Available online at http://www.journalijdr.com

IJDR

International Journal of DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 06, Issue, 11, pp.9942-9945, November, 2016

Full Length Research Article

REVIEW ON APPLICATIONS OF NANOTECHNOLOGY IN AGRICULTURE

***Shilpi Yadav and Dr. M. K. Yadav**

Deptt. Of Agriculture Biotechnology, SVPUA&T, Meerut 250110, India

ARTICLE INFO

Article History:

Received 27th August, 2016
Received in revised form
14th September, 2016
Accepted 28th October, 2016
Published online 30th November, 2016

Key Words:

Agriculture,
Nanofertilisers,
Nanotechnology,
Nanoparticles.

ABSTRACT

Agriculture sector contributes significantly to the national economy and S&T 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. Frontier cutting edge technology like nanotechnology is one such emerging area in S&T, which holds significant promise for agriculture. Nanotechnology is a promising field of interdisciplinary research. It opens up a wide array of opportunities in various fields like medicine, pharmaceuticals, electronics and agriculture. The potential uses and benefits of nanotechnology are enormous. The current global population is nearly 7 billion with 50% living in Asia. A large proportion of those living in developing countries face daily food shortages as a result of environmental impacts or political instability, while in the developed world there is surplus of food. For developing countries, the drive is to develop drought and pest resistant crops, which also maximize yield. The potential of nanotechnology to revolutionize the health care, textile, materials, information and communication technology, and energy sectors has been well publicized. The application of nanotechnology to agriculture and food industries is also getting attention nowadays. Investments in agriculture and food nanotechnologies carry increasing weight because their potential benefits range from improved food quality and safety to reduced agricultural inputs and improved processing and nutrition. While most investment is made primarily in developed countries, research advancements provide glimpses of potential applications in agricultural, food, and water safety that could have significant impacts on rural populations in developing countries. In the near future nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants.

INTRODUCTION

The current global population is nearly 7 billion with 50% living in Asia. A large proportion of those living in developing countries face daily food shortages as a result of environmental impacts or political instability, while in the developed world there is a food surplus. Agriculture sector contributes significantly to the national economy and S&T has played a significant role in increasing agricultural productivity over the years.

****Corresponding author: Shilpi Yadav***
Deptt. Of Agriculture Biotechnology, SVPUA&T, Meerut 250110, India

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. Nanotechnology is a promising field of interdisciplinary research. It opens up a wide array of

opportunities in various fields like medicine, pharmaceuticals, electronics and agriculture. The potential of nanotechnology to revolutionize the health care, textile, materials, information and communication technology, and energy sectors has been well-publicized. The application of nanotechnology to the agricultural and food industries was first addressed by a United States Department of Agriculture roadmap published in September 2003. The prediction is that nanotechnology will transform the entire food industry, changing the way food is produced, processed, packaged, transported, and consumed. Attempts to apply nanotechnology in agriculture began with the growing realization that conventional farming technologies would neither be able to increase productivity any further nor restore ecosystems damaged by existing technologies back to their pristine state; in particular because the long-term effects of farming with "miracle seeds", in conjunction with irrigation, fertilizers, and pesticides, have been questioned both at the scientific and policy levels, and must be gradually phased out. Nanotechnology is emerging as the sixth revolutionary technology in the current era after the Industrial Revolution of Mid 1700s, Nuclear Energy Revolution of the 1940s, The Green Revolution of 1960s, Information Technology Revolution of 1980s and Biotechnology Revolution of the 1990s.

What is Nanotechnology?

Nanotechnology is defined by the US Environmental Protection Agency as the science of understanding and control of matter at dimensions of roughly 1–100 nm, where unique physical properties make novel applications possible. This definition is slightly rigid with regard to size dimensions. Greater emphasis could have been placed on the problem-solving capability of the materials. Other attempts to define nanoparticles from the point of view of agriculture include "particulate between 10 and 1,000 nm in size dimensions that are simultaneously colloidal particulate" (Nakache *et al*., 1999). Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. Nanotechnology can work from the top down (which means reducing the size of the smallest structures to the nanoscale e.g. photonics applications in nanoelectronics and nanoengineering) or the bottom up (which involves manipulating individual atoms and molecules into nanostructures and more closely resembles chemistry or biology). The definition of nanotechnology is based on the prefix "nano" which is from the Greek word meaning "dwarf". In more technical terms, the word "nano" means 10^{-9}, or one billionth of something. For comparison, a virus is roughly 100 nanometres (nm) in size. The word nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometres, however it is also inherent that these materials should display different properties from bulk (or micrometric and larger) materials as a result of their size. These differences include physical strength, chemical reactivity, electrical conductance, magnetism, and optical effects. Nanotechnology is such a recent technology that is going to affect human life in near future in such a big way that we can say that we are moving towards nano age (Joseph *et al*., 2006).

Nanotechnology in Agriculture

Agricultural scientists are facing a wide spectrum of challenges such as stagnation in crop yields, low nutrient use efficiency, declining soil organic matter, multi-nutrient deficiencies, climate change, shrinking arable land and water availability and shortage of labor besides exodus of people from farming. To address these problems, there is a need to explore one of the frontier technologies such as 'Nanotechnology' to precisely detect and deliver the correct quantity of nutrients and pesticides that promote productivity while ensuring environmental safety and higher use efficiency. The nanotechnology can be exploited in the value chain of entire agriculture production system (Subramanian *et al*., 2011). Nanotechnology is a multidisciplinary field and has the enormous potential to boost agricultural research. Recently the science of the materials at the nanometer scale has emerged as one of the most promising subject. Novel materials and surface characteristics might be utilized to enhance agricultural productivity and production.

Nanotechnology can be a tool in better understanding of various cellular processes, mechanisms regulating important agronomic traits and development of genotypes tolerant to abiotic and biotic stresses. Nanotechnology offers better products and improved means of production. On the basis of current development in nanotechnology research prediction is that it will transform food industry by changing the way food is produced, processed, packaged, transported and consumed. Potential applications of nanotechnology in agriculture include nano-coating, nucleic acid bioengineering, bio-analytical nano-sensors, nano-material and bio-selective surface etc. Development of low cost sensor for diagnostics can detect the presence of food borne and agriculturally important pathogens, filtering undesirable compounds from food and drinks. Nutrient deficiency and toxicity seems to be one of the major factor affecting agricultural production. Nano-particles may be used to study soil nutrient status as well as micro flora and fauna. In the past, agriculture benefited from many different technological innovations, including hybrid varieties, synthetic chemicals and biotechnology and researchers are now seeking in nanotechnology a new source of agricultural improvement. However, while the food industry can be seen to be clearly benefiting from nanotechnology (in particular for food processing, distribution, packaging and functional food), its real contribution to the agricultural sector is still uncertain (Claudia *et al*., 2014).

Overview of nanotechnology research activities in the agricultural sector

The application of nano-materials in agriculture aims in particular to reduce applications of plant protection products, minimize nutrient losses in fertilization, and increase yields through optimized nutrient management. Despite these potential advantages, the agricultural sector is still comparably marginal and has not yet made it to the market to any larger extent in comparison with other sectors of nanotechnology application. Nanotechnology devices and tools, like nano-capsules, nanoparticles and even viral capsids, are examples of uses for the detection and treatment of diseases, the enhancement of nutrients absorption by plants, the delivery of active ingredients to specific sites and water treatment processes. The use of target-specific nanoparticles can reduce the damage to non-target plant tissues and the amount of chemicals released into the environment. Nanotechnology derived devices are also explored in the field of plant breeding and genetic transformation. The potential of nanotechnology in agriculture is large, but a few issues are still to be addressed,

such as increasing the scale of production processes and lowering costs, as well as risk assessment issues. In this respect, particularly attractive are nanoparticles derived from biopolymers such as proteins and carbohydrates with low impact on human health and the environment.

For instance, the potential of starch-based nanoparticles as nontoxic and sustainable delivery systems for agrochemicals and biostimulants is being extensively investigated. Nano-materials and nanostructures with unique chemical, physical, and mechanical properties – e.g. electrochemically active carbon nano-tubes, nano-fibers and fullerenes – have been recently developed and applied for highly sensitive bio-chemical sensors. These nanosensors have also relevant implications for application in agriculture, in particular for soil analysis, easy bio-chemical sensing and control, water management and delivery, pesticide and nutrient delivery. At present in India research is mainly concentrated on nano particle synthesis, smart release of nutrients from nano-fertilizers, nano-induced polysaccharide powder for moisture retention/soil aggregation and C build up, regulated release of active ingredients from nano-encapsulated herbicides, nano-seed invigoration, and slow and steady release of pesticides, nano-film for extended shelf-life of perishables and nano-remediation of soil and aquatic pollutants. These are cutting-edge researchable areas which are expected to expand in the years to come. However, if the nano-products and the processes for creating them are not managed judiciously, there could be serious health and environmental risks. Nanotechnology applied to agricultural production could play a fundamental role for this purpose and research on agricultural applications is ongoing for largely a decade by now.

Applications of Nanotechnology

Nanoparticles for seed germination

Seed is most important input determining productivity of any crop. Conventionally, seeds are tested for germination and distributed to farmers for sowing. In spite of the fact that seed testing is done in well equipped laboratories, it is hardly reproduced in the field due to the inadequate moisture under rainfed conditions. In India, more than 60% of the net area sown is rainfed; hence, it is quite appropriate to develop technologies for rainfed agriculture. A group of research workers is currently working on metal oxide nano-particles and carbon nanotube to improve the germination of rainfed crops. Nano particles play considerable role in seed germination. Germination of black gram and tomato seeds with ZnO nano particles has been found to increase from 10-15% to 80-85%. Khodakovskaya *et al.* (2009) have reported the use of carbon nanotube for improving the germination of tomato seeds through better permeation of moisture. Their data show that carbon nanotubes (CNTs) serve as new pores for water permeation by penetration of seed coat and act as a passage to channelize the water from the substrate into the seeds. These processes facilitate germination which can be exploited in rainfed agricultural system.

Nanofertilizers for crop nutrition

In India, fertilizers, along with quality seed and irrigation, are mainly responsible for enhanced food grain production. Considering its importance, the Government of India is heavily subsidising the cost of fertilizers particularly urea. This has resulted in imbalanced fertilization and occurrence in some areas, nitrate pollution of ground waters due to excessive nitrogen application. In the past few decades, use efficiencies of N, P and K fertilizers have remained constant as 30-35%, 18-20% and 35-40%, respectively, leaving a major portion of added fertilizers to accumulate in the soil or enter into aquatic system causing eutrophication. In order to address issues of low fertilizer use efficiency, imbalanced fertilization, multi-nutrient deficiencies and decline of soil organic matter, it is important to evolve a nano-based fertilizer formulation with multiple functions. Nanofertilizers are synthesized in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nanofertilizers are more efficient than ordinary fertilizer (Liu *et al*., 2006a). Nanofertilizers could be used to reduce nitrogen loss due to leaching, emissions, and long-term incorporation by soil microorganisms. They could allow 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 (Suman *et al*., 2010). Impact of nano-fertilizer products on morphological, physiological, biochemical and nutritional changes in plants as well as on rhizosphere microorganisms and biogeochemical cycles of nutrients are some potential areas yet to be addressed properly.

Nanoherbicides for weed control

Weeds are menace in agriculture. Herbicides available in the market are designed to control or kill the above ground part of the weed plants. None of the herbicides inhibits activity of viable belowground plant parts like rhizomes or tubers, which act as a source for new weeds in the ensuing season. Soils infested with weeds and weed seeds are likely to produce lower yields than soils where weeds are controlled. Improvments in the efficacy of herbicides through the use of nanotechnology could result in greater production of crops. The encapsulated nano-herbicides are relevant, keeping in view the need to design and produce a nano-herbicide that is protected under natural environment and acts only when there is a spell of rainfall, which truly mimics the rainfed system. Developing a target specific herbicide molecule encapsulated with nanoparticle is aimed for specific receptor in the roots of target weeds, which enter into roots system and translocated to parts that inhibit glycolysis of food reserve in the root system. This will make the specific weed plant to starve for food and gets killed (Chinnamuthu *et al*., 2007). Adjuvants for herbicide application are currently available that claim to include nanomaterials. One nanosurfactant based on soybean micelles has been reported to make glyphosate-resistant crops susceptible to glyphosate when it is applied with the 'nanotechnology-derived surfactant'.

Nanopesticides

Persistence of pesticides in the initial stage of crop growth helps in bringing down the pest population below the economic threshold level and to have an effective control for a longer period. Hence, the use of active ingredients in the applied surface remains one of the most cost-effective and versatile means of controlling insect pests. In order to protect the active ingredient from the adverse environmental conditions and to promote persistence, a nanotechnology approach, namely "nano-encapsulation" can be used to

improve the insecticidal value. Nanoencapsulation is a process through which chemicals like insecticides are slowly but efficiently released to a particular host plant for insect pest control. Nanoencapsulation with nanoparticles in the form of pesticides allows for proper absorption of the chemicals into the plants (Scrinis and Lyons, 2007). This process can also deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests (Torney, 2009). Release mechanisms of nanoencapsulation include diffusion, dissolution, biodegradation and osmotic pressure with specific pH (Ding and Shah, 2009; Vidhyalakshmi et al., 2009). Neem based micro emulsion has been developed and found effective in controlling sucking pests such as thrips, aphids and mites (Gunasekaran, 2011). Nanoencapsulation is currently the most promising technology for protection of host plants against insect pests. Now, most leading chemical companies focus on formulation of nanoscale pesticides for delivery into the target host tissue through nanoencapsulation.

Agricultural engineering issues

Nanotechnology has many applications in the field of agricultural machinery. These cover: application in machine structure and agricultural tools to increase their resistance against wear and corrosion and ultraviolet rays; producing strong mechanical components with use of Nano-coating and use of bio-sensors in smart machines for mechanical-chemical weed control; production of Nano-cover for bearings to reduce friction. The use of Nanotechnology in production of alternative fuels and reduction of environmental pollution are also worth mentioning.

Expected Outcome from Nano Platform

- To address the food and nutritional security; advanced research in nano sciences and nanotechnology in agricultural sciences will be carried out.
- To pursue research in cross- cutting theme areas at least 200 Indian Agricultural Scientists will be trained.
- At least 30 different hand held simple diagnostic kits and devices will be developed.
- Nano-agri inputs such as fertilizers, herbicides, insecticides and
- seed invigoration that reduces the cost of cultivation and improve yield of crops in long run up to 10-15% will be evolved.
- To reduce post-harvest losses nano film technology will be implemented in food packaging.
- Important nutrients delivery system will be in place.

Conclusion

Nanotechnology will play a vital role in the development of the agricultural sector, as it is capable of being used in agricultural products that protect plants and monitor plant growth and detect diseases. Scientists have been working towards exploring new applications of nanotechnology in agriculture and the food industry - if these discoveries are applied sensibly, the environment, the agricultural sector and the food industry will indeed see tremendous changes for the better in the coming years.

REFERENCES

Chandrasekaran, B. and C. Ramasamy (Eds.) Tamil Nadu Agricultural University, Coimbatore, India.

Bouwmeester H, Dekkers S, Noordam MY, Hanges WI, Bulder AS de Heer C, ten Voorde SECGS, Wijnhoven WP, Marvin HJP and Sips AJAM 2009. Review of health safety aspects of nanotechnologies in food production. *Regulatory Toxicology and Pharmacology*, 53: 52-62.

Chinnamuthu CR and Kokiladevi E 2007. Weed management through nanoherbicides. In: Application of nanotechnology in agriculture. C.R. Chinnamuthu,

Ding WK and Shah NP 2009. Effect of various encapsulating materials on the stability of probiotic bacteria. *J. Food Sci*. 74(2): 100-107.

Gunasekaran S and Renganayaki V 2011. Spectroscopic and Chromatographic Analysis of Some Commercial Samples of Neem Oil. *Asian Journal of Chemistry*, 23 (2): 755-761.

Khodakovskaya M, Dervishi E, Mahmood M, Yang Xu, Zhongrui Li, Watanabe F and Biris AS 2009. Carbon nanotubes are able to penetrate plant seed coat and dramatically affect seed germination and plant growth. *ACS Nano*, 3: 3221–3227.

Liu X, Feng Z, Zhang S, Zhang J, Xiao Q and Wang Y 2006. Preparation and testing of cementing nano-subnano composites of slow- or controlled release of fertilizers. *Scientia Agricultura Sinica* 39: 1598-1604.

Nair R, Varghese, SH, Nair BG, Maekawa T, Yoshida Y and Shakti Kumar D 2010. Nanoparticulate material delivery to plants. *Plants Sciences*, 179: 154-163.

Nakache E, Poulain N, Candau F, Orecchioni AM and Irache JM 1999 Biopolymer and polymer nanoparticles and their biomedical applications. In: Nalwa HS, editor. *Handbook of Nanostructured Materials and Nanotechnology*. New York, NY, USA: Academic Press.

Salamanca-Buentello F, Persad DL, Court EB, Martin DK, Daar AS and Singer PA 2005. Nanotechnology and the developing world. *PLoS Medicine* 2: 383–386.

Scrinis G and Lyons K 2007. The emerging nano corporate paradigm: nanotechnology and the transformation of nature, food and agri-food systems. *Int. J. Sociol. Food Agric.* 15: 22-44.

Sharon M, Choudhary A and Kumar R 2010. Nanotechnology in agriculture diseases and food safety. *Jornal of Phytology*, 2: 83-92.

Subramanian, KS and Tarafdar, JC 2011. Prospects of nanotechnology in Indian farming. *Indian Journal of Agricultural Sciences* 81: 887-893.

Suman PR, Jain VK, Varma A 2010. Role of nanomaterials in symbiotic fungus growth enhancement. *Curr. Sci.* 99: 1189-1191.

Tarafdar JC, Agrawal A, Raliya R, Kumar P, Burman U and Kaul RK 2012. ZnO nanoparticles induced synthesis of polysaccharides and phosphatases by *Aspergillus* fungi. *Advanced Science, Engineering and Medicine* 4: 1-5.

Torney F 2009. Nanoparticle mediated plant transformation. Emerging technologies in plant science research. Interdepartmental Plant Physiology Major Fall Seminar Series. *Phys*. p. 696.

Vidhyalakshmi R, Bhakyaraj R, Subhasree RS 2009. Encapsulation the future of probiotics-A Review. *Adv. Biol. Res*. 3(3-4): 96-103.

****