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NANOTECHNOLOGY: A TOOL FOR PLANT DIAGNOSTIC AND TREATMENT OF ALL ITS ESSENTIAL ELEMENT TO SUSTAIN LIFE: A REVIEW

Chhaya Pawar*   H.K.Gautam**
**R.A.E.O., Farmer Welfare and Agril. Development, Block- Narwar, Dist-Shivpuri,M.P.*
***Assistant Professor, Department. Of Entomology, Sri Durga Ji Post Graduate College Chandeshwar, Azamgarh,U.P.*

Abstract
In the current agricultural scenario, the extensive use of agrochemicals to boost agricultural production has polluted the top soil, groundwater and food. Increasing agricultural productivity is necessary, but keeping in mind the damage to the ecosystem new approaches need to be considered. Nanotechnology is becoming increasingly important for the agricultural sector. Promising results and applications are already being developed in the areas of delivery of pesticides, biopesticides, fertilizers and genetic material for plant transformation. The use of nonmaterials for delivery of pesticides and fertilizers is expected to reduce the dosage and ensure controlled slow delivery. A main contribution anticipated, is the application of nanoparticles to stabilize biocontrol preparations that will go a long way in reducing the environmental hazard. Nanotechnology, by exploiting the unique properties of nonmaterial, has developed nanosensors capable of detecting pathogens at levels as low as parts per billion. Apart from detection, nanotechnology also has solutions for degrading persistent chemicals into harmless and sometimes useful components. The tools of nanotechnology can be employed to address the urgent issues of environmental protection and pollution. Nanotechnology can endeavor to provide and fundamentally streamline the technologies currently used in environmental detection, sensing and remediation.

Key words:-Nanotechnology, agriculture, production, management.

Although the scientific studies on the applications of nanotechnology in the agriculture are less than a decade old yet the prospects of nanotechnology in this field are considerable. The rapid developments in the nanosciences have a great impact on agricultural practices and food manufacturing industries. Nanotechnology has an enormous potential to offer smarter, stronger, cost-effective packaging materials, biosensors for the rapid detection of the food pathogens, toxins and other contaminants or food adulterants. It is also plays an important role in developing new generation of pesticides with the safe carriers, preservation and packaging of food and food additives, strengthening of natural fibre, removal of various contaminants from the soil and water bodies by using functionalized nanoparticles and improving the shelf-life of the vegetables, flowers and fruits. In spite of the above mentioned immense uses, the competency is being exhibited in some of success business models in developing nanotechnology based products. The safety and regulatory concerns of the application of nanotechnology for human beings, environments and ecosystems are required to be debated, particularly in the developing countries. There are few potential points of direct human exposure to nonmaterial along with the agric-food chains (from the worker to the consumers), and the threat of the possibility of the nanoparticles reaching the non-targeted sites which can also pose health and environments problems. Keeping in mind all the above benefits and risks associated with nanotechnology, an effective risk management strategy should be followed in parallel to the technological developments or advancements. Moreover, a stable governance model system should be adopted during the entire process (from production to consumption) of nonmaterial with continuous interactions and involvement of all the stakeholders. (**Dhewa 2015).**

The term Nanotechnology has been defined as the branch of the science that deals with the understanding and control of matter at the dimensions of about 1-100 nm by the US Environmental Protection Agency. It includes controlling, building and restructuring of the devices and other materials of physical, chemical and biological features at nanoscale level i.e. on the scale of atoms and molecules a nanometer (nm) is one billionth (10^9) of a meter). The functionality can be added to nanoparticle by interfacing them with bimolecular or structures. In the twenty first century, nanotechnology has emerged with the great influence on global economy, industries and public lives. If we look at the historical part of agricultural applications of nanotechnology, it came only in recent years but the seeds of research in this field start growing nearly half a century ago (Mukhopadyay, 2014).The uses of nonmaterial specifically for the agricultural purposes are required for improving the fertilization process, increase in yields through nutrient optimization and minimized the requirements of plant protection products (Huang et. al., 2015).

Applications of nanotechnology in agriculture

In recent years, some devices and tools developed by nanotechnology such as nanodevices, nanocapsules etc. being used to detect and treat the plant diseases, delivery of active components to the desired target sites, treatment of waste water and also to enhance the absorption of nutrients in plants. The targeted delivery of nanoparticles not only reduces the damage to non-

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target plant tissues, but also minimizes the amount of harmful chemicals that pollutes the environment. Hence, this technology is not only eco-friendly but also helps in reducing the environmental pollutants. There are some specific nanoproducts that have been developed for using as soil-enhancer products which promote the even distribution of water and storage. Thus, useful in water saving. Besides, some of the important developments in production of nanotechnology products like nonmaterial, nanostructures, nanofibers, nanotubes, etc. with unique physical, mechanical and chemical properties which make them electrochemically active. Such devices play vital role in plants and animal breeding (Prasanna, 2007), genetic engineering and also have been applied in biochemical sensors due to rapid response along with high sensitivity. Nonmaterial can also be used in delivery of nutrients and pesticides in the plants (Srilatha, 2011), analysis of soil samples and waste water treatment. Agricultural wastes have attracted their uses as raw materials for the production of nonmaterials. The main applications of nanotechnology in agriculture are (i) Determination of enzyme-substrate (E-S) interactions (by detection of single molecule). (ii) For more efficient delivery of fertilizers, pesticides, vaccines, growth regulatory hormones and other chemicals using nanocapsules or annotates. (iii) In genetic engineering of plants, delivery of desired DNA into the plants using nanoparticles. (iv) Delivery of vaccines into plants using nanocapsules. (v) The use of nanosensors for the detection of the plant pathogens, monitoring the soil conditions and plant growth, etc.

Detection of nutrients and pathogens

For effective protection of agricultural health and environment needs the quick and sensitive devices to detect pollutants and pathogens. To achieve this, accurate sensors are required for in-situ detection, as miniaturized portable instruments, remote of ex-situ sensors, for the real-time monitoring of large areas in the field. The biosensors have been developed by nanotechnology for the detection of contaminants or pollutants in various kinds of wastes such as water, foods products, etc. with high performance competences. They offer high specificity and sensitivity, rapid response, operator-friendly and small size at a low cost of production. The enzymatic biosensors have also been developed that can used for the specific sensing of many elements. The electronic nose (E-nose) is athat gas (Ditta, 2012). They are also used for the rapid and sensitive detection of various products and organisms. For example, alcohol production during fermentation, growth of variety of microorganisms, bakery products, foul odor produced by bacterial rotting, etc. Bacteria, beneficial as well as harmful life forms in the nature, are responsible for a variety of diseases. Human beings may acquire certain diseases i.e. food borne illnesses from contaminated water and agricultural products. Therefore, their detection is very important to avoid infections or diagnosis and treatment of the diseases. Bacterial cells can be easily detected by staining method by using different dyes. To stain bacterial cells, the most widely practiced boilable i.e. organic dyes. Such dyes are expensive and their fluorescence disappears with time. Recent advancements in the field of nanotechnology i.e. development of luminescent nanocrystals, discovered quantum dots (QDs), which can be used in fluorescent labeling in biological recognition of molecules. As compare to the organic dyes QDs are superior to conventional organic dyes because of their more efficient luminescence, narrow emission spectra and excellent photo stability properties.

Nano-scale carriers for targeting delivery

The nanotechnology has developed ways of delivering important compounds to the plants for improving their yields. The nanoscale carriers i.e. nanotubes, for this purpose, can be used for delivering pesticides, herbicides, fertilizers, plant growth regulators, other chemicals efficiently to the target site (NAAS, 2013). For this purpose, polymers and dendrimers are used. The agents are attached at the surface of these polymers and dendrimers by ionic and weak bonds. These carriers are able to bind the roots of plants efficiently to the surrounding soil and organic materials. By this way of delivery of these chemicals helps in improving the stability of compounds by reducing the degradation in the environment. Hence, the increased stability of these compounds in the natural environment reduces the amount required to be applied. The reduction in the amount not only reduces the environmental pollution but also the cost of productions. Ultimately, this will also help in the reduction of the wastes produced. The biosensor device that consists of gas sensor composed by nanoparticles i.e. ZnO nanowires. This is based on the activity of human nose, used for the identification of the odors of various kinds, identification of odorant i.e. the determination of the type of odorant, for estimating its concentration (quantity), and for finding the characteristics (its quality). The detection by this device is based on the operation of human nose. As the a particular gas passes, the resistance of the device changes and generates a changed electrical signal and this signal forms a fingerprint pattern to detect the type, quality and quantity of developments and innovations in nanofabrications and characterization of tools have enabled us to understand the interactions (physical, chemical and biological) between plant cells and pathogens. The improved and increased understanding of the mechanisms involved in the interactions and the development of diseases, thus it enabled us to develop better ways of the treatment of such diseases. In addition, the development of the micro-fabricated xylem vessels (nano-sized features) has enabled us to study various types of mechanisms involved between the plant-pathogen interactions which was earlier not possible to study using traditional strategies.

Wastewater treatment and disinfection

An application of photo catalytic decomposition properties of nanoparticle has earned acceptance in cleaning and decontamination of polluted water. The photo catalysis is a process, which involves the use of the nanoparticles (a product of the nanotechnology). In this, nanoparticles are the catalyst. In this process, the reaction of the nanoparticles with the specific chemical compounds occurs in the existence of light. Such process can be used to decompose the toxic chemical compounds including pesticides that are generally not degraded under normal conditions. When a particular compound is bound to the nanoparticles, after the exposure of UV rays, those electrons present in the outermost shell called „valence electrons‟ becomes excited and the excitation leads to creation of the electron hole pairs (negative electrons and positive holes). Now, such negative electrons acts as excellent oxidizing agents (i.e. ZnO, ZnS, etc.), and shows very high capacity of degradation and disinfection because of their large surface to volume ratio. The surface atoms are increased as the particle size decreases that cause the tremendous increase in the reactivity of the chemical compounds and other properties that are essential for the activity. The pollution or contamination of natural water bodies is presently a major problem in the growing world. The wastewater has negative influence not only on the environment but also on the health of animals and human beings. Therefore, the treatment of wastewaters is now very serious issue that required to be solved with an immediate effect using eco-friendly technologies. Although, from past many years, several methods have been applied to treat the polluted water yet, nanotechnology has emerged in this sector with immense potential. For example, the process of photo catalysis can be applied to treat the contaminated water. It has been scientifically proved that by using semiconductor sensitized photosynthetic and photo catalytic processes, the organic compounds, destruction of cancer cells, removal of bacterial cells and viruses can be achieved. Nanotechnology is also useful in cleaning of waste water. During disinfection of water, the nanoparticles, when excited with the light source, negative electrons are released. These electrons can be used for removing the bacterial cells from the contaminated water. In addition, these nanoparticles can also be used as disinfectant in food packaging industries (Soutter, 2014).

Bioremediation

Nanotechnology has played a significant role in microbial remediation. In agricultural system, some chemicals such as pesticides are slow degrading or resistant to degradation in nature hence they remain in the environment for longer time and cause serious problems, by applying nanotechnology, these toxic or harmful compounds can be degraded under certain conditions. If they are not degraded, they may enter the food chain and may cause serious health problems. Recent developments in agricultural nanotechnology have shown a promising step in this direction. For example, nanoparticle-water slurry can be mixed in contaminated soil and in due course of time, these particles will reduce the toxicity of slowly degradable or resistant pesticides.

Quality enhancement of agri-products: The nutritive properties and health related benefits of the agricultural products by applying the nanotechnology have attracted the interest of the consumers and the agri-food industry in this field. From studies, it has been concluded that the Zinc spray of the nanoparticles was found to be essential to increase the vegetarian protein, fat, and fibers in the Indian diets. There are many studies going on for testing the genotoxicity of the nonmaterial's and still underway for developing and testing various nano particles to protect crops from powdery mildews (Hiregoudar, 2014). From the early years, the gold was also an attractive and useful metal because of its unique and valuable nature. The development of gold nanoparticles has many commercial applications. They are also used for the detection of the biomolecules. The detection is based on the fact that the shape, size, refractive index of the nearby medium and the distance between the gold nanoparticles are the major factors on which the color of these colloids is dependent. Even a small variation in the above factors may cause the measurable change in the Surface Plasmon Response (SPR) absorption peak. The specific molecules are attached to the gold nanoparticles by their adsorption at the surface of the particle that subsequently changes the RI (refractive index) of the gold nanoparticles. If the bimolecular to be attached are larger than the gold nanoparticles, only few molecules will be adsorbed at the surface of the nanoparticles and will lead to formation of the lumps and this ultimately changes the color of the gold nanoparticles. The changes in the color of nanoparticles have resulted from the shift in SPR that ultimately cause the reduction in the spacing of particles. A very interesting development in the field of nanotechnology is the „smart dust‟. This technology can be used to monitor different parameters in food or environment such as temperature, humidity etc. (Ditta, 2012).

Identification and tracking of agri-foods

Identification (ID) tags play very important role in our routine life. They have been useful in wholesale trading of food and agricultural products. Because of small size, nanomaterials have been used in different sectors encoding of agricultural products. Nanobarcodes have been used in multiplexed bioassays and usual encoding due to their great potential of development of numerous blends that make them useful for this purpose Particles that are used in the nanobarcode should

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have encode able, readable by the machine, robust enough to be used for longer time and sub-micro nanometer in size. The nanobarcodes have both biological and no biological applications in the agricultural fields (Ditta, 2012). The advancement and developments in the nanotechnology have led to the improvement in the plant resistance properties against many environmental stresses i.e. resistance to drought, salinity, various infections, etc. (Beyrouthya and Azzia, 2014). 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 (USDA, 2003). However, the application of nanotechnologies in the agronomic and environmental domains is still in its infancy (Gonzalez-Melendi et al., 2008). Major challenges related to agriculture, such as low productivity in arable areas, large non-arable areas, shrinkage of arable lands, wastage of inputs such as water, fertilizers, pesticides, wastage of products and, of course, food security can be addressed through various applications of nanotechnology. Applications of nanotechnology in agriculture are still in their infancy and not many studies have been carried out in this field (Baruah and Dutta, 2009). Despite the scientific and technical knowledge achieved so far, in many conditions, crop productivity potential has not been fully realized. This is attributed to low nutrient and water use efficiency of crops and stiff competition from weeds and crop pests (Schroeder et al., 2005). Nanotechnology offers a new scientific approach to break this yield barrier and may improve our understanding of the biology of different crops. This has the potential to enhance yields and nutritional values, and improve systems for monitoring environmental conditions and delivering nutrients or pesticides as appropriate. Some studies demonstrated the role of nonmaterial's in enhancing seed germination rates in tomato (Khodakovskaya et al., 2009), spinach (Zheng et al., 2005) and rice (Lin and Xing, 2007), and consequently the crop dry matter yield, at least in the early stages of growth. However, several concerns remain on the possible phytotoxicity of some types of nanomaterials, depending on their composition, concentration, size and physical chemical properties (Ma et al., 2010a) and on the susceptibility of the plant species (Khot et al., 2012; Taylor and Fauquet, 2002; Torney et al., 2007). Toxicity of nanomaterials could possibly be reduced by coating them with biocompatible products before their application to seeds, increasing their effectiveness for plant germination and growth while avoiding negative impacts on seedlings (Khot et al., 2012). However, research findings are far from fully explaining the complex connections between the characteristics of NPs and plant traits with phytotoxicity (Ma et al., 2010a). Plant production could also be increased through the development of nanomaterials that can be used as a coating layer to enable the slow release of traditional fertilisers. For example, the possible role of chitosan NPs (Corradini et al., 2010; Mura et al., 2011a) and of kaolinbased nanolayers (Liu et al., 2006) was assessed for slow release of NPK fertiliser, but further investigation is still needed (Ghormade et al., 2010). Nanomaterials have been recently reported to have a potential role in plant protection by: i) increasing the dispersion and wettability, and the affinity to pesticide target (Bergeson, 2010; Jianhui et al., 2005); ii) providing better penetration of herbicides through cuticles and tissues of weeds (Gonzalez-Melendi et al., 2008; Perez-de-Luque and Rubiales, 2009); iii) altering viral capsids to achieve different configurations and deliver specific nucleic acids, enzymes or antimicrobial peptides acting against the parasites (Torney et al., 2007). The use of nanostructured catalysts could improve the efficiency of pesticides and herbicides, allowing lower doses to be used (Corredor et al., 2009). Perez-de-Luque and Rubiales (2009) suggested that a potential development of new nanomaterials is towards the building of agrochemicals containing different nano-substances for different functions (plant protection, fertilisation, hormones, etc.) and encapsulated separately to avoid interactions between them and degradation. In this way, several substances could be applied with the same treatment to the crop, and the nanocapsules could be regulated to release their load according to the characteristic of every loaded substance. Some studies showed the potential use of nanotechnologies to detect microbes (Karn et al., 2009; Ma et al., 2010b) contaminants (Hillie and Hlophe, 2007), toxic pollutants (Balaji, 2006) and for monitoring soil conditions, crop growth, plant microenvironment and enzyme/substrate interactions (Gonzalez-Melendi et al., 2008). Nanotechnology can also be applied for remediation purposes through the construction of nano-photocatalysts able to degrade organic pesticides and industrial pollutants in harmless and useful products (Otto et al., 2008; Karn et al., 2009; Sidorenko et al., 2003). Filters or catalysts could also be created to reduce pollution or clean-up existing pollutants (Han et al., 2008). This technology, combined with others such as biotechnology, can make genetic manipulation of plants easier. It allows NPs, nanofibers or nanocapsules to be used as vectors of new genetic material instead of conventional viral vectors. These new vehicles could carry a larger number of genes, as well as substances able to trigger gene expression (Miller and Senjen, 2008; Nair et al., 2010) or to control the release of genetic material over time.

Nanotechnology could have several applications in soil science (Lal, 2007). The nanoscale delivery vehicles may be designed to fix the surrounding soil particles or organic matter (Johnston, 2010), allowing more efficient release mechanisms. These features could promote the active substances to be taken up at a slower rate throughout crop growth, avoiding temporal overdoses, and minimizing input and waste (Chen and Yada, 2011). The slow release of nutrients into the environment could be achieved by using zeolites; these are a group of naturally occurring minerals with a honeycomb-like layered crystal structure. Fertilizer particles can be coated with nanomembranes that facilitate slow and steady release of nutrients. Coating and cementing of nano and subnano-composites are capable of regulating the release of nutrients from the fertiliser capsule

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(Liu et al., 2006). A patented nano-composite consisting of nitrogen, phosphorus, potassiunm (NPK), micronutrients, mannose and amino acids that increases the uptake and utilisation of nutrients by grain crops has been reported by Jinghua (2004). Nitrogen leaching was found to be lowered when slowrelease fertilisers were coated by nanomaterials such as plastic-starch composites applied to wheat (Zhang et al., 2006). The installation of nanosensors, or nanoscale wireless sensors, in farmers' field is being applied to enable the real time monitoring of soil and the early detection of potential problems such as soil nutrient depletion and water deficit (Scott and Chen, 2003). In this context, nanosensors can be a means to extend the logic of precision farming in novel ways in order to detect and rectify agronomic problems in very short time frames. Nanomaterials, such as hydrogels and zeolites, were reported to be useful to improve water-holding capacity of the soil (El-Salmawi, 2007) and to absorb environmental contaminants (Yuan, 2004; Baruah and Dutta, 2009).

Fertilizer play pivotal role in the agriculture production up to 35 to 40% of the productivity. To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nanofertilizer might be a best alternative. Attempts have been made to synthesize nanofertilizer particulary for zinc in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nanonutrients are more efficient than ordinary fertilizer(Raliya,2012). An enhanced production has been observed by foliar application of nano particles as fertilizer(Raliya and Tarafdar ,2013).
Traditional strategies like integrated pest management used in agriculture are insufficient, and application of chemical pesticides have adverse effects on animals and human beings apart from the decline in soil fertility. Therefore, nanotechnology would provide green and efficient alternatives for the management of insect pests in agriculture without harming the nature. This art is focused on traditional strategies used for the management of insect pests and potential of nanomaterials in insect pest control as modern approaches of nanotechnology (Ragaei and Sabry ,2014)

Table 1. Several examples of polymers often used in the nanoparticle production.

Polymer	Active	compound	Nanomaterial Reference
Lignin-polyethylene	glycol-ethylcellulose	Imidacloprid Capsule	Flores-Cespedes et al.2012
Polyethylene glycol _	Cyfluthrin Capsule	Polyethylene glycol	Loha et al. (2012)
Chitosan	Etofenprox	Capsule	Hwang et al. (2011)
Polyamide	Pheromones	Fiber	Hellmann et al. (2011)
Lignin	Aldicarb	Gel	Kok et al. (1999)
N-(octadecanol-1-glycidyl ether)-O-sulfate chitosanoctadecanol glycidyl ether	Rotenone	Micelle	Lao et al. (2010)
Polyethyleneglycoldimethyl esters	Carbofuran	Micelle	Shakil et al. (2010)
Carboxymethyl chitosanricinoleic acid	Azadirachtin	Particlea	Feng and Peng (2012)
Chitosan-poly(lactide)	Imidacloprid	Particlea	Li et al. (2011)
polyvinylchloride	Chlorpyrifos	Particle	Liu et al. (2002)

Nanoparticles loaded with garlic essential oil are efficacious against Tribolium castaneum Herbst (Yang et al., 2009). Nanotube filled with aluminosilicate can stick to plant surfaces, while ingredients of nanotube have the ability to stick to the surface hair of insect pests and ultimately enter the body and influence certain physiological functions (Patil, 2009). Salamanca-Buentello (et al., 2005) has categorically grouped the top ten applications of the nanotechnologies and the detailed examples of the applications. Other nanomaterials with potential application include kaolin and polymeric biocompatible NPs used biodegradable, polymeric chitosan NPs (~ 78 nm) for controlled release of the NPK fertilizer sources such as urea, calcium phosphate and potassium chloride (Wilson et al., 2008 and Corradini et al., 2010). Significant increase in yields have been observed due to foliar application of nano particles as fertilizer (Tarafdar et al., 2012a; Tarafdar et al., 2012b). Fertilizers encapsulated in nanoparticles will increase the uptake of nutrients (Tarafdar et al., 2012c).

Adhikari et al. (2010) has opined that nanofertilizers for slow release and efficient use of water and fertilizers by plants are the prime potential application of the technology. Fertilizer particles can be coated with nanomembranes that facilitate slow and steady release of nutrients (Chinnamuthu and Boopathi, 2009). In regard to use of nanotechnologies in organic production currently, there are no national or international regulation, definitions, licensing or declaration requirements. We are still a long way off from conclusively assessing nanotechnologies or individual substances with nanoparticles, since we do not yet have the toxiclogical and ecological bases to do this. In our view, all of nanotechnology applications should be

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evaluated case by case. Positive or negative lists seem to be a good tool to regulate the use of nanotechnology in organic agriculture.(JAHANBAN and DAVARI, 2014) The organic community has adopted four guiding principles, the CHEF principles: care, health, ecology and fairness (IFOAM, 2005).

Previous studies confirmed that metal nanoparticles are effective against plants pathogens, insects and pests. Hence, nanoparticles can be used in the preparation of new formulations like pesticides, insecticides and insect repellants (Barik et al. 2008; Gajbhiye et al. 2009; Goswami et al. 2010; Owolade et al. 2008). Torney (2009) reviewed that nanotechnology has promising applications in nanoparticlemediated gene (DNA) transfer. It can be used to deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests. Yang et al. (2009) demonstrated the insecticidal activity of polyethylene glycol-coated nanoparticles loaded with garlic essential oil against adult Tribolium castaneum insect found in stored products. It has been observed that the control efficacy against adult T. castaneum was about 80 %, presumably due to the slow and persistent release of the active components from the nanoparticles. Goswami et al. (2010) studied the applications of different kind of nanoparticles viz. silver nanoparticles (SNP), aluminium oxide (ANP), zinc oxide and titanium dioxide in the control of rice weevil and grasserie disease in silkworm (Bombyx mori) caused by Sitophilus oryzae and baculovirus BmNPV (B. mori nuclear polyhedrosis virus), respectively. Teodoro et al. (2010) for the first time studied the insecticidal activity of nanostructured alumina against two insect pests viz. S. oryzae L. and Rhyzopertha dominica (F.), which are major insect pests in stored food supplies throughout the world.

Agriculture is the backbone of developing countries, with more than 60% of the population depending on it for their livelihood (Brock et al., 2011). Agricultural and food systems security, disease management delivery systems, new techniques for molecular and cellular biology, new materials for pathogen detection and protection of the environment are examples of the important links of nanotechnology to the science and engineering of agriculture and food systems (Suman et al., 2010).

There are new challenges in this sector including a growing demand for healthy, food safety, an increasing risk of disease and threats to agricultural production from changing weather patterns (Biswal et al., 2012). In the agricultural sector, nanotech research and development is likely to aid and frame the next level of expansion of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques (Prasad et al., 2012a). Nanosensors disseminated in the field are able to sense the existence of plant viruses and the level of soil nutrients (Ingale and Chaudhari, 2013).

Nanotechnology in irrigation water filtration

The emerging technologies that will benefit farmers all over world, especially in developing countries include several nanomaterials which are considered economically effective in purification of irrigation water. Nano-enabled water treatment techniques based on membranes filters derived from carbon nanotubes, nanoporous ceramics, and magnetic nanoparticles inspite using chemicals and UV light are common in traditional water treatment (Hillie and Hlophe, 2007). Filters made from carbon nanotube could be employed in removing contaminants and toxicants from potable water. Carbon nanotube fused mesh that can remove water-borne pathogens, heavy metals like lead, uranium and arsenic has been suggested by researchers. Employing nanoceram filter with positive charge can trap bacteria and viruses with negative charge. This sophisticated filtering machine removes microbial endotoxins, genetic materials, pathogenic viruses, and micro-sized particles (Argonide, 2005).

Nanocapsules for efficient delivery of pesticides, fertilizers and other agrochemicals

Nano encapsulation is a process through which chemicals like insecticides are slowly but efficiently released to a particular host plant for insect pest control. Nano encap-sulation 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 nanoencap-sulation include diffusion, dissolution, biodegradation and osmotic pressure with specific pH (Ding and Shah, 2009; Vidhyalakshmi et al., 2009). Nano encapsulation is cur-rental 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.Fertilizer plays a pivotal role in agriculture production (35 to 40%). To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nano-fertilizer might be a best alternative. Nan fertilizers are synthesized in order to regulate the release of nutrients depending on the requirements of the crops, and it is also reported that nano fertilizers 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 microor-ganisms. 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).

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Nanoherbicides

The easiest way to eliminate weeds is to destroy their seed banks in the soil and prevent them from germinating when weather and soil conditions become favourable for their growth. Being very small, nanoherbicides will be able to blend with the soil, eradicate weeds in an eco-friendly way without leaving any toxic residues, and prevent the growth of weed species that have become resistant to conventional herbicides. Weeds survive and spread through underground structures such as tubers and deep roots. Ploughing infected fields while removing weeds by hand can make these unwanted plants spread to uninfected areas. Whether the nano application is due to a nanosized active ingredient or the creation of a nanosized formulation through the use of an adjuvant, the use of nano application is same. If the active ingredient is combined with a smart delivery system, herbicide will be applied only when necessary according to the conditions of the agriculture field. Lower agricultural yields are obtained in soils contaminated with weeds and weed seeds. Improvements in the efficacy of herbicides through the use of nanotechnology could result in more crop production without causing any harmful effects to agricultural workers who are supposed to physically remove weeds if no application of herbicides is practised(prasad et al 2014)

Nanoparticles and plant disease control

Some of the nano particles that have entered into the arena of controlling plant diseases are nanoforms 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 (Young, 2009), 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). 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.

Thus, use of nanoparticles has been considered an alternate and effective approach which is eco-friendly and cost effective for the control of pathogenic microbes (Kumar and Yadav, 2009; Prasad et al., 2011; Swamy and Prasad, 2012; Prasad and Swamy, 2013). These nanoparticles have a great potential in the management of plant diseases compared to synthetic fungicides (Park et al., 2006). Zinc oxide (ZnO) and magnesium oxide (MgO) nanoparticles are effective antibacterial and anti-odour agents (Shah and Towkeer, 2010). The increased ease in dispensability, optical transparency and smooth-ness make ZnO and MgO nanostructures an attractive antibacterial ingredient in many products. Both have also been proposed as an anti-microbial preservative for wood or food products (Aruoja et al., 2009; Huang et al., 2005; Sharma et al., 2009). Properly functionalized nanocap-sules provide better penetration through cuticle and allow slow and controlled release of active ingredients on reaching the target weed. The use of such nano-biopesticide is more acceptable since they are safe for plants and cause less environmental pollution in comparison to conventional chemical pesticides (Barik et al., 2008).

Nanoparticles as pesticides

Nanoparticles are also effective against insects and pests. Nanoparticles can be used in the preparation of new formulations like pesticides, insecticides and insect repellants (Barik et al., 2008; Gajbhiye et al., 2009). Torney (2009) reviewed that nanotechnology has promi-sing applications in nanoparticle gene mediated DNA transfer. It can be used to deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests. Porous hollow silica nanoparticles (PHSNs) loaded with validamycin (pesticide) can be used as efficient delivery system of water-soluble pesticide for its controlled release. Such controlled release behaviour of PHSNs makes it a promising carrier in agriculture, especially for pesticide controlled delivery whose imme-diate as well as prolonged release is needed for plants (Liu et al., 2006b). According to Wang et al. (2007), oil in water (nano-emulsions) was useful for the formulations of pesticides and these could be effective against the various insect pests in agriculture. Similarly, essential oil-loaded solid lipid nanoparticles were also useful for the formulations of nano-pesticides (Liu et al., 2006b). Nanosilica, a silica product, can be effectively used as a nanopesticide.

Conclusions

Nanotechnology applications have the potential to change agricultural production by allowing better management and conservation of inputs to plant production. Researchers in nanotechnology can do a lot to benefit society through applications in agriculture and food systems . Introduction of any new technology always has an ethical responsibility associated with it to be apprehensive to the unforeseen risks that may come along with the tremendous positive potential. Public awareness about the advantages and challenges of nanotechnology will lead to better accep-tance of this emerging technology. Rapid testing techno-logies and biosensors related to the control of pests and cross contamination of agriculture and food products will lead

IJMDRR
E- ISSN –2395-1885
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to applications of nanotechnology in the near future. Nanotechnology application in agriculture and food systems is still at the nascent stage and a lot more applications can be expected in the years to come. Nanoparticles present an extremely gorgeous platform for a diverse range of biological applications. As it provides the single step process for biosynthesis of nanoparticles, it attracts more researchers to go for future developments in the area of electrochemical sensor, biosensors, medicine, healthcare and agriculture. New research also aims to make plants use water, pesticides and fertilizers more efficiently, to reduce pollution and to make agriculture more environmental friendly.As in the case of every nonconventional technology, for example, genetic engineering, some fear that nanotech-nology can give people too much control. Agriculture technology should take advantage of the powerful tools of nanotechnology for the benefit of mankind. Nanotech-nology can endeavour to provide and fundamentally streamline the technologies currently used in environ-mental detection, sensing and remediation. The potential uses and benefits of nanotechnology are enormous. These include agricultural productivity enhancement involving nanoporous zeolites for slow release and efficient dosage of water and fertilizer, nanocapsules for herbicide delivery and vector and pest management and nanosensors for pest detection.

Some nanotechnology applications are near commercialization: nanosensors and nanoscale coatings to replace thicker, more wasteful polymer coatings that prevent corrosion, nanosensors for detection of aquatic toxins, nanoscale biopolymers for improved deconta-mination and recycling of heavy metals, nanostructured metals that break down hazardous organics at room temperature, smart particles for environmental monitoring and purification, nanoparticles as a novel photocatalyst for environmental catalysis, among others. Thus nano-technology will revolutionize agriculture including pest management in the near future. Over the next two decades, the green revolution would be accelerated by means of nanotechnology. Nanoparticles help to produce new pesticides, insecticides and insect repellents.

Nanotechnology has great potential in agriculture as it can enhance the quality of life through its applications in fields like sustainable and quality agriculture and the improved and rich food for community. All over the world, this technology has become the future of any country. One has to be very cautious with any novel technology to be introduced about its probable unforeseen and unexpected jeopardy that could land through its optimistic possibilities. Though, it is also significant for the future of a state to create skilled prospect manpower for this novel technology. Therefore, it becomes vital to inform the common man about its benefits at the first step, which will incredibly augment in the awareness and innovation of novel applications in all spheres. The outlook of nanoscience in agriculture is vague owing to a lot of grounds, for example, the unconstructive response from people towards genetically modified (GM) crops, need of a lot of required cleverness in government agricultural research and technology units for nano type of explorations and poorly-equipped new instruments and new-fangled technologies. There is a terrible call to slash down the jagged outline existing among the society, common man and budding scientific notions and if we achieve something in overcoming this line, then an unexpected bright and beneficial future will be at the door step of society.

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