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Nanoparticles and their Impact on Plants

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ABSTRACT

Nanoparticles are atomic or molecular aggregates having dimension between 1 and 100 nm. They posses different physico-chemical (strength, electrical and optical) properties due to the variation in surface area compared with those of their counterpart-bulk materials. The nanoparticles can be made from bulk materials. They can explicate their actions depending on both the chemical composition and the crystalline structure of the particles. Nanoparticles known to be exist from the beginning of the earth history and still occur in the environments like, volcanic dust, lunar dust, mineral composites, etc. Incidental or engineered nanoparticles, also defined as waste or anthropogenic particles, may be formed as the result of manmade industrial processes, like diesel exhaust, coal combustion, welding fumes, etc. These nanomaterials can be grouped as carbon based (fullerene, single- and multi walled carbon nanotube) and metal based (quantum dots, nanogold, nanozinc and nanoaluminum) materials. Their utility spectrum has been increased enormously in the last decade and used as a tool in variety of technological platforms for the study and transformation of biological systems. A few studies have been focused on the effects and mechanisms of nanomaterials on plants. The results of these studies have been reported with the aim to provide further insight into connections between plants and nanomaterials. Nanoscales metal oxides, like TiO_2, ZnO and Al_2O_3 dendrimers (nano-sized polymers built from branched units) are capable of performing specific chemical functions. In this context, engineered nanomaterials have received a particular attention for their positive impact in improving, among others, consumer products, pharmaceutics, cosmetics, transportation, energy and also in agriculture. Possibility of the existence of useful nanoparticles in plant tissues and exploitation of their practical benefits seems to be very intriguing. In fact, multi walled nanoparticles known to act at the level of seed germination and root growth in higher plant species including *Raphanus sativus*, *Brassica napus*, *Lolium multiflorum*, *Lactuca sativa*, *Zea mays* and *Cucumis sativus*. In the presence of ZnO nanoparticles the ryegrass biomass significantly reduced, root tip shrank, root epidermal and cortical region highly vacuolated or most of the cells are collapsed at the cortical region. Critical observations revealed that ZnO nanoparticles greatly adhered onto the root-surface of plant and individual nanoparticles were observed present in apoplast and protoplast of the root endodermis and stele of the plant. Translocation factor of Zn from root to shoot of the plant remained very low under ZnO nanoparticles treatments in the plant. While, the nano TiO_2 treatments induced an increase in activity of chloroplasts which accelerated Fe-Cy reduction and oxygen evolution in addition to increase in non-cyclic photo-phosphorylation activity of plants. The explanation of these effects clearly denotes that the nano-TiO_2 might enter the chloroplast and its oxidation-reduction reactions might accelerated electron transport and oxygen transfer. There are many gaps in our knowledge on plant nanotechnology. Though the nanotechnology industry is growing in a very fast way, there is a crucial urgency to perform further studies on this subject, especially on the impact of nanoparticles on plants. Moreover, it looks imperative to hold an extensive debate about the risks and benefits of the many manufactured nanomaterials for plants and ecosystem. This article will focus on this aspect.

Key words: Nanoparticles, plants, functions of nanomaterials on plant, risk in ecosystem

INTRODUCTION

The plant is the best part of the earth, as because; it has the tremendous potential to maintain the earth's ecosystem and biodiversity. Its potential benefit could be enhanced much more by understanding plant physiology. Plant physiology is a science of study which relates with the law of the life activity of plant which enumerate the knowledge on plant function encompassing the dynamic processes of growth, metabolism and reproduction in living plant (Taiz and Zeiger, 2006). Evaluating the plant physiology helps us to know the basic principles associated with carbon assimilation process by the use of energy of sun and their conversion to energy rich compounds. They are also excellent sources for information on how to distribute nutrients and water and use them for growth and development in addition to exploit the knowledge on responding towards environment, stress, etc (Buchaman *et al*., 2000). In nutshell, this will help us to understand and uncover the law of life activity of plant, to protect and utilize plant in the agricultural and industrial practice according to the law. In another side, the plant physiology also deals with the application of manure (fertilizer), basal manure, seed manure and top dressing and fertilize in the soil with legume (Liebig, 1840; Von Saches, 1882; Pfeffer, 1904). In the present century, the development of several technologies like, biochemistry, biophysics, cell biology, isotope technology, molecular biology and recently developed nanotechnology, etc., enhance the development of plants physiology both in theory and application.

Fertilizer application in agricultural field is one of promoting activity for plant growth which develops a micro to macro phenomena among plants in the agricultural field. This is possible only through the process of photosynthesis and N-fixation by organism, energy transformation and regulation of enzymes within the plants. For example, iron as ionic form play significant role in metabolic reactions of all living entities including plants. In general, Fe_3O_4 has created interest in scientific and technological levels due to its unique electric and magnetic properties along with its high chemical reaction property (Abhilash *et al*., 2011; Bystrzejewska-Piotrowska *et al*., 2012) because of its potential to transfer the electrons between Fe2+ and Fe3+ in the octahedral sites (Bystrzejewska-Piotrowska *et al*., 2009; Fu *et al*., 2001; Bystrzejewska-Piotrowska *et al*., 2012). However, the knowledge about the accumulation and effects of iron (II, III) oxide nanoparticles on plants is not satisfactory and only a few studies have been undertaken in the plant aspects

(Bystrzejewska-Piotrowska *et al.*, 2012). Reports on interaction between iron (II, III) oxide nanoparticles (Fe_3O_4-NPs) and plants revealed that iron oxide particles can be taken up by *Lepidium sativum* and *Pisum sativum* L. and enter the trophic chain where these Fe_3O_4-NPs accumulate mainly in roots (>90%). However, accumulation of Fe_3O_4-NPs clearly depends on the concentration of nanostructures in growth process (Zhu *et al.*, 2008; Wang *et al.*, 2011). Transfer factor for *Lepidium sativum* roots and shoots and *Pisum sativum* L. shoots decreased with increasing NP concentration in growth process while in *Pisum sativum* L. roots the tendency was totally reversed (Zhu *et al.*, 2008; Wang *et al.*, 2011). Synthetic nanoparticles, with their diameters ranging roughly between 1 and 100 nm, have natural relationship between molecules and with a gradual polymer; thus produce a tunable particle size and shape for strong reaction with the target site (Lowry *et al.*, 2012a). Plant synthesized nanoparticles are of the most interest now a days because of their unique properties such as having increased electrical conductivity, ductility and toughness. Thus, the semiconductor metals can take part in several functions of plant physiology, though previously it was not established that the nanoparticles in plants have no such role in the plant physiology (Boghossian *et al.*, 2013; Tvrdy *et al.*, 2013; Giraldo *et al.*, 2014). Tobacco is a unique model species for investigation of the effects of aluminum oxide nanoparticles on the growth and development of agricultural plants. Moreover, it also helps in investigation of the potential role of miRNAs during the agricultural plant growth, though sometime the aluminum oxide nanoparticles exhibit the negative effect in the tobacco plants too. Still, the miRNA reported to has a vital role in gene regulation of tobacco plants due to effect of aluminum oxide nanoparticles (Zhang *et al.*, 2006). Several nanoparticles like, multi-walled carbon nanotubes, aluminum, alumina, zinc and zinc oxide execute its effect on seed germination and root growth of six higher plant species like, radish, rape, ryegrass, lettuce, corn and cucumber etc. (Stampoulis *et al.*, 2009; Nair *et al.*, 2010). Our main emphasis in this chapter will be on role of the newly achieved nanosized magnetite/semiconductor materials in plants and their role in plant related different sectors reported sporadically (Bhattacharyya *et al.*, 2009, 2011; Chakravarthy *et al.*, 2012a; Bhattacharyya, 2009; Bhattacharyya and Debnath, 2008; Zonneveld *et al.*, 2008).

METAL NANOPARTICLES IN AGRICULTURAL FIELD AND ACCUMULATION OF NANOPARTICLES IN PLANTS

Nanoparticles are bits of chemicals a thousand times smaller than a human cell. While, nanoparticles occur naturally in the environment, they increasingly are being manufactured for use in electronics to cosmetics, fuel cells to medical procedures. Yet the human and environmental health risks associated with these tiny engineered particles are not well known. Because chemical compounds can take on different properties at such a reduced size-lead in a pencil reportedly becomes stronger than steel, for example-there is concern that these invisible particles could easily be breathed in by humans and animals, with damaging or toxic effects. Plants serve as a foundation of the food chain and the plants were grown hydroponically in an aqueous medium to which nanoparticles of iron oxide, or magnetite, a magnetic form of iron ore.

Several experiments help us to propose that iron (II, III) oxide nanoparticle (Fe_3O_4 -NPs) has the ability to accumulate in *Lepidium sativum* and *Pisum sativum* L. plants. Thus this type of observation denotes us to know the role of these nanoparticles in the natural eco-system (Bystrzejewska-Piotrowska *et al.*, 2012). The use of polymeric nanoparticles especially loaded with insecticides along with plant extracts are unique to use in the agricultural field (Perlatti *et al.,* 2013). Nano-agrochemicals can be load in the single or double layered carbon nano tubes which posses' high solubility, stability and effectiveness as these release the loaded agrochemicals in time controlled manner to specific plants in response to certain stimuli from the surrounding environment. These processes are safe and easy to handle by plant growers in the agricultural field. In fact, the nanosilica has been successfully used to control a range of agricultural insect pests (Neuhaus and Spangerberg, 1990). It is known fact that plant cell wall acts as a barrier for easy entry of any external agent including nanoparticles into the plant cells. Hence, only nanoparticles or nanoparticle can aggregates near the surface of plants in the agricultural field. If internalization occurs in the plants during endocytosis with the help of a cavity like structure that form a mass of nanoparticles by plasma membrane then they may also cross the membrane using embedded transport carrier proteins or through ion channels. The nanoparticles also may enter through the stomatal openings of the plant leaves or through the bases of trichomes and then translocated to various tissues of plants (Neuhaus and Spangerberg, 1990; Bolik and Koop, 1991). Magnetic Co:Nd:Fe_2O_3, luminescent Eu:Gd_2O_3 core-shell nanoparticles (MLNPs) could be used as carriers of different plant products (Nichkova *et al*., 2007). In *Zea mays*, *Cucumis sativus*, *Glycine max*, *Daucus carota* and *Brassica oleracea* plants where the pure alumina nanoparticles (13 nm in size) interaction retarded the growth. Whereas, the effect of zinc oxide based nanoparticles exhibited the positive response on seed germination of zucchini seeds and root growth while, carbon nanotubes demonstrated promising effect on regulators of seed germination and plant growth. Hence, while industrial production and applications of CuO NPs one need to be careful evaluated on the risk factors which are extremely lacking in a ladle way (Adhikari *et al*., 2012; Liang *et al*., 2013). In another study, the soybean seeds treated with very low nanometal (like, carboxymethyl cellulose (CMC) and mixed with stabilizer for (Fe and Co) nanoparticles) dose found to promote plant growth and development (Chau *et al*., 2013). Improved pigeon pea-*Cajanus cajan* (L.) Millsp growth by nanomaterials has been observed when introduced Cu-Nano-containing potentized CCC (Homeopathic medicine) and potentized Maleic Hydrazide (MH). It was observed that in addition to the plant growth; the chlorophyll content, sugar content and protein content of the leaves found to be increased due to the effect of homeopathic drug containing copper nanomaterials (Sukul *et al*., 2008). Furthermore, in another experiment on lady's finger plants-*Abelmoschus esculentus*, elevated the growth of this plant was observed upon supplementation of homeopathic potencies (CCC) dose with copper nano-materials (Sukul *et al*., 2009).

PLANTS ACT AS NANO-FACTORIES

The use of biological systems for the synthesis of nanoparticles is gaining increased attention since it is more ecofriendly compared to various physical and chemical methods. Among various biological systems, plants provide an easy and safe green route for the synthesis of various metal nanoparticles and for this the metal of interest should be present in the growth medium of plants and observed that the metal nanoparticles efficiently transported through the plant root cells (Chau *et al*., 2013). It has also been reported that the formation and growth of gold nanoparticles (Au NPs) inside live alfalfa plants and sesbania seedlings grown with gold enriched media. Some wetland plants have the ability to transform copper into metallic nanoparticles at the site of soil-root interaction with the help of some endomycorrhizal fungi. There are some reports on the formation of gold-silver-copper nanoparticles using plant as initiator. Naturally, in future there is a great scope of using plant product for the production of mixed metal nanoparticles (Chau *et al*., 2013; Noda *et al*., 2014).

PLANTS-THE GREEN ROUTE FOR BIOSYNTHESIS OF NANOPARTICLES

The first report of the plant employed in the synthesis of nanoparticles is attributed to *Medicago sativa* (alfalfa) which was capable of synthesizing gold and silver nanoparticles. Since then, more attention has been sprinkled on plants. The production of nanoparticles by plants relays on various factors among which, type of processing with optimized parameters is very much essential towards synthesis of nanoparticles such as growing plant in a media incorporated with raw material for the synthesis of nanoparticles, use of dried powdered plant material which is employed in the synthesis of plant material, drying plant material and evaluating nanoparticles synthesis (Table 1) and employing fruits and flowers in the synthesis of nanoparticles (Gardea-Torresdey *et al*., 2003).

Plant science could significantly contribute to fully explore the potential of phyto-synthesis of metal nanoparticles (Marchiol, 2012). Nature has devised various processes for the synthesis of nano materials in plants. Exploitation of such green synthesis of nanoparticles is effective with respect to environmental friendliness, non-toxic and plant are safe reagents. Phytoremediation treatment for environmental problems is one of the best approaches to dispose the contaminants where the use of plants that mitigate the environmental problem without the need to excavate the contaminant material. Hyper accumulating species of plants have a unique physiological mechanism that regulates the soil metal concentration. Mechanism of accumulation of nanomaterials in plants may be associated with phytoremediation which can be visualized the process by which inorganic silicon is incorporated into living organisms as silica and that silica may store in plants (*Magnolia kobus* and *Diopyros kaki*) as huge quantity; which can be used for purification of the agricultural soil (Salam *et al*., 2012; Singh and Vidyasagar, 2014). Rahul *et al*. (2014) reported that plant nematodes can be controlled by introducing the natural products of *Serratia marcescens*. It is a new and emerging area of research in the scientific world, where day-by-day developments is noted and exhibits a bright future in near future (Salam *et al*., 2012; Singh and Vidyasagar, 2014). Natural plants like leaves of *Acalypha indica* are the important source for synthesis of zinc oxide nanoparticles. Gnanasangeetha and Thambavani (2014) suggested that green synthesis approach is environmentally benevolent and renewable aqueous leaf extract of *Acalypha indica* can be used as a stabilizing agent for the synthesis of zinc oxide nanoparticles.

Table 1: Synthesis of nanoparticles using plants (Kasthuri *et al*., 2009)

Nano particles	Plant names
Silver nanoparticles	*Brassica juncea*
	Ipomoea aquatic
	Nelumbo nucifera
	Parthenium hysterophorus
	Tanacetum vulgare
	Coriandrum sativum
	Camellia sinensis
	Cymbopogon exuosus
Gold nanoparticles	*Ocimum basilicum*
	Syzygium aromaticum
	Tamarindus indica
	Psidium guajava
	Terminalia catappa
	Emblica officinalis
Silver and gold nanoparticles	*Cinnamomum camphora*
	Emblica officinalis
	Apiin (henna leaves)
	Murraya koenigii

Several metallic nanoparticles like, silver aluminum, gold, zinc, carbon, titanium, palladium, iron, fullerenes and copper are most promising agent for medical uses. All these nanoparticles can be synthesized using plants. Now, it has been established that plant based the green synthesis approach is one of the effective method for silver nanoparticles (AgNPs) production. They can be produced from *Eucalyptus*, *Jatropha curcas* seeds, *Acalypha indica* leaves, *Rosarugosa*, *Trianthema decandra* roots, *Ocimum sanctum* stems and roots, *Sesuvium portulacastrum* leaves, *Murraya koenigii* (*curry*) leaves, *Macrotyloma uniflorum* seeds, *Ocimum sanctum* (*Tulsi*) leaves, *Stevia rebaudiana* leaves, *Nicotiana tobaccum* leaves (Burklew *et al*., 2012), *Ocimum tenuiflorum*, *Solanum trilobatum*, *Syzygium cumini*, *Centella asiatica*, *Citrus sinensisleaves*, *Arbutus unedo* leaves, *Ficus benghalensis* leaves, Mulberry leaves, *Olea europaea* leaves, some *Acanthe phylum* and *Chenopodium album* leaves (Vadlapudi and Kaladhar, 2014). The roots and leaves of *Acorus calamus* have the ability to synthesis silver nanoparticle in addition to antioxidant, antimicrobial and insecticidal activities (Dhanasekaran *et al*., 2014).

Plants have been known to be excellent sources for many drugs, products, food, fodder, etc., for many centuries. Several drugs (e.g., aspirin, salbutamol, digoxin, quinine, morphine, atropine, colchicine, bromelain, etc.) have been extracted from the plants as their active components for treating various diseases. Morphine was isolated as a first drug from the plant opium popy (*Papaver somniferum*) used as a pain killer. Quinine extracted from the cinchona tree (C*inchona officinalis*) is used to treat malaria and aspirin isolated from willow bark is used for the treatment of fever. Most of the plants and formulations (e.g., curcumin, triphala, pomegranate kalonji, sariva, etc.) have explored the potential to cure cancer and inflammation (Pandey and Pandey, 2014). Among different plants, the *Phyllanthus* genus belongs to the Euphorbiaceae family has special status with respect to utility towards mankind. There are over 300 genera with >5000 species in the Euphorbiaceae worldwide, while *Phyllanthus* itself posses about 750-800 species, found in tropical and subtropical regions worldwide. A number of the *Phyllanthus nirur* and other species of the same genus are widely used in traditional medicine for the treatment of flu, dropsy, diabetes, jaundice, gall and bladder calculus, liver disease etc. (Kathireswari *et al*., 2014). With the utility of several plants, scientific communities performed several experiments on the synthesis of silver nanoparticles using plant extract of *Murraya koenigii* (green curry leaves), *Zea mays* (Baby corn) (Deb, 2014). Moreover, ground leaves extract of *Artemisia annua* and *Sida acuta* clearly denotes that the said plants are also responsible for production of silver nanoparticles (AgNps) which are as usual helps in several disease control phenomena (Johnsona *et al*., 2014). Silver nanoparticles are also can be produced from red apple (*Malus domestica*) fruit belongs to the *Rosaceae* family (Umoren *et al*., 2014).

Bioreduction of Ag^+ ions is the major mechanism involved in the synthesis of silver nanoparticles where reductase enzymes are present in the cell of *Fusarium oxysporum*, proteins, terpenoids present in neem leaf extract, ascorbic acid present in leaf of *Ocimum sanctum* are responsible for reduction process. *Myristica fragrans*, commonly known as nutmeg and a common flavoring agent in Indian cooking, belongs to the Myristicaceae family also possesses medicinal and aromatic properties. It serves as an antidiarrhoeal, stomachic stimulant, carminative, intestinal catarrh and colic to stimulate appetite. The elemicin, eugenol, isoelemicin, isoeugenol, methoxyeugenol, pinene, sabinene, safrol, myristic acid, myristicin and lignan were found in *Myristica fragrans,* the seed extract of medicinally important plant, *Myristica fragrans*, act as a template for silver nanoparticles synthesis (Cuong *et al*., 2013; Sharma *et al*., 2014a). Several reports on biological synthesis of gold nanoparticles were found by using the extract of stem of *Breynia rhamnoides*, sugar beet pulp, C*assia fistula*, leaf extract of *Memecylon edule*, *Justicia gendarussa* leaf, algae extract of *Turbinaria conoides*, fruit extracts of *Ananas comosus* (L.) etc. (Firdhouse and Lalitha, 2014). The medicinal plant like *Clitoria ternatea* callus of the said plants also helps in synthesize silver nanoparticles (Malabadi *et al*., 2012). Latex of *Alstonia scholaris* and *Hevea brasiliensis*, *Calotropis gigantean*, *Musa paradisiacal* and *Achras sapota*, also posses the potential to produce green nanoparticles (Mondal *et al*., 2011).

Oukarroum *et al*. (2013) working on relationship between silver nanoparticles and plant metabolism reported that *Lemna gibba* growth and cellular functions were altered by silver nanoparticles. It is really an interesting field that the dose dependent AgNPs some time protect plants community and some time toxic to the plants. This may be due to the nature of silver nanoparticles which vary their size depending on silver atoms associated with it. The high charge silver nanoparticles (AgNPs) may react in different ways with the different chemical substances of root, leaf, stem of several plant species (Kaegi *et al*., 2011). In natural world the majority of the silver nanoparticles reacts with the natural sulfur, oxygen and can orient their structure and functions. These newly created silver compounds can be more stable and less toxic than the non reacted silver nanoparticles. Thus, the newly formed silver was taken up by the plants, insects and fish living in the ridicule ecosystems (Lowry *et al*., 2012b).

More studies on green approach to biosynthesize selenium nanoparticles (Se-NP) using dried *Vitis vinifera* (raisin) extracts is an important door for producing different drugs. The FTIR study on this plant clearly denotes that the presence of highly stable lignin biopolymer on the surface of selenium nanoballs which suggest us to propose the possible role of this nanoballs act as capping agent (Sharma *et al*., 2014b). Plant mediated synthesis of metal nanoparticles is gaining more importance owing to its simplicity and rapid rate of synthesis of green nanoparticles. Presently, the researchers are looking into the development of cost-effective procedures for producing reproducible, stable and biocompatible metal NPs through several types of plants (Ahmed *et al*., 2013).

NANO-PLANT-INSECT INTERACTION

It is very interesting to consider that plant has the ability to produce secondary metabolites which are the best known as chemical stimuli elicited via host plants as attractant, repellent, feeding and ovi-position stimulant etc. These deterrents induce the different behavioral responses of insects toward a food source or towards host plants (Wheeler, 1899; Kennedy, 1945, 1974, 1977, 1986; Finch, 1986; Visser, 1986; Shorey, 1973). Chemical based stimuli of host plant selection by insects are the true facts but recently it has been observed that not only the plant based synthesis of chemicals are the only source of insect-plant interaction. Now, it is clear that the stored nanoparticles in plants are also poses some role in insect-plant interaction (Fraenkel and Gunn, 1961).

PLANT RELATED NANOPARTICLES ROLE IN PRODUCTION OF NANO PESTICIDES

Plants which have ability to produce nano synthesizing materials are solely responsible for producing metallic nano materials. The mechanism involved in production of this eco-friendly nanoparticle could be an effective method for preparation of nanoformulation as the plant producing nano particles are highly acceptable, as because, it maintains uniform size and shape without aggregation or agglomeration. Exploitation of this character of plants is a key for biological way of nano-pesticides production, a unique pathway for future eco-friendly pesticides. There are several methods reported in the literature to produce plant-nanoparticle-pesticide core-shell conjugate which can be used to control agricultural insect pests. These conjugant nano particles may be in different shape, size (2-150 nm) and various forms (Sooresh *et al*., 2011).

The applications of 'smart' delivery systems to specific target tissue of agricultural plants that can reduce the damage of plant tissues are some of the modern techniques. It is well known that the delivery of proteins or codelivery of proteins and DNA to plant cells has great biological significance towards enhancing the genetic transformation and gene targeting plants helps in boost up the crop production in which porous surface of root and seed tissues of plants are responsible for penetration of loaded materials. Researchers noticed that the gold-zinc oxide nano materials placed in carbon nanotubes penetrated tomato (*Lycopersicon esculentum*) plants tissues of the plants (Gonzalez-Melendi *et al*., 2008; Park *et al*., 2006; Cui *et al*., 2011; Rai and Ingle, 2012; Ahmed *et al*., 2013).

One can consider this type of mechanism to irradiate the tobacco caterpillar, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) which is a major pest with high mobility and reproductive capacity by plant based nanomaterials (Chakravarthy *et al*., 2012b; Bhattacharyya *et al*., 2008, 2009). It is widely distributed throughout tropical and temperate Asia, Australasia and Pacific Islands. *Spodoptera litura* feeds on more than 120 host plants but major ones include tobacco, cotton, groundnut, jute, lucerne, maize, rice, soybeans, tea, cauliflower, cabbage, capsicum, potato and castor which can be controlled by inorganic nanoparticles CdS, Nano-Ag and Nano-TiO_2 etc. (Chakravarthy *et al*., 2012a). The same nanoparticles can synthesis by plants also and can react with other several organs. Keeping this in view, the plant mediated metal nanoparticles are also introduced as insect pest control in agricultural sector. The Devadhari, Vishamusti, Nagamusti, Tellieswari, Mayurasikha, Malleru, Chillaginjalu, Tippateega etc and other several plants are responsible for production of several secondary metabolites which helps agricultural insect pest control loaded with nanomaterials.

PLANTS AND NANOTOXICITY

Plants are always being exposed to different environments of air and soil. It has already being said that the nanoparticles are always adsorbed to the plants. The adsorbed nanoparticles on plants are gradually penetrated in to the plant tissues. Nanoparticles of all types including SiO_2 and TiO_2 can enter in the plants through the shoot and root, like, cuticle, epidermis, stomata, hydathodes, stigma, root tips, rhizodermis, cortex lateral plants, root junctions, bark and other several surfaces of plants which can take part in the natural food chain. The absorbed nanoparticles in plants either synthesize by plants or from nature, these all can take part in human food chain and also can expose in agricultural food chain as noxious (Shaymurat *et al*., 2011; Kurepa *et al*., 2014). It has been authenticated by several experiments where growth of plants retarded by expose of several nanoparticles (Buzea *et al*., 2007; Kumar and Yadav, 2009; Sharma *et al*., 2009; Dietz and Herth, 2011; Najafi and Jamei, 2014).

Several terrestrial plant species like *Amaranthus gracilis* (Amaranthaceae), *Cannabis sativa* (Cannabinaceae), *Catharanthus roseous* (Apocynaceae), *Cynodon dactylon* (Poaceae), *Euphorbia hirta* (Euphorbiaceae) *Medicago sativa* (Fabaceae), *Ocimum sanctum* (Lamiaceae), *Phyllanthus fraternus* (Euphorbiaceae), *Portulaca grandiflora* (Portulacaceae), *Tagetes erecta* (Asteraceae), *Vernonia cinerea* (Asteraceae), *Brassica juncea* (Mustard), *Cicer arietinum* (Fabaceae), *Lycopersicon esculentum* (Solanaceae), *Triticum aestivum* (Poaceae), *Vigna mungo* (Fabaceae) etc have the ability to expose several metal ion developed tolerance mechanisms in their perspective plants tissue.

However, heavy metal tolerance vary in different plant species for survival in nature (Pardha-Saradhi *et al*., 2014a; Najafi and Jamei, 2014; Pardha-Saradhi *et al*., 2014b; Shabnam *et al*., 2014).

Till to date several nanoparticles like: silver, zinc oxide, copper oxide, aluminum oxide, fullerenes, silicon dioxide or titanium oxide and cerium oxide have been studied more or less with all crops of plants. In all cases, toxicity has been observed in the shoots and roots of exposed plants. The role of plant nanomaterials study is just in the process of investigations, more observation on plant study will explore the reality of the plant nanomaterials function (De la Torre-Roche *et al*., 2012, 2013; Pan and Xing, 2012; Zhu *et al*., 2012; Wang *et al*., 2012, 2013; Atha *et al*., 2012; Koelmel *et al*., 2013; Kelsey and White, 2013; Ma *et al*., 2013).

BIOINSPIRED GREEN FORM NANO AND REMOVAL OF CORROSION

Generally "Top down and Bottom up" process helps to produce organic nanoparticles. The recent process to produce green synthesis of nanomaterials is unique phenomenons which are totally nontoxic. In the present century the plant related green nanomaterials are using to protect corrosion. Corrosion can be defined as a process of degradation of materials' properties due to interactions with their environments and corrosion of most metals (many materials for that matter) is predictable based the reactive properties. Naturally, corrosion inhibiting abilities of tannins, alkaloids, organic, amino acids and organic dyes produced by plants are most interesting in recent years. By understanding the role of plant origin metal nanoparticles it is confirmed that these nanomaterials can act as corrosion protector. It is most interesting to say that the recent awareness on the corrosion protection may helps to introduce desire characters to the natural products of plant origin (Vayssieres *et al*., 2000; Saji and Thomas, 2007; Obot and Obi-Egbedi, 2009, 2010; Obot *et al*., 2010; Rani and Basu, 2012). It has been proved now-a-day, that green extracts of *Delonix regia* plants are the inhibitors of the corrosion of aluminum in hydrochloric acid solutions. This inhibition of corrosion is considered due to the following process like, with ethanolic extract of African bush pepper (*Piper guinensis*) on mild steel; *Carica papaya* leaves extract; neem leaves extract (*Azadirachta indica*) also on mild steel in H_2SO_4 media. More investigation on plant extracts revealed that *Papaia* sp., *Poinciana pulcherrima*, *Cassia occidentalis*, *Datura stramonium* seeds extract, *Calotropis procera*, *Azadirachta indica*, *Gossypium hirsutum*, *Rosmarinus officinalis* and *Auforpio turkiale* sap extracts are also corrosion inhibitors. Generally one can think that in most cases the leave extracts and the seed extracts are the most effective corrosion inhibitors, of course, with some chemical interaction (Saji and Thomas, 2007; Obot and Obi-Egbedi, 2009; Obot *et al*., 2010; Rani and Basu, 2012). In the present day, sol-gel processes are the most authentic criteria to control the corrosion. This sol-gel process is formed through green coating and it is easy to introduce in room temperature. The proposed technique is widely acceptable to protect the corrosion in a satisfactory manner (Wang and Bierwagen, 2009).

GREEN NANOPARTICLES IN FOOD INDUSTRY

Agricultural sustainability is facing challenges both in respect to food security and ecological vulnerability all over the world. Day by day food prices are increasing while the food production seems to be drastically low. This brings out the issues of sustainability covering both agro-ecological and socio-economic indicators. It has been observed that the number of hungry people will be more than one billion by 2015. Since, agriculture is the main existence in the nature which allow us to get food, nanotechnology is being explored in the agriculture field for increased food production.

Now-a-days, agriculture in India has permitted widespread adoption of genetically improved new seeds, chemical fertilizers, pesticides, intensive irrigation, optimum agronomic conditions and modern machinery to some crops. Advances in breeding for crop improvement, higher nutrition, abiotic and biotic stress resistance, post-harvest preservation, etc. have met with limited success (Bhattacharyya *et al*., 2011, 2014). The present adopted processes clearly denote the loss of original seed crops from the nature which limits availability of the natural food products in near future. In the same way there are several new techniques are developed in the present decade to face the challenges of enhancing crop production and providing nutritionally satisfactory diets for the increasing population, under uncertain climatic condition. Still, nanotechnology potential carries with its significant concerns with respect to safety and adequate use in addition to acceptance by society. Therefore, experts have pointed out the need of an international standardization of the production processes of nanomaterials worldwide. As a result, the eco-nanotoxicology research is very essential for introducing 'smart' regulatory framework in the sense of guarantee through which safe nanomaterials can be introduced in the human society (Zonneveld *et al*., 2008; Kjolberg *et al*., 2008; Dunford, 2010; Bhattacharyya *et al*., 2011, 2014).

Day-by-day several techniques are being accepted in agriculture and also in the food quality system. Therefore, the most new technology, the nanotechnology, especially the green nanotechnology has been taken in account for improved food quality. This technology not only improves the quality of food but also helps to reduce the agricultural fertilizer inputs and thus the development of agricultural plants grows in a healthy way. Therefore, the use of this technology in agricultural related food industry exhibits a significant impact on rural populations in developing countries. Moreover, the modern approach of nanotechnology can build a sustainable agriculture management and also in food industry (Bhattacharyya *et al*., 2011, 2014; Prasad *et al*., 2014).

FUTURE PROTOCOLS

Plant mediated protocols of synthesis of nanoparticles have an upswing in recent past as a safe, eco-friendly and an alternative for most popular conventional methods which are bound with various implications. Promoting biosynthesis of nanoparticles can predominant the commercial applications of these nanoparticles in the field of pharmaceuticals and other medical sciences which are limited factors for nanoparticles synthesized via conventional methods.

It is fat that the harvesting the endangered plant species may pose a risk among the plant diversity which can form a major impact. Hence, in this regard new technologies endeavour isolation of biomolecules responsible for synthesis of nanoparticles and challenge synthesizing the nanoparticles forming template based synthesis of nanoparticles. In the near future, a thorough detailed study will be valuable enough to give a clear confession of biomolecules mediating the synthesis of nanoparticles which will influence the rate of synthesis and improve properties of nanoparticles with stability (Baker *et al*., 2013).

CONCLUSION

Recent rapid advances of plant nanoparticles study certainly helped in understanding, synthesis and manipulation of nanoparticles in plants which undoubtedly will continue in a controversial manner. This could be further confirmed by my interaction with Great Plant Physiologist, Professor "Peter Nick (BOT)", Germany. According to Professor, I do not think that there is a receptor for nanoparticles in plant cells, there exist a couple of membrane channels transporting specific ions and these might be used for heavy metal ions. As I tried to make clear, I do not think that plants "produce Nano" and that there is any use for them of nano in plants and it is questionable. Accordingly toxic metal ions are dumped in the vacuole of the plant cell and there they may form crystals. In some cases, nanotubes are taken up into the plant and deposited in the cytoplasm. This could be done by Transmission Electron Microscope (TEM) but would be even possible by careful histology after microtome sectioning. Only, if this has been confirmed, it is meaningful to go for more detailed work, otherwise one will be hunting a phantom.

Still with this controversy, plants are correspondingly increasing in the release of nanoparticles (NPs) into the environment and will generate nanowastes. The existing knowledge available on the positive or negative effects of some nanoparticles on the physiology and biochemistry of plants is meager and does not convey any clear idea. Silver nanoparticles and other so many heavy metals are considered as antimicrobial agents in many cases and used in textiles and detergents. However, the benefits or reversed effects on the ecosystem are more yet to know thoroughly in relation to plants. There are many gaps in our knowledge on the nature, shape-size variation, functions of plant nanomaterials and also on ecotoxicity of nanoparticles-NPs in plant physiology. There are many unresolved problems and new challenges concerning the biological and physiological effects of these nanoparticles (NSPs) in plants.

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