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SCOPE AND IMPORTANCE OF NANOTECHNOLOGY IN AGRICULTURE: A REVIEW

***Pragada Venkata Yaswanth, Pothula Himabindu, Yalagandhula Abhilash, M. Shanmukha Reddy Kondru Swetha and A. H. Madakemohekar**

School of Agriculture, Lovely professional University, Phagwara- 144411(Punjab), India
*Correspondent author E-mail: venkatayaswanth3@gmail.com

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ABSTRACT

Now a day due to increase in the population and climate changes nanotechnology is the best option, because nanoparticles have distinctive physical, chemical and biological traits. Nanoparticles contain herbicides, pesticides, fertilizers, which act as 'magic bullets', these are target specific in nature and release their content slowly based on crop requirement. Nanotechnology is using different fields moreover in this study of agriculture is the most useful to the future increasing population. The current review underlines the application of nanotechnology in nano-fertilizers, Nanoherbicides, nano pesticides. Nanotechnology usedin vegetables and in management of plant pathogen and also introduction of biosensors to detect nutrients and contaminants.

Keywords : Nanotechnology, Agriculture, Nanoparticles, Nanopesticides, Nanofertilizers.

INTRODUCTION

The word nanomaterial originate from Greek word, "nano" means "dwarf". Exactly the nano measures as 10^{-9}m. Generally, the term nanomaterial is used to measure things, between one to hundred nm range (Rai, Mahendra and Ingle, Avinash, 2012). Richard Feynman first discussed (1959) the concept of seeded nanotechnology in his talk "*There's plenty of Room at the Bottom"*. The term 'nano-technology' was first used by Norio Taniguchi in 1974. Inspired by Feynman's concept K. Eric Drexler used the term nanotechnology in his book '*Engines of Creation: The Coming Era of Nanotechnology'*.

In developing countries agriculture plays a major role, out of 100% more than 60% of the population hang on agriculture for their livelihood. In present scenario department of agriculture Scientists are facing numerous challenges, including decreased crop yield, decreased organic content in soil, reduced nutrient use quality, multi nutrient deficiencies, adverse climatic conditions, declining arable land and water availability, and a labour shortage in addition to that people start quitting from the farming. To unravel these problems, we need to explore a novel technology like 'Nanotechnology' as well as we need to bring sustainable growth in agriculture. Nanotechnology has the potential to revolutionise the agricultural industry (Subramanian, and Tarafdar, 2011). After the industrial revolution in the mid-1700s, nanotechnology is the 6th ground-breaking technology in the current century. Nanotechnology can be utilized in different disciplines i.e., Biology, Physics, Chemistry, Electronics, Medicine, Energy, Material science, Soil science, Environment and Health sector.

In future, implication of nanotechnology plays major role in agriculture, the future food will be designed according to consumers taste, texture, nutrient content and longer shelf life. The food will be packed in safety packaging, which can detect the contaminants and spoiling agents. Nanotechnology is an innovative, interdisciplinary scientific approach that involves designing, development at molecular level in nanometer scale i.e. at least one dimension ranges in size from 1-100 nm (Lin, Henry, and Ram H. Datar, 2006). The first decade of 21st century witnessed as vigorous increase in nanofood market. The utilization of nanotechnology in agriculture is major role, because it enhanced food values, reduced agricultural inputs, improved nutrient content and longer shelf life.

The measurement of different organisms and biogenic substances on the micro and nanometric plate are as follows:

1) Plant, animal cell: 10-100µm; 10000-100000nm
2) Bacteria: 1-10µm; 1000-100nm
3) Virus: 0.03-0.1µm; 30-100nm
4) Atoms (DNA base) : 0.0001-0.001µm; 0.1-1nm

Why Agriculture and Food Industry?

The gradual increase in human population and reducing the healthier habitat condition due to increased pollution, utilization of agriculture land and water resources for civilization, due to these limitations there is a lot of food shortage occur in developing countries. In developing countries pest and drought resistant crops were developed, which also increase yield. In developed countries the agro food industry produce fresh and healthier food based on consumer demand. In near future the food production won't satisfy the increasing world population. With limited land

and water resources, we need to apply modern technology to satisfy demand-output ratio in agriculture. Nanotechnology, that specialize in special properties of materials emerging from nanometric size has the potential to revolutionize the agricultural and food sectors, biomedicine, environmental engineering, safety and protection, water management, energy conversion, and a variety of other fields are just a few of them. In 2003 the US Department of Agriculture first introduced Nanotechnology's application in agriculture and the food industry Nanotechnology is expected to change the entire food industry, altering how food is produced, stored, packaged, transported, and consumed.

The appliance of nano-technology in disease control, slow release of pesticides and developing diagnostic tools, and development of functional food systems, to supply interactive, edible nano wrappers to stay the pathogens away, targeted release of chemicals, packaging, extensive nano surveillance, interactive agrochemicals as herbicides and pesticides are discussed during this review.

Application of Nanofertilizers:

In India, fertilizers, alongside quality seed and irrigation, are mainly responsible for enhanced grain production (55 Mt) in1960s to (254 Mt) in 2011 coinciding with the spectacular increase in fertilizer consumptions from 0.5 Mt to 23 Mt, respectively. It's been conclusively demonstrated that fertilizer contributes to the tune of 35-40% of the productivity of any crop. Considering its importance, the govt. of India is heavily subsidizing the value of fertilizers particularly urea. This has resulted in imbalanced fertilization and occurrence in some areas, nitrate pollution of groundwater 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, excess fertilizers accumulate within the soil and also causing eutrophication in lakes by entering into the aquatic system. So as to address problems with 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.

Nanofertilizer technology is innovative, reporters noticed a remarkable increase in yield of the crops due to foliar application of nanoparticles as fertilizers (Tarafdar *et al.,* 2012), (Ramesh Raliya *et al.,* 2012). Nanoparticles have wide surface area, so they contain more nutrients and release slowly into the soil based on the crop requirement then plants absorb nutrients according to their need without any difficulty. In recent studies, nano mixture consist of micronutrients, Nitrogen, phosphorus, potassium and amino acids(AA) so this mixture increases the absorption capacity and grain crops usage (Guo, Jinghua, 2004). Bhattacharya (2004), shown that proper implication of NPK along with Sulphur, Zinc, Boron and Molybdenum will be an effective solution for higher grain yield of pulses in red and laterite soil. Thus nanoparticles used in the membrane, which control release of nutrients. Subramanian *et al.* (2008), shown, use of Nanofertilizers to control particular amount of nutrients released from fertilizer granules, then to promote nutrient efficiency without loose of nutrient ions from environment. Now a day's nanoporous zeolite usage in farming was increased because chemical fertilizers adversely damage the environment (Ramesh *et al.,* 2010). According to above information and implementation of these patented products will promote the scope for the Nanofertilizers in future generations (DeRosa *et al.,* 2010). Nanofertilizers are more efficient than ordinary fertilizers.

Development of new type of nano pesticides

Pests are the one of the major problem in agriculture. Pests on average causes 25-30% yield loss in agriculture crops (Kwon, 1998). Generally, pesticides are used to control pest population in field but by using normal pesticides there are several complications are present. So, to overcome these difficulties we need to utilize nanotechnology in agriculture. To create innovative pesticides and eco-friendly pesticides. We need to apply pesticide at the initial stage of crop, it helps to reduce the pest population below the economic threshold level. But, at the same time we need to look on persistence of pesticides. As long the persistent of active ingredient on the surface of crop have an effective control of pests for longer period of time. To achieve this condition nanotechnology, introduce an approach called 'nano-encapsulation' it can improve the insecticidal value by promote persistent of active ingredient as well as protection from adverse climatic conditions.

In this approach the size of active ingredient reduced to nano-sized particles these are encapsulated by protective coat. There is an effective control of pests will be observed by using these encapsulated nematicides, insecticides, fungicides and at the same time there will be no chance to accumulation of chemical residues in the soil. In this way we can protect the active ingredient from degradation and promote the persistence of formulations. There is one more advantage of this approach is controlled release of pesticide, which can increase the efficiency of pesticide. So within small amount of active ingredient there will be effective control of pests, then we can reduce cost and reduce environmental hazards. Several manufacturers are developing encapsulated pesticides (OECD, 2008).

Application of nano pesticides on crop through spraying by mixing of pesticides with water, then we can increase control capacity of pesticides. The efficiency of biopesticides are three times of normal pesticides, and reduced cost of nanopesticides compared to ordinary pesticides (Diengngan, 2015). Jinggangmycin nanocapsules contain as the core material of Jinggangmycin, which is prepared by micro-emulsion polymerisation. Which is used as against the rice sheath blight (*Rhizoctonia solani*), indoor experiment represents the 1/2 level of Jinggangmycin nanocapsule is 4.23 μg/ml, contain 88 times over the original drug.

Application of nanotechnology in vegetable crops:

The seeds of cowpea, cabbage and cucumber are soaked in water treated with nano-863. The legume seeds are soaked for 2 hours, brassica for 4hours and cucumber for 12hours. The average germination rate, state of germination, bud length, diameter and fresh weight are higher than the seeds treated with normal chemical water (control). The germination % of treated cowpea seeds is 25.8% higher than control group and the germination % increased up to 30.7%. It also enhances disease resistant ability of flower. The height of garlic bolts increased up to 5 cm longer than, where garlic treated with normal chemicals, when garlic was soaked in nano-863 for 20 days. By using nanotechnologies, we can study nitrate, nitrite and vitamin C content in vegetables. By using this nanotechnology device on vegetables, there is no fluctuation changes in vitamin C content (Zhang *et al.,* 2008)

Nanotechnology in Management of Plant Pathogen

By using nanotechnology different types of nanoparticles are used as plant protectants. These nanoparticles have different peculiar biological, physical and chemical properties (Yang *et al.,* 2008). Alone nanoparticles have the capability to applied directly to plant parts such as seeds, foliage, roots for protection from viruses, bacteria, insects. Researchers found that antiviral, antibacterial and antifungal properties are present in metal nanoparticles such as titanium dioxide, zinc oxide, silver and copper nanoparticles (Kah *et al.,* 2014; Gogos *et al.,* 2012; Kim, *et al.,* 2018). Recently, due to green synthesis in plants, bacteria, fungi the popularity i.e., utilization of silver nanoparticles was increased (Rafique *et al.,* 2017). By the process of diffusion assay silver nanoparticles shown antifungal properties against *to Alternaria alternata, Sclerotinia sclerotiorum, Macrophomina phaseolina, Rhizoctonia solani, Botrytis cinerea* (Krishnaraj *et al.,* 2012).

Silver nanoparticles also shown antifungal properties, there is complete suppression of sun-hemp rosette virus was observed when silver nanoparticles were applied onto the bean leaves (Jain and Kothari, 2014). Bean yellow mosaic virus was one of the major disease in *Vicia faba*, (Elbeshehy *et al.,* 2015). Conduct one experiment in that he sprayed silver nanoparticles to post infection of crop and in another normal chemical were applied at before infection of disease. Surprisingly better results obtained in nanoparticles. These silver nanoparticles have colossal capacity in plant disease management against fungal, bacterial pathogen, but these nanoparticles have significant snags such as production, soil interaction and toxicity (Kah and Hofmann, 2014; Mishra, and Singh, 2015). Apart from silver nanoparticles regularly used metal nanoparticles are titanium dioxide, gold and copper. Scientists observed in their research was antimicrobial properties seen in copper, silver, titanium dioxide nanoparticles and insecticidal properties seen in aluminium nanoparticles (Kah and Hofmann, 2014). Apart from that titanium dioxide also used in fertilizers and they protect crop from bacteria and virus (Sadeghi *et al.,* 2017). By using mechanical abrasive technique scientists invented poly-dispersed gold nanoparticles, which melt and dissolve the Barley yellow mosaic virus and gives resistant to plant (Alkubaisi *et al.,* 2015).

The another popular nanoparticle called as Chitosan. It has following traits such as non-allergenicity, biocompatibility, biodegradability, antimicrobial activity and non-harmful to the humans and animals (Cota–Arriola *et al.,* 2013). These nanoparticles also induce mosaic virus resistant to alfalfa, snuff, peanut, potato and cucumber by protecting them from this viral infection (Kochkina *et al*., 1995; Pospieszny *et al*., 1991; Chirkov, 2002). Malerba and Cerana (Malerba and Cerana, 2016) mentioned some of the antimicrobial mechanisms of these nanoparticles such as destruction of cell membrane, agglutination, hindrance of proton ATPase activity, reduce the production of toxin, hampering the microbial growth, blockage of protein and messenger RNA synthesis. Chitosan also against to some of the pests such as root knot nematode, nymphs of spear psylla, cotton leaf worm, oleander aphid. Chitosan are less effective against to bacteria and these are used as nanocarriers. Researchers also observed antifungal properties in chitosan nanoparticles, the mode of inhibition will be mention below

a) The chitosan nanoparticles have positive charge and fungi membrane has negative charge, So the chitosan positive charge combines with negatively charged phospholipid component of cell membrane, which results the changes occur in plasma membrane permeability, ultimately it leads to death of the cell (García-Rincón *et al.,* 2010).

b) Chitosan coordinate with metal ion, it is one of the mode of antimicrobial action (Rabea *et al.,* 2003). In this mode the chitosan barge in the normal growth of fungi by interact with trace elements and making that nutrients inaccessible for its development (Roller and Covill, 1999).

c) In this mode the chitosan inhibits the mRNA synthesis by penetration of fungal cell wall and alter the normal function of its DNA, which results in blockage of protein and enzymes production (Sudars han, *et al*., 1992).

The new techniques of detection of diseases by using nanobiosensors (Yalcin and Otles, 2010), it is a fast and instant detection tool within a less time (hr) and provide desired results. Different detection techniques are listed below:

1) Nanoscale Biosensor
2) Antibody Biosensor
3) Gold nanoparticles and Quantum dots (QDs)
4) Nanofabrication
5) Portable nanopore sequencing and genome sequence
6) Portable PCR systems and portable equipment
7) Fluoroescent silica nanoparticles merge with antibody molecules (FSNP)
8) Modified copper nanoparticles with gold electrode
9) Carbon electrodes are screen printed by TiO_2 and SnO_2 nanoparticle
10) Nanobiosensor diagnostics

Nanoherbicides

Weeds are the most serious threat to agriculture, as they reduce crop production by consuming nutrients that would otherwise be available to crop plants. Weed eradication by traditional methods takes a long time. Herbicides are commercially distributed in a variety of forms. They destroy weeds in the fields, but they also damage crops. Reducing the soil fertility and causing soil pollution, these are resulted by using available market herbicides. Nanoherbicides have the potential to play a critical role in clearing weeds from crops in an environmentally sustainable manner, leaving no toxic residues in the soil or ecosystem (Pérez-de-Luque and Rubiales, 2009). Nanoherbicides are less toxic to environment i.e., these herbicides are safely encapsulated in nature friendly polymeric nanoparticles, so this polymeric coating naturally degraded substance no harmful effect to environment and at the same time require quantity of herbicide release slowly in the soil (Kumar *et al.,* 2015). Herbicides used in excess over prolonged periods of time leave residues in the soil, causing damage to subsequent crops (Chinnamuthu and Boopathi, 2009).

Generally, weeds got resistant to herbicides because, by continuous utilization of same herbicides for longer period of time. The potential of nano zerovalent iron (nano ZVI) has been tested for its ability to dechlorinate the herbicide atrazine (2-chloro-4ethylamino-6-isopropylamino-1,3,5-triazine) from atrazine contaminated water and soil (Satapanajaru *et al.,* 2008) The transmission of herbicide-loaded nanoparticles to the roots of weeds has been established. These molecules get into the weeds' roots, translocate to cells, and block metabolic pathways including glycolysis. Plants would eventually die as a result (Nair *et al.,* 2010; Ali, *et al.,* 2014) Researchers observed the herbicides, ametryn and atrazine toxic to both alga (*Pseudokirchneriella subcapitata)* and the microcrustacean (*Daphnia similis*). When these same herbicides encapsulated in the poly (ε-caprolactone) nanocapsule different result was observed i.e., here high toxic to the microcrustacean and less toxic to the alga (Clemente *et al.,* 2014). Here some of the nanoparticles are used as herbicides toxic to the weeds as follows:

1. Silver nanoparticles-chitosan encapsulated praquate toxic to *Eichornia crasipes* (Namasivayam *et al.,* 2014).
2. Ag, Cu, Fe, Zn, Mn are used as herbicide against to *Allium cepa* (Konotop *et al.,* 2014).
3. CuO toxic to the *Raphanus sativus*, *Lolium perenne* and *Lolium rigidum* (Atha *et al.,* 2012).
4. CuO and ZnO toxic to the *Cucumis sativus* and *Fagopyrum esculentum* (Lee *et al.,* 2013; Kim *et al.,* 2012).

Biosensors for detection of nutrients and contaminants in soil

The rapid, sensitive identification of pollutants and pathogens with molecular precision is needed to protect soil health and the environment. Soil fertility testing has been done for the past sixty years using the same series of guidelines, which may be outdated for today's processing systems and precision farming techniques. In situ identification, miniaturised handheld instruments, and remote sensors for real-time monitoring of vast areas in the field all need accurate sensors.

Long microbial research and immunoassays can be completed in a fraction of the time using these instruments. These devices are used to track toxins in a variety of bodies, including water systems, raw agricultural materials, and food items. Since enzymes are very particular in their connection to specific biomolecules, they can be used as a sensing element. The electronic nose (E-nose) uses a sequence of reaction through an array of gas sensors to distinguish various types of odours. It will classify the odorant, estimate the concentration of the odorant, and determine the odor's characteristic properties in the same manner as the human nose can. It primarily consists of nanoparticle-based gas sensors, such as ZnO nanowires. Through the transit of a certain gas, their resistance increases, resulting in an electrical signal transition that create the fingerprint pattern for gas detection. Biosensors are high-performance devices that can detect toxins in food or in the atmosphere. At a low cost, they have high accuracy and sensitivity, fast response, user-friendly service at small scale (Amine *et al.,* 2006). Though direct enzyme inhibition sensors do not yet have the analytical capability to distinguish between multiple toxic substances in a sample (for example, the inclusion of a heavy metal and a pesticide at the same time), they may be useful as a screening method to assess if a sample contains one or more pollutants. These techniques may be used in single-use test strips (making them useful to those in the field). A nonmagnetic particle was used in an enzyme associated immune sorbent assay (ELISA) test to (Hu *et al.,* 2010) detect several residues of organophosphorus pesticides, according to the researchers. According to the scientists, ELISA is less costly than analytical experiments that require expensive laboratory instruments and a high degree of expertise.

CONCLUSION

In present situation we facing great challenges particularly due to an increase in world population and change in climate, the adverse climatic conditions effect the agriculture crop system i.e., reduce the yield and production quality, the implication of nanotechnology and introduction of nanomaterials in agriculture, which improve sustainability. It enhances the efficient use of fertilizers and pesticides by using nanoscale carriers and compounds without loss of productivity. It also used for reducing the waste and efficient reuse of waste. Introduction of biosensors play a very important role to detect nutrients and contaminants, based on information we can provide recommend dose nutrients at the same time we can find the remedies for contaminants.

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