International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 488-491

Received: 13-05-2019
Accepted: 15-06-2019

Praveen Verma
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Suman Bodh
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Shivender Thakur
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Correspondence
Praveen Verma
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Nanotechnology in agriculture: A review

Praveen Verma, Suman Bodh and Shivender Thakur

Abstract
Nanotechnology is the art and science of manipulating and rearranging individual atoms and molecules at nano scale to create useful materials, devices and systems. 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.

Keywords: Nanotechnology, agriculture, food chain, nano scale

Introduction
With the growing limitation in arable land and water resources, the development of agriculture sector is only possible by increasing resources use efficiency with the minimum damage to agro ecology through effective use of modern technologies. Among these, nano technology has the potential to revolutionize agricultural systems, biomedicine, environmental engineering, safety and security, water resources, energy conversion, and numerous other areas. Nanotechnology is working with the smallest possible particles which raise hopes for improving agricultural productivity through encountering problems unsolved conventionally (Singh and Rattanpal, 2014) [6]. In the management aspects, efforts are made to increase the efficiency of applied fertilizer with the help of nano clays and zeolites and restoration of soil fertility by releasing fixed nutrients. Research on smart seeds programmed to germinate under favourable conditions with nano polymer coating are encouraging. In the controlled environment agriculture and precision farming input requirement of crops are diagnosed based on needs and required quantities are delivered in right time at right place with the help of nano biosensor and satellite system. Nano herbicides are being developed to address the problems in perennial weed management and exhausting weed seed bank. Nano structured formulation through mechanisms such as targeted delivery or slow/controlled release mechanisms and conditional release, could release their active ingredients in response to environmental triggers and biological demands more precisely. Studies show that the use of nano fertilizers causes an increase in nutrients use efficiency, reduces soil toxicity, minimizes the potential negative effects associated with over dosage and reduces the frequency of the application. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries (Manjunatha *et al.* 2016) [3].

Applications of Nanotechnology in Agriculture
Nanotechnology has the potential to increase the efficiency and quality of agricultural production and food storage, to enhance the safety of food supplies for the protection of consumers and producers and to introduce new functionality (value-added products) for food, fiber and agricultural commodities. Nanotechnology will pave the ways for new researchable areas and applications such as DNA chip, protein identification and manipulation, novel nucleic acid engineering based films, smart delivery of DNA using gold nanoparticles.

Biological tests measuring the presence or activity of selected substances become quicker, more sensitive and more flexible when nano-particles are put to work as tags or labels. Magnetic nanoparticles, bound to suitable antibody are used to label specific molecules, structures or microorganisms.

Nanotechnology for crop biotechnology

Nanocapsules can facilitate successful incursion of herbicides through cuticles and tissues, allowing slow and regular discharge of the active substances. This can act as 'magic bullets', containing herbicides, chemical origins which target exacting plant parts to liberate their substance (Pérez-de-Luque and Rubiales, 2009) [5]. Torney *et al*. (2007) [11] exploited a 3 nm meso porous silica nanoparticle in delivering DNA and chemicals into isolated plant cells. Meso porous silica nanoparticles are chemically coated and act as containers for the genes delivered into the plants; they trigger the plant to take the particles through the cell walls, where the genes are put in and activated in a clear-cut and controlled way, without any toxic side effects. This technique firstly has been applied to establish DNA fruitfully to tobacco and corn plants.

Nanotechnology in Seed Science

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 rain fed conditions. In India, more than 60% of the net area sown is rain fed; hence, it is quite appropriate to develop technologies for rain fed agriculture. A group of research workers is currently working on metal oxide nano-particles and carbon nanotube to improve the germination of rain fed crops. Khodakovskaya *et al.* (2009) [2] 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 penetrating 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 rain fed agricultural system.

Nano-fertilizers for balanced crop nutrition

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. Nano-fertilizer technology is very innovative but scantily reported in the literature. However, some of the reports and patents strongly suggest that there is a vast scope for the formulation of nano-fertilizers. Significant increase in yields has been observed with the foliar application of nano particles as fertilizer (Tarafdar, 2012; Tarafdar *et al.* 2012a) [7-8-9-10]. Currently, research is underway to develop nano-composites to supply all the required essential nutrients in suitable proportion through smart delivery system. Preliminary results suggest that balanced fertilization may be achieved through nanotechnology (Tarafdar *et al.* 2012b) [7-8-9-10]. Indeed the metabolic assimilation within the plant biomass of the metals, e.g., micronutrients, applied as nano-formulations through soil-borne and foliar application or otherwise needs to be ascertained. Further, the nano-composites being contemplated to supply all the nutrients in right proportions through the "Smart" delivery systems also need to be examined closely. Currently, the nitrogen use efficiency is low due to the loss of 50-70% of the nitrogen supplied in conventional fertilizers. New nutrient delivery systems that exploit the porous nano scale parts of plants could reduce nitrogen loss by increasing plant uptake. Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients (Tarafdar *et al.* 2012c) [7-8-9-10]. In the next generation of nano fertilizers, the release of the nutrients can be triggered by an environmental condition or simply released at desired specific time.

Nano-herbicide for effective weed control

Weeds are menace in agriculture. Since two-third of Indian agriculture is rainfed farming where usage of herbicide is very limited, weeds have the potential to jeopardize the total harvest in the delicate agro-ecosystems. 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. Improvements 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 nanoparticles is aimed for specific receptor in the roots of target weeds, which enter into roots system and Trans located 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 and Kokiladevi, 2007) [1]. Adjuvant for herbicide application are currently available that claim to include Nanomaterial. 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'.

Nano-pesticide

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. Nan encapsulation comprises nano-sized particles of the active ingredients being sealed by a thin-walled sac or shell (protective coating). Recently, several research papers have been published on the encapsulation of insecticides. Nano-encapsulation of insecticides, fungicides or Nematicides will help in producing a formulation which offers effective control of pests while preventing accumulation of residues in soil. In order to protect the active ingredient from degradation and to increase persistence, a nanotechnology approach of "controlled release of the active ingredient" may be used to improve effectiveness of the formulation that may greatly decrease amount of pesticide input and associated environmental hazards. Nano-pesticides will reduce the rate of application because the quantity of product actually being effective is at least 10-15 times smaller than that applied with classical

formulations, hence a much smaller than the normal amount could be required to have much better and prolonged management. Several pesticide manufacturers are developing pesticides encapsulated in nanoparticles. These pesticides may be time released or released upon the occurrence of an environmental trigger (for example, temperature and humidity, light). Nano-based viral diagnostics, including multiplexed diagnostics kits development, have taken momentum in order to detect the exact strain of virus and the stage of application of some therapeutic to stop the disease. Detection and utilization of biomarkers, that accurately indicate disease stages, is also an emerging area of research in bio-Nanotechnology. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. Clay nanotubes have been developed as carriers of pesticides at low cost, for extended release and better contact with plants, and they will reduce the amount of pesticides by 70-80%, thereby reducing the cost of pesticide with minimum impact on water streams.

Nanotechnology in Water Management

Nanotechnology, offers the potential of novel Nanomaterial for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. Due to their unique activity towards recalcitrant contaminants many nanomaterials are under research and development for use for water purification. To maintain public health, pathogens in water need to be identified rapidly and reliably. Unfortunately, traditional laboratory tests are time consuming. Faster methods involving enzymes, immunological or genetic tests are under development. Water filtration may be improved with the use of Nanofiber membranes and the use of nanobiocides, which appear promisingly effective. Bio films contaminating potable water are mats of bacteria wrapped in natural polymers which are difficult to treat with antimicrobials or other chemicals. They can be cleaned up only mechanically, which cost substantial down-time and labour. Work is in progress to develop enzyme treatments that may be able to break down such bio films.

Nanotechnology in organic farming

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

Nanoparticles and Plant Disease Control

Some of the nano particles that have entered into the arena of controlling plant diseases are nano forms of carbon, silver, silica and alumino-silicates. At such a situation, nanotechnology has astonished scientific community because at nano-level, material shows different properties. The use of nano size silver particles as antimicrobial agents has become more common as technology advances, making their production more economical. Since silver displays different modes of inhibitory action to microorganisms, it may be used for controlling various plant pathogens in a relatively safer way compared to commercially used fungicides. Silver is known to affect many biochemical processes in the microorganisms including the changes in routine functions and plasma membrane (Pal *et al*. 2007) [4]. The silver nanoparticles also prevent the expression of ATP production associated proteins (Yamanka *et al.* 2005). In a nutshell, the precise mechanism of bio molecules inhibition is yet to be understood.

Nanoparticles and Recycling Agricultural Waste

Nanotechnology is also applied to prevent waste in agriculture, particularly in the cotton industry. When cotton is processed into fabric or garment, some of the cellulose or the fibres are discarded as waste or used for low-value products such as cotton balls, yarns and cotton batting. With the use of newly-developed solvents and a technique called electro spinning, scientists produce 100 nanometre-diameter fibres that can be used as a fertilizer or pesticide absorbent.

Nanotech Delivery Systems for Plant Hormones

Through nanotechnology, scientists are able to study plant's regulation of hormones such as auxin, which is responsible for root growth and seedling establishment. Scientists at Purdue University developed a nano sensor that reacts with auxin. This interaction generates an electrical signal which can be a basis for measuring auxin concentration at a particular point. The nano sensor oscillates, taking auxin concentration readings at various points of the root. This is a breakthrough in auxin research because it helps scientists to understand how plant roots adapt to their environment.

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 and researchers should work on reducing the potential risks associated with the technology. Proper regulatory authorities and regulatory acts should be framed and enforced to increase popularity and acceptance of technology among common people.

References

1. Chinnamuthu CR, Kokiladevi E. Weed management through nano herbicides. In: Application of nanotechnology in agriculture. C.R. Chinnamuthu, B. Chandrasekaran, C. Ramasamy (Eds.) Tamil Nadu Agricultural University, Coimbatore, India, 2007.
2. Khodakovskaya M, Dervishi E, Mahmood M, Yang Xu, Zhongrui Li, Watanabe F *et al.* Carbon nanotubes are able to penetrate plant seed coat and dramatically affect seed germination and plant growth. ACS Nano. 2009; 3:3221–3227.
3. Manjunatha SB, Biradar DP, Aladakatti YR. Nanotechnology and its applications in agriculture: A review. J Farm Sci. 2016; 29:1-13.
4. Pal S, Tak YK, Song JM. Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A study of the Gram-negative bacterium Escherichia coli. Appl Environ Microbiol. 2007; 73:1712–1720.

5. Pérez-de-Luque Alejandro and Rubiales Diego. Nanotechnology for parasitic plant control. Pest Management Science. 2009; 65:540-545.
6. Singh Gurteg, Rattanpal HS. Use of nanotechnology in horticulture: A review. Int. J Agric. Sc & Vet. Med, 2014, 2.
7. Tarafdar JC. Perspectives of nanotechnological applications for crop production. NAAS News. 2012; 12:8-11.
8. Tarafdar JC, Agrawal A, Raliya R, Kumar P, Burman U and Kaul RK *et al.* ZnO nanoparticles induced synthesis of polysaccharides and phosphatases by Aspergillus fungi. Advanced Science, Engineering and Medicine. 2012; 4:1-5.
9. Tarafdar JC, Raliya R, Rathore I. Microbial synthesis of phosphorus nanoparticles from Tri-calcium phosphate using *Aspergillus tubingensis* TFR-5. Journal of Bio nano science. 2012; 6:84-89.
10. Tarafdar JC, Xiang Y, Wang WN, Dong Q, Biswas P. Standardization of size, shape and concentration of nanoparticle for plant application. Applied Biological Research. 2012; 14:138-144.
11. Torney F, Moeller L, Scarpa A, Wang K. Genetic engineering approaches to improve bioethanol production from maize. Current Opinion in Biotechnology. 2007; 18:193-199.
12. Yamanka M, Hara K, Kudo J. Bactericidal actions of silver ions solution on *Escherichia coli* studying by energy filtering transmission electron microscopy and proteomic analysis. Appl. Environ. Microbiol. 2005; 71:7589-7593.