomposite films reinforced with fax cellulose nanocrystals play an important role in improving the mechanical properties (tensile strength and Young's modulus) and water resistance of the starch-based materials. Synthesis and characterization of polymer nanocomposites derived from organoclay with selected thermosetting and thermoplastic polymers have been reported.

Applications of biochar include carbon sequestration, soil amendment, and sorption of several classes of undesirable components from water, soil, or industrial processes.Researchers reported developing low-dose, high-efficiency biochar–nanoparticle composites, as well as initial field trial results and detailed characterization of biochar–fertilizer composite, to highlight the potential of such biochars. The nanoporous and hydrophobic properties of biochar portend interactions with engineered nanoparticles that are being studied toward accurate nanotoxicity risk assessment. Nanocomposite films of methyl cellulose incorporated with pediocin and zinc oxide nanoparticles presented antimicrobial activity against *Staphylococcus aureus* and *Listeria monocytogenes*.

Nanotechnological applications in agrowaste reduction and high-value products such as biofuels

Currently, the discouraging energy trends and challenges are a result of overreliance on limited fossil fuels tied with ever-increasing energy demand. Among the solutions is the nanotechnology approach to help in the smooth transition to alternative and renewable energy sources. The use of nanotechnology in transesterification, gasification, pyrolysis, and hydrogenation, as well as in the reforming of biomass-derived compounds has been reported. Cellulose-based nanomaterials have been of increasing interest as potential nanoreinforcing filler into biocomposites for industrial and biomedical applications. Nanomaterials could stimulate microorganism metabolism. In such a situation, the use of nanomaterials could improve the efficiency of the lipid extraction and even accomplish it without harming the microalgae. Nanomaterials such as calcium oxide and magnesium oxide nanoparticles have been used as biocatalyst carriers or as heterogeneous catalysts in oil transesterification to biodiesel. The advances in application of nanotechnology in microalgae lipid accumulation, extraction, and transesterification were reported.

Nanotechnologies are among the appropriate technologies for the biofuels of the future. Most of the current effort in second-generation conversion to liquid biofuels is based on biomass cellulosics to ethanol and biodiesel. The future supply of biofuels must be of such a scale that nonfoodfeedstocks and new technologies are intensively employed.

Nanotechnology in organic agriculture

An International Federation on Organic Agriculture Movements Position Paper on the Use of Nanotechnologies and Nanomaterials in Organic Agriculture rejected the use of nanotechnology in organic agriculture. However, Nano Green Sciences, Inc. sells a nanopesticide that they claim is organic. Canada has banned nanotechnology in organic food production. An amendment was added to Canada's national organic rules banning nanotechnology as a "Prohibited Substance or Method".

Nanotechnology for crop improvement

An enhanced production has been observed by foliar application of nanoparticles as fertilizer. A variety of nanomaterials, mostly metal-based nanomaterials and carbon-based nanomaterials, have been exploited for their absorption, translocation, accumulation, and particularly, effects on growth and development in an array of crop plants. The positive morphological effects included enhanced germination percentage and rate; length of root and shoot, and their ratio; and vegetative biomass of seedlings in many crop plants, including corn, wheat, ryegrass, alfalfa, soybean, rape, tomato, radish, lettuce, spinach, onion, pumpkin and cucumber. Enhancement of many physiological parameters such as enhanced photosynthetic activity and nitrogen metabolism by metal-based nanomaterials in a few crops including soybean,spinach, and peanutwere also reported. Recently, researchers showed that SWCNTs containing cerium nano-particles passively transport and irreversibly localize within the lipid envelope of extracted plant chloroplasts, promoted over three times higher photosynthetic activity than that of controls, and enhanced maximum electron transport rates.Nanobiotechnology provides the tool and technological platforms to advance agricultural productivity through genetic improvement of plants and delivery of genes and drug molecules to specific sites at cellular levels. The interest is increasing with suitable techniques and sensors for precision in agriculture, natural resource management, early detection of pathogens and contaminants in food products, and smart delivery systems for agrochemicals like fertilizers and pesticides. The genetic implications of nanoparticle-induced positive changes have been validated through decreased oxidative stress to spinach chloroplast under ultraviolet-B radiation by nano-titanium dioxide, generational transmission of fullerol through seeds in riceand changes in gene expression at plant and cellular level in tomato and tobacco by multi-walled carbon nanotubes. However, there is only one report on the improvement of agronomic traits that documented increased leaf and pod dry weight and grain yield of soybean by exposure to nano-iron oxide.

Germinating maize seeds in the presence of magnetic fluid followed by exposure to electromagnetic field was observed to cause a pronounced increase in nucleic acid level due to the regeneration reactions of plant metabolism processes.

Magnetic nanoparticles coated with tetramethylammonium hydroxide led to an increase in chlorophyll-a level in maize. Use of iron oxide in pumpkin was also observed to increase root elongation that was attributed to the iron dissolution.

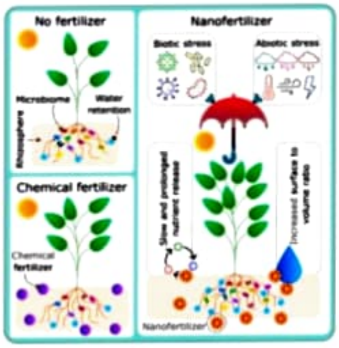
Spent tea (solid waste) could be used for the production of biodiesel, bioethanol, and also hydrocarbon fuel gases. Researchers reported three steps for the conversion of spent tea (*Camellia sinensis*) into biofuels. First of all, spent tea was gasified using cobalt nanocatalyst at 300°C and atmospheric pressure. This catalytic gasification of spent tea yielded 60% liquid extract, 28% fuel gases, and 12% charcoal. Gaseous products contain 53.03% ethene, 37.18% methanol, and 4.59% methane. In the second step of the experiment, liquid extract of spent tea obtained from gasification, on transesterification gave 4 0.79% ethyl ester (biodiesel). In the third step, *Aspergillusniger's* growth on spent tea produced 5 7.49% bioethanol. The world today is consuming several million tons of tea yearly. The present technology could be utilized to produce alternate energy.

Nano fertilizer

Nano fertilizer technology is very innovative and scant reported literature is available in the scientific journals. Substituting nano fertilizers for traditional methods of fertilizer application is a way to release nutrients into the soil gradually and in a controlled way, thus preventing autrification and pollution of water resources. Treatment with TiO_2 nanoparticles on maize had a considerable effect on growth, whereas the effect of TiO_2 bulk treatment was negligible. Titanium nanoparticles increased light absorption and photo energy transmission. In another experiment, a compound of SiO_2 and TiO_2 nanoparticles increased the activity of nitrate reductase in soybeans and intensified plant absorption capacity, making its use of water and fertilizer more efficient. Iranian researchers have produced the nano-organic iron-chelated fertilizer that is environmentally sustainable. Nanofertilizers have unique features like ultrahigh absorption, increase in production, rise in photosynthesis, and significant expansion in the leaves surface area.

Potential Benefits of Nano-fertilizers

The use of nanofertilizer leads to an increased efficiency of the elements, reduces the toxicity of the soil, to at least reach the negative effects caused by the consumption of excessive consumption of fertilizers, and reduces the frequency of application of fertilizers. The positive effect (uptake and the penetration of zinc oxide nanoparticles in the leaves) of zinc oxide nanoparticles on tomato plants opens an avenue for its potential use as a future nanofertilizer. Pot studies with foliar spray approach showed that plants sprayed with 20 mg mL^{-1} zinc oxide nanoparticle solution showed improved growth and biomass production as compared to control plants.



Fertilizers based on nanotechnology have the potential to surpass conventional fertilizers. Innovation in nanofertilizers requires a multidisciplinary approach. In nanofertilizers, nutrients can be encapsulated by nanomaterials, coated with a thin protective film, or delivered as emulsions or nanoparticles. Nanobased slow-release or CR fertilizers have the potential to increase the efficiency of nutrient uptake. Engineered nanoparticles are useful for mitigating the chronic problem of moisture retention in arid soils and enhancing crop production by increasing the availability of nutrients in the rhizosphere. Coating and binding of nano- and subnano-composites help to regulate the release of nutrients from the fertilizer capsule.[104] In this context, researchers showed that application of a nanocomposite consisting of nitrogen, phosphorus, potassium, micronutrients, mannose, and amino acids enhanced the uptake and use of nutrients by grain crops. Zinc–aluminium layered double-hydroxide nanocomposites have been employed for the controlled release of chemical compounds that act as plant growth regulators. Urea-modified hydroxyapatitenanoparticle-encapsulated Gliricidiasepium nanocomposite displayed a slow and sustained release of nitrogen over time at three different pH values.

Nanoporouszeolite based on nitrogen fertilizer can be used as alternate strategy to improve the efficiency of nitrogen use in crop production systems. As superfertilizer, carbon nanotubes were found to penetrate tomato seeds and affect their germination and growth rates. Analytical methods indicated that the carbon nanotubes penetrated the thick seed coat and supported water uptake inside seeds.[108] Encapsulation of fertilizers within a nanoparticle is done in three ways: the nutrient can be 1) encapsulated inside nanoporous materials, 2) coated with thin polymer film, or 3) delivered as particles or emulsions of nanoscale dimensions.[109] The roles of nanofertilizers in sustainable agriculture have been reported.

Conclusion

Nanotechnology has made a lot of advancements over the past decades and fairly in the field of agriculture. They have initiated new concepts of how our fields, crops, plants, and fruits can be protected and their growth can be maximized at a greater level. The research carried out in this regard has massively proved beneficial against the agenda that it began for which was bringing advancements in the field of agriculture.

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