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Nanotechnology in Agriculture: A Review

Yogesh Bhagat[1]*, K. Gangadhara[2], Chidanand Rabinal[1], Gaurav Chaudhari[1] and Padmabhushan Ugale[1]

[1]Department of Biotechnology, University of Agricultural Sciences, Dharwad, Karnataka - 580005, India.
[2]Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad, Karnataka - 580005, India.

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Nanotechnology has been extensively used in food production, plant protection, processing, packaging transportation of agricultural products and quality control and environmental management. It has great potential to make agriculture more efficient by using nanosensors and nanoagricultural chemicals. Nanopore filters, nanoceramic devices, nanofilteration, nanofeeds, nanolamination, nanodelivery systems, could precisely deliver drugs or micronutrients at the right time and to the right part of the material. Research in nanobiotechnology is advancing toward the ability to sequence DNA in nanofabricated gel free systems, which would allow for significantly more rapid DNA sequencing of crop germplasm can potentially provide highly useful information about molecular markers associated with agronomically and economically important traits. Thus, nanobiotechnology can enhance the pace of progress in molecular marker assisted breeding for crop improvement. Use of certain engineered nanoscale materials in agriculture, food and environment may have risks for human consumption and environment. The lack of sufficient scientific knowledge about key risk-assessment factors, such as nanoparticle toxicity, bioaccumulation, exposure information, or ingestion risks, causes the most concern. With the current application and advancements soon to come, nanotechnology will have a great impact on the direction that agriculture will take.

Key words: Nanosensors, Nanoparticles, Nanobiotechnology, DNA sequencing.

Agriculture is the backbone of India, with more than 60% of the population reliant on it for their livelihood. India achieved self sufficiency in food production due to green revolution during 1960s. Food security has always been the biggest concern of the mankind. Nations, communities and governments have been struggling with the issue since long. Particularly, it's a prime agenda for the developing world including India.

Agriculture sector in India contributes significantly to the national economy. Science and technology has played a significant role in increasing agricultural productivity over the years. An extensive agricultural research system with a widespread extension machinery and government policy has enabled the agriculture sector to respond to the increasing demand for agricultural produce. However, in recent decades the agricultural scenario has witnessed several challenges like declining farm profitability, depletion of natural resources, resurgence of new pests and diseases, global warming and climate change. With increasing population there is further pressure on this sector to meet the growing food demand. In order to address these issues, there is a need to focus on research, technology generation and diffusion along with human resources development. Towards this end the conventional research approaches need to be supplemented by new science and technology interventions that are

* To whom all correspondence should be addressed.
E-mail: bhagatyogesh2010@gmail.com

cost and time effective. 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[23].

Nanotechnology science

Nanotechnology is a field of applied science and technology which deals/involves in manipulating atoms and molecules to fabricate materials, devices and systems. The term nano derived from greek word "dwarf". Nanotechnology was first introduced in 1959, in a talk by the nobel prize-winning physicist, entitled "There's Plenty of Room at the Bottom" Richard Feynman proposed using a set of conventional-sized robot arms to construct a replica of themselves, but one-tenth the original size, then using that new set of arms to manufacture an even smaller set, and so on, until the molecular scale is reached. If we had many millions or billions of such molecular-scale arms, we could program them to work together to create macro-scale products built from individual molecules - a "bottom- up manufacturing" technique, as opposed to the usual technique of cutting away material until you have a completed component or product–"top-down manufacturing". In 1986, K. Eric Drexler introduced the term 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 or thousandth of a thousandth of a thousandth 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[14].

Multidisciplinary and interdisciplinary research at the union of disciplines like life sciences, medicine, physics, chemistry, material sciences and engineering sciences are the cornerstone of nanoscience and technology. Development of products, devices and applications would necessitate research across a variety of disciplines that are linked together for the common goal of technology development. Several areas like water purification technology, nutrition and health care technologies, energy, textiles, electronics, advanced manufacturing and advanced materials would necessitate cross disciplinary research in the context of science and technology.

Major Challenges of Agriculture to be addressed by Nanotechnology

1) Food security for growing numbers
2) Low productivity in cultivable areas
3) Lower agricultural input efficiency
4) Unsustainable farm management
5) Large uncultivable areas
6) Shrinkage of cultivable lands
7) Wastage of products
8) Perishability/ low shelf life
9) Post harvest losses (processing,packaging)
10) Diseases and vulnerabilities to climate change due to global warming

Nanotechnology developments in India

India, with its more than one billion people, a wide landscape and a diverse socio-economic base, has tremendous possibilities for any technological intervention including nanotechnology. India has been slow to adopt the technologies and even slower to experiment them. This has happened primarily because the risk taking ability of individuals, organizations and the Governments has been low. Moreover, because of lack of communication to the rest of the world, the level of confidence in the innovations has been low. Nanotechnology in India is a public driven initiative. Industry participation has very recently originated. Nanotechnology research and development barring a few exceptions is largely being ensued at publically funded universities as well as research institutes.

Scope of Nanotechnology in India

For India, nanotechnology applications in agriculture and food sector make all the more relevance and importance since the Indian economy is predominantly agriculture and given the large population to feed, the food security concern is all the more serious. The Indian agricultural scenario is also characterized by diversity of soils and agro-climatic conditions and thus diversity in crops and fluctuation in productivity. This offers as much potential as challenges in the sector

1) India's 60% population depends on agriculture, but income levels are low because productivity is low and is marred by low inputs, pests, diseases and losses.
2) India is has massive food requirement and has variety of crops, fruits, flowers and vegetables but food sector is handicapped due to inefficiencies in production, processing, storage and packaging.
3) India gets excellent solar radiation, every roof top can become a power house, but solar energy is not generated because right and affordable technology is not in place.
4) India gets excellent rains but still drinking and irrigation water is not available in many parts because water storage and purification techniques are not perfect.
5) India is urbanizing fast but still faster is the level of pollution because of urban waste, untreated water etc.
6) Most of the processing and packaging in industry and agriculture leaves behind a trail of environmental hazards, which if not tackled at this juncture, will lead and add to long term ecological problems including global warming.

Government agencies

Department of Science and Technology, the nodal department for organising, coordinating and promoting science and technology activities in India is the chief agency engaged in the development of nanoscience and nanotechnology. It is at the helm of the principal program, the Nanoscience and Technology Mission (NSTM) established to develop India as a key player in nanoscience and technology. While it will steer this initiative between the years 2007-2012 it also hosted the flagship program, the Nanoscience and Technology Initiative (NSTI) that was pioneered in 2001 until 2006.

Nanoscience and Technology Initiative (NSTI) Initiated in 2001, the NSTI has served as the primary vehicle for India engagement with nanoscience and technology. The NSTI took root when the Government of India identified the need to initiate a program that focused on nanoscience and technology in the 10th Five Year Plan. A panel on nanotechnology was established under the guidance of Prof. C N R Rao, and these helped crystallize the Nanoscience and Technology Initiative (NSTI). The focus areas of the NSTI were to Support R and D projects in nanoscience and technology through establish Centers of Excellence and strengthen characterization facilities**,** develop human resources**,** Instigate and encourage international collaborative programs and Initiate joint Institution Industry Linked projects and Public Private Partnership activities.

Nanoscience and Technology Mission (NSTM)

The NSTM commenced in 2007 and is planned until 2012. The Nano Mission Council that is presently chaired by Prof. C.N.R. Rao (National Research Professor and Honorary President and Linus Pauling Research Professor, Jawaharlal Nehru Centre for Advanced Research, Bangalore) guides the NSTM. DST was assigned as the nodal agency for its implementation. The mission seeks to strengthen national capacity, leverage the progress made during the tenure of the NSTI and forge ahead in making India a globally strong player in this emerging field. The aim is to expand the national support base in terms of research and technology development, infrastructure, human resource development, collaborations and public-private partnerships. The mission together with setting its sights on building capability in nanotechnology has also articulated the aim of harnessing this technology's potential for national development. The focus area and objectives of the NSTM are includes Promotion of basic research development of Infrastructure for nanoscience and technology research and promote Nano applications and technology development programs.

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[7].

Agriculture is an area where new technologies are often applied to improve the yield of crops. Nanoagriculture involves the employment of Nano particles in agriculture these particles will impart some beneficial effects to crops[2].

Agricultural Production

Precision farming

Nanotechnology application here makes farming more targeted and scientific. Precision farming makes use of computers, global satellite positioning systems, and remote sensing devices to measure various parameters. Accurate information through applications of Nanotechnology for real time monitoring of soil conditions, environmental changes and diseases and plant health issues.

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. 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[1].

Recent advances in materials science and chemistry have produced mastery in nanoparticle 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 fiber is lost to scrap or waste. However, Margaret Frey, an assistant professor of textile science at Cornell University, has developed a technique called electro spinning that makes good use of the scrap material that would otherwise be used to make low-value products like cotton balls, yarn, and cotton batting[6].

Nanotechnology and water safety in India

Nanoscience applications in water management assume a special importance for a vast developing region like India. Given the diverse geographical conditions, different regions face a range of water problems varying in terms of magnitude. Problems of safe and potable water prevail alike other developing regions of the world, more so in the arid and semi arid regions. The prevalence of waterborne diseases is also quite high. Improving the quantum of supply of water as well as its quality, at an affordable cost, is what a common Indian would expect the most from the researchers and experts engaged in exploring strategic applications of nanoscience. This one area can change the socio economic scenario substantially

Challenges in the water sector in India Water availability has been a problem as a result of rising population, rapid urbanization, growing industrialization and expanding agriculture. Water treatment and remediation has been cited as the third most critical area where nanotechnology applications might aid developing countries. Some of the interventions includes Nanomembranes for water purification, desalination, and detoxification, Nanosensors for the detection of contaminants and pathogens, nanoporous zeolites, nanoporous polymers, and attapulgite clays for water purification, magnetic nanoparticles for water treatment and remediation and TiO_2 nanoparticles for the catalytic degradation of water pollutants.

Nanotechnology interventions might be sought at specific junctures to alleviate the following challenges. Improve quantity and quality of water and wastewater treatment systems: The water treatment systems need to address the removal of contaminants present in the surface and ground water in order to provide potable drinking water. Many technologies exist such as candle filter, biosand filter, activated carbon, UV and chemical based systems. These have been found suitable for contaminant removal from water; however, the performance can be improved and systems made more efficient by use of nanotechnology.

Nano-enabled water treatment techniques incorporating carbon nanotubes, nanoporous ceramics, and magnetic nanoparticles can be used to remove impurities from drink-ing water and could potentially remove bacteria, viruses, water-borne pathogens, lead, uranium, and arsenic, among other contaminants[9]. Magnetic nanoparticles could be used to filter water at the point of use to remove nanocrystals and arsenic. Nanoparticle filters can be used to remove organic particles and pesticides from water.

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.

Nanosensors

Nanotechnology may be used in agriculture and food production in the form of nanosensors for monitoring crop growth and pest control by early identification of animal or plant diseases. These nanosensors can help enhance production and improve food safety. The sensors function as external monitoring devices and do not end up in the food itself. Nanomaterials can also be introduced in or on the food itself. The effectiveness of pesticides may be improved if very small amounts are enclosed in hollow capsules with a diameter in the nanometer range which can be designed to open only when triggered by the presence of the pest to be controlled. Nanosensors may detect contaminants, pests, nutrient content, and plant stress due to drought, temperature, or pressure. They may also potentially help farmers increase efficiency by applying inputs only when necessary.

The developed biosensor system is an ideal tool for online monitoring of organophosphate pesticides and nerve agents. Bioanalytical nanosensors are utilized to detect and quantify minute amounts of contaminants like viruses bacteria, toxins bio-hazardous substances etc. in agriculture and food systems. Most analysis of these toxins is still conducted using conventional methods; however, biosensor methods are currently being developed as screening tools for use in field analysis[21].

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 alumino-silicates. Pesticides inside nanoparticles are being developed that can be timed-release or have release linked to an environmental trigger. Combined with a smart delivery system, herbicide could be applied only when necessary, resulting in greater production of crops and less injury to agricultural workers. Leading chemical companies are now formulating efficient nanopesticides and nanohericides at nano scale. One of such effort is use of Alumino-Silicate nanotubes with active ingredients. Pesticides via Encapsulation, Pesticides containing nano-scale active ingredients are already on the market, and many of the world's leading agrochemical firms are conducting reserach on the development of new nano-scale formulations of pesticides.

Smart Treatment Delivery Systems

Today, application of agricultural fertilizers, pesticides, antibiotics, probiotics and nutrients is typically by spray or drench application to soil or plants, or through feed or injection systems to animals. Delivery of pesticides or medicines is either provided as "preventative" treatment or is provided once the disease organism has multiplied and symptoms are evident in the plant or animal.

Nano Silver

Nanosilver 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 studied the antifungal effectiveness of colloidal nano silver (1.5 nm average diameter) solution, against rose powdery mildew caused by *Sphaerotheca pannosa* var *rosae.*

Nano silica-silver composite Silicon (Si) is known to be absorbed into plants to increase disease resistance and stress resistance. The pathogens disappeared from the infected leaves 3days after spray and the plants remained healthy thereafter also studied the 'effective concentration' of nanosized silicasilver on suppression of growth of many fungi; and found that, *Pythium ultimum*, *Magnaporthe grisea*, *Colletotrichum gloeosporioides*, *Botrytis cinere* and, *Rhyzoctonia solani*, showed 100% growth inhibition at 10 ppm of the nanosized silica-silver[12]. Whereas, *Bacillus subtilis*, *Azotobacter chrococum*, *Rhizobium tropici*, *Pseudomonas syringae* and *Xanthomonas compestris* pv. *Vesicatoria* showed 100% growth inhibition at 100 ppm.

Nano-emulsions

It is a mixture of two or more liquids (such as oil and water) that do not easily combine. In nanoemulsion, the diameters of the dispersed droplets are 500 nm or less. Nano-emulsions can encapsulate functional ingredients within their droplets, which can facilitate a reduction in chemical degradation.

Input Management: Nanofertilizers

Nanofertilizers could be used to reduce nitrogen loss due to leaching, emissions, and long-term incorporation by soil microorganisms. They could allow for selective release linked to time or environmental condition. Slow-controlled-release fertilizers may also improve soil by decreasing toxic effects associated with fertilizer over application.

Veternary Sciences

Nanofeed additives

Chicken feed containing nanoparticles that bind with harmful bacteria could help reduce food-borne pathogens. Nanoclays can ameliorate aflatoxin's deleterious effects on poultry.

Nanocoatings

Self-sanitizing photocatalyst coating for use in poultry houses with nano–titanium dioxide could be used to oxidize and destroy bacteria in the presence of light and humidity.

Smart delivery systems can detect and treat an animal infection or nutrient deficiency and provide timed-release drugs or micronutrients.

Food Safety and Nutrition

Nanofood

A food is nanofood when nanoparticles, nanotechnology techniques or tools are used during cultivation, production, processing or packaging of the food. Nanofood is often associated with color & flavor improvement, better storage & preservation, pathogen detection, antimicrobial properties, intelligent packaging, etc. for example drinks that turn pink or yellow when microwaved, Nanocapsules incorporating tuna fish oil, a source of É-3 fatty acids into bread. A nanoadditive for animal feed can deactivate aflatoxin, deoxynivalenol, and zealalenone mycotoxins in animal feed. Nanoparticles can also remove food-borne patho-gens in the gastrointestinal tracts of livestock.

Nano lamination

This technique is another viable option for protecting the food from moisture, lipids and gases. Moreover, they can improve the texture and preserve flavor as well as color of the food. Nanolaminates consist of two or more layers of nano-sized (1-100) thin food grade films which are present on a wide variety of foods: fruits, vegetables, meats, chocolate, candies, baked goods, and French fries. Nanolaminates are prepared from edible polysaccharides, proteins, and lipids has shown that polysaccharide- and protein-based nanolaminates are good barriers against oxygen and carbon dioxide, but poor in protecting against moisture. Whereas, lipid-based nanolaminates are good at protecting food from moisture[2].

Enhanced barriers to microbial contamination or spoilage

Barriers can reduce opportunity for microbial contamination by keeping bacteria away from food or preventing condi-tions that allow bacteria to grow. Nanocomposites used in food and beverage containers provide effective barriers to gas transmission.

Food processing

Nanocapsulated flavor enhancers Nanocapsules to improve bioavailability of neutraceuticals in standard ingredients such as cooking oils Nanotubes and nanoparticles as gelation and viscosifying agents nanocapsule infusion of plant basd steroids to replace a meat's cholesterol Nanoparticles to selectively bind and remove chemicals or pathogens from food Nanoemulsions and particles for better availability and dispersion of nutrients.

Food packaging

Conventional plastics, used widely in food packaging, are difficult to degrade thereby creating a serious problem of solid waste disposal. In this context, biomass based materials have been explored for the development of eco-friendly food packaging. The challenge is to overcome performance related issues (e.g. poor mechanical strength, brittleness, poor gas and moisture barrier), processing problems (e.g. low heat distortion temperature), and high cost associated with biopolymer based packaging. Silver nano-particles can be embedded in polymeric materials such as PVC, PE, PET while polymerization occurs. Silver nanoparticles kill pathogens, bacteria, viruses and fungus and are used as a good and safe packaging pot. Such nanotechnology based packaging materials are 100 times more secure than the normal one for the storage of juices, milk and other agri-products. Food packaging films in the name of "hybrid system" films have enormous number of silicate nano particles. They massively reduce the entrance of oxygen and other gases, and the exit of moisture, thus preventing food from spoiling or drying.

Nanoclays

Clays and silicates are layered inorganic solids that are readily available at low cost; further they are easy to process and can result in significant improvement in properties. The most extensively investigated clay is montmorillonite, hydrated alumina-silicate layered clay[15]. Addition of nanoclays in polymer formulations results in several benefits viz. enhanced mechanical properties, superior barrier properties because of the high tortuosity imparted by these materials thus, permeability of oxygen and water vapor can be significantly reduced[22].

Cellulose nanofiber

This is a low cost and readily available nanomaterial obtained from the natural polymer cellulose. This has been used to improve thermo mechanical and barrier properties in biopolymers like starch without affecting the biodegradability. Cellulose nanoreinforcements also improve moisture barrier and enhance thermal stability.

Detection of food-borne pathogens or spoilage organisms

Nano-based methods of detecting harmful pathogens are being developed for several pathogens: a nanobiosensor can identify the presence of *E. coli* and prevent the consumption of contaminated foods. Similarly, nanosensors can indicate the deterioration of foods due to spoilage microorganisms or other factors.

Detection of pesticides, heavy metals, or other chemical contaminants

Several nano-based biosensors have been developed to detect contaminants, such as crystal violet or malachite green concentrations in seafood and parathion residues or residues of organophosphorus pesticides on vegetables.

Quality Maintenance

Identity Preservation (IP) is a system that creates increased customers with information about the particles and activities used to produce a particular crop or other agricultural products. Quality assurance of agricultural products safety and security could be significantly improved through IP at the nanoscale. Nanoscale IP holds the possibility of continuous tracking and recording of the history which a particular agricultural product experience.

Quality control and testing

Food safety is a major concern for food producers, consumers and food safety authorities. Nanosensors may help to improve food safety by enabling faster quality control and testing not only in the factory but also on the shelf and even in your refrigerator. These sensors can be integrated in the food processing equipment or in refrigerators and do not introduce nanoparticles into the food itself. A nanosensor is a device consisting of an electronic data processing part and a sensing layer or part, which can translate a signal such as light, or the presence of an organic substance or gas into an electronic signal.

Impact on Environment

Nanotechnology will also help protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants. Nanotechnology Research also aims to make plants use water, pesticides and fertilizers more efficiently.

Crop improvement

Nanobiotechnology

Research in nano-biotechnology is advancing toward the ability to sequence DNA in nano fabricated gel-free systems,which would allow for significantly more rapid DNA sequencing. Coupled with powerful approaches such as association genetic analysis, DNA sequencing data of the crop germplasm, including the cultivated crop gene pool and the wild relatives can potentially provide highly useful information about molecular markers associated with agronomically and economically important triats. Thus, nanobiotechnology can enhance the pace of progress in molecular marker assisted breeding for crop improvement.

DNA Microarrays and Expression Profiling

Microarrays based hybridization methods allow to simultaneously measure the expression level for thousands of genes.

Protein Microarrays

The structures and functions of proteins are much more complicated that of DNA, and proteins are less stable than DNA. Protein microarrays are being used to discover protein biomarkers that indicate disease stages to access potential efficacy and toxicity of pesticides to measure different protein production across cell types and developmental stages, in both healthy and diseased stages, to study the relationship between protein structure and function and to evaluate binding interactions between proteins and other molecules.

Atomically Modified Seeds

In March 2004, ETC group reported a nanotechology research initiative in Thailand that aims to atomically modify the characteristics of local rice varieties. They drilled a hole through the membrane of rice cell to insert nitrogen atom that would stimulate the rearrangement of the rice. DNA, they are able to change the colour of local rice variety from purple to green one of the attraction of this nano-scale technique is that it does not require the controversial technique of genetic modification.

Nanofuels

Levesque's lab (University of Otawwa) is working on nanoconversion of agricultural materials into valuable products. The design and development of new nanocatalysts for the conversion of vegetable oils into biobased fuels and biodegradable solvents is already under scientific examination and could be greatly enhanced with the help of nanotechnological abilities. This is based on the concept that the organic fuels at nano scale would be able to give greater energy with lesser energy loss during conversion.

Particle Farming

Nanoparticles may not be produced in a laboratory, but grown in fields of genetically engineered crops what might be called particle farming.Researchers have shown that plant can also soak up nanopacticles that could be industrially harvested alfalfa plant were grown on an artificially gold rich soil. Gold nanopacticles in the roots and along the entire shoot of plant are then extracted simple by dissolving them in organic material. NCL, Pune, India have been carring out similar work with geranium leaves immersed in gold-rich solution.

Carbon Nanotubes (CNTs)

CNTs have become attractive electronic materials to date and their applications in future electric circuits and bio-sensing chips. CNT as vehicle to deliver desired molecules into the seeds during germination that can protect them from the diseases. Since it is growth promoting, it will not have any toxic or inhibiting or adverse effect on the plant.

Mesoporous silica Nanoparticles (MSNs)

MSNs have been extensive investigated as a drug delivery system. It is well know that MSNs possess excellent properties such high specific area, high pore volume, tunable pore structures and physicochemical stability. In the beginning MSNs were used for controlled delivery of various hydrophilic or hydrophobic active agents. Later advances in the MSNs surface properties such as surface functionalization and PEG ylation rendered them as a promising drug delivery[3].

Mesoporous silica Nanoparticles (MSN) helps in delivering DNA and chemicals into isolated plant cells. MSNs are chemically coated and serve as containers for the genes delivered into the plants. The coating triggers the plant to take the particles through the cell walls. It was found that MPS/DNA complexes showed enhanced transfection efficiency through receptor-mediated endocytosis via mannose receptors. These results indicate that MPS can be employed in the future as a potential gene carrier to antigen presenting cells[13].

Nanosilica based transformation in plant cells

Francois Tourney Brian Tsceoyn & colleagues at Jowa State University describe the use of silica nanoparticles to deliver foreign genetic material into plant cells in a process called transformation. Nanoparticles can be used to carry and release effectors small molecule (-estradiol) that induce the expression of genes within the plant cells in a controlled fashion.

Nanoparticles mediated nonviral gene delivery

Gene delivery systems are an important area in the field of genetic nanomedicine. Gene delivery involves the transport of genes, which requires a transport vehicle referred to as a vector. Possible vectors include viral "shells" or lipid spheres (Liposomes), which have properties that allow them to be incorporated into host cells[5]. Peptides and proteins have become the drugs of choice for the treatment of numerous diseases as a result of their incredible selectivity and their ability to provide effective and potent action[4]. These studies suggest that research should be focused on designing a drug with an enhanced permeability and retention (EPR) effect. nanoconjugate is being developed for non-invasive detection of gene expression in cells[8].

Polymer based gene transfer

Non-viral gene medicines have emerged as a potentially safe and effective gene therapy method for the treatment of a wide variety of acquired and genetic diseases[20]. An important advantage of polymer-based gene delivery systems over viral transfection systems is that transient gene expression without the safety concerns can be achieved. In addition to the polymeric systems to deliver DNA, therapeutic ultrasound is potentially useful because ultrasound energy can be transmitted through the body without damaging tissues and could be applied on a restricted area where the desired DNA is to be expressed[16].

Liposome gene transfer

The liposome-based gene transfer strategy is one of the most studied Nonviral gene delivery strategies. A liposomal delivery system requires a complete understanding of the physicochemical characteristics of the drug liposome system. Many bacteria can control plant diseases by altering molecular processes leading to the production of pathogenicity and/or virulence factors by the pathogen[18]. Liposomes may offer several advantages as vectors for gene delivery into plant cells. Enhanced delivery of encapsulated DNA by membrane fusion, protection of nucleic acids from nuclease activity, targeting to specific cells, delivery into a variety of cell types besides protoplasts by entry through plasmodesmata. In liposome based gene therapy there is no toxicity potential in humans and plants.

Biobeads gene transfer

Micrometer-sized calcium alginate beads referred to as "bio-beads" that encapsulate plasmid DNA molecules carrying a reporter gene. In order to evaluate the efficiency of the bio-beads in mediating genetic transfection, protoplasts isolated from cultured tobacco cells. Transfection was up to 0.22% efficient. These results indicate that bio-beads have a possibility for efficient transformation in plants[19]. Application of Nanoscale materials has been grown exponentially due to high sensitivity and fast response time[11].

Key Challenges Ahead

Societal effects

Coming nanotechnologies in the agricultural field seem quiet promising. However, the potential risks in using nanoparticles in agriculture are no different than those in any other industry. Through the rapid distribution of nanoparticles to food products – whether it be in the food itself or part of the packaging - nanoparticles will come in *direct* contact with virtually everyone. The environmental group ETC (Action Group on Erosion, Technology and Concentration) is deeply concerned with the implications and regulation of nanotechnology used in food. Currently, there are none. Their main concern is that of the unknown. Since there is no standardization for the use and testing of nanotechnology, products incorporating the nanomaterials are being produced without check. The ability for these materials to infiltrate the human body is well known, but there is really no information on the effects that they may have. While there is no evidence of harm to people or the environment at this stage, nanotechnology is a new and evolving area of study that could cause a great deal of harm due to its still ambiguous chemical properties. With the current application and advancements soon to come, nanotechnology will have a great impact on the direction that agriculture will take.

Cost and Access

Intellectual property rights, innovation, and technology access: In private-sector development, economic incentives, such as intellectual property rights (IPR), play a critical role in the innovation process in a globalized world. Patents provide incentive for research and invest-ment, but their use still generates significant criticism. Enforcing IPR and, more specifically, patents can create barriers to entry and raise the cost of products for consumers, thereby contributing to a growing divide between developed and developing economies.

Environmental and human-health risks

Using nanomaterials is not inherently risky for instance, traditional foods contain many nanoscale materials but the use of certain engineered nanoscale materials in agriculture, water, and food may have risks for human use and consumption, for the environment, or for both (Nakamura.,2011). Possible migration of the nanoparticles from such bulk materials into the food or the environment is the issue. Food safety experts are looking into whether the legislative controls on food packaging materials already in place for plastics etc are adequate to deal with the new properties of nanoparticles of the same food grade materials.

CONCLUSION

Nanotechnology can contribute to enhancing agricultural productivity in a sustainable manner, using agricultural inputs more effectively, and reducing by-products that can harm the environment or human health. Nanotechnology applications in basic agriculture, value addition, preservation of crops and food can therefore bring a sea change in the agriculture scenario of India. Thus, applications of nanotechnology in agriculture can prove to be a big boon. In the field of agriculture, there are still many possibilities to explore and a great deal of potential with up-coming products and techniques There is an urgent need for informed public debate on nanotechnology agriculture and food. There are currently several dozen food and beverage products with nanotechnology on the market according to their producer or experts. Governments and food companies in several countries are investing in hundreds of projects developing nanotechnology in food and agriculture. Nanotechnology can be applied in all aspects of the food chain, both for improving food safety and quality control, and as novel food ingredients or additives, which may lead to unforeseen health risks.

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