Role and effects of nanotechnology used in pesticides and agriculture field

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Role and effects of Nanotechnology used in Pesticides and Agriculture Field

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Abstract: Nanotechnology is used in various fields of applied sciences such as chemists, physicists, biologists, medical doctors and engineers. Nanotechnology has been provisionally defined as relating to materials, systems and processes which operate at a scale of 100 nm or less. In the agricultural sector, nanotech research and development is likely to facilitate and frame the next stage of development of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques. Pesticides are used on large scale and most of the pesticides are resistant to biodegradation and are found to be carcinogenic in nature even at trace levels. Conventional methods of pesticide removal are disadvantageous due to their inherent time consumption or expensiveness. Nanoparticles alleviate both of these drawbacks and hence, they can be effectively utilized for the mineralization of pesticides. Nanoparticles of defined concentrations could be successfully used for the control of various plant diseases caused by several phytopathogens like silver, alumina-silicate, TiO_2, carbon nanotubes etc.

Key words: Nanotechnology, pesticides, disease, degradation, residues

INTRODUCTION

In today's scenario, pesticides are used worldwide for control of different types of pests in agriculture, due to this, soil, surface and ground water gets contaminated. They persist in the environment and pose a significant health threat. Among the possible effects related to this exposure, genetic damage has important health implications for the induction of lung cancer, non-Hodgkin's lymphoma, pancreatic cancer, bladder cancer and leukaemia [30]. Here majority of the pesticides are defiant to biodegradation and are found to be carcinogenic in nature even if present at trace levels. Various conventional methods employed for removal of pesticide are surface adsorption, photo-catalysis, membrane separation and biodegradation [22]. However, these methods have disadvantages such as time consumption and expensive. Nanotechnology has developed as one of the most ground-breaking scientific fields in decades and alleviates both of the above mentioned drawbacks. Nanotechnology is the understanding and control of matter at dimensions approximately 1 to 100 nanometers (nm) where unique phenomena involved novel applications. Nanoscale materials show unusual physical, chemical and biological properties, which are completely distinct from their bulk materials and individual molecules [20]. These unique properties find its novel applications in all the fields and possess strong affinity to targets such as proteins [17]. With the global efforts to reduce generated hazardous waste and the growing demand for synthesis of safe nanomaterials, researchers adopted green synthesis methods. The synthesis of nanoparticles from the plant extracts and microbes is a boon for advance research in nanotechnology. Synthesis of extracellular nanoparticles with variety of locally available biological agents is a novel and economical concept for bioprospecting. It provides new avenues to exploit wide variety of biological species for product development. According to [25] nanoparticles (NPs) have unique properties which includes very large specific surface area, high surface energy and quantum confinement it creates new opportunities to use NPs as a novel element of the plant protection toolbox. Alternative methods are being sought, particularly in forestry, which may offer phytosanitary protection and growth improvement with minimal impact on the environment [8].

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MANAGEMENT OF PESTS WITH NANOPARTICLES

It was found by Kumar [10] that silver nanoparticles have promising effect against gram positive S. Aureus, as metal nanoparticle embedded paints have been synthesized using vegetable oils and have been found to have good antimicrobiology activity. The sporulation test showed that, relative to control samples, the number of spores formed by mycelia increased in the culture after contact with silver Nanoparticles, especially on the nutrient-poor PDA medium. The antibacterial potentiality of zinc oxide (ZnO) nanoparticles (NPs), compared with conventional ZnO powder, against nine bacterial strains, mostly foodborne including pathogens, was evaluated using qualitative and quantitative assays. ZnO NP was more efficient as antibacterial agent than powder. Gram-positive bacteria were generally more sensitive to ZnO than Gram negatives [34].

Pimentel [28] reported that globally insect pests cause a huge crop loss of 14% and plant pathogens cause an estimated loss up to 13% per year. Nano materials are used efficiently for safe administration of pesticides, herbicides and fertilizers at lower doses [18]. Pesticides cause adverse effects on human health and on pollinating insects. So, nanomaterials play an important role in decreasing toxicity and in turn help in increasing the efficacy of pesticides [24]. Nanopesticide formulations increase the solubility of poorly soluble active ingredient and helps in releasing the active ingredient slowly. The bioavailability of water soluble agrochemicals can be increased through the use of additives or by nanoparticulate formation of agrochemicals.

Formulation stability is also an important aspect at the nano level as a stable nanopesticide (bifenthrin) was formulated using polymer stabilizers such as Poly (acrylic acid)-b-poly(butylacrylate) (PAA-b-PBA), Polyvinylpyrrolidone (PVP), and Polyvinyl alcohol (PVOH). A flash nano-precipitation technique was used to prepare 60-200 nm bifenthrin particles. While using such techniques commercially; stability of the polymers over an extended period of time needs to be considered. Anjali [3] reported formulation of artificial polymer-free nanopermethrin as an effective larvicide that was stabilized by plant extracted natural surfactants. More of such studies that investigate the use of natural stabilizers for nanopesticide formulations in agricultural plant protection are needed. Another area of advanced research could be the development of nanomaterials that can be used as a coating or protective layer to enable slow release of traditional pesticides and fertilizers Primarily, nano-clay materials offer interactive surfaces with high aspect ratio for encapsulating agrochemicals such as fertilizers, plant growth promoters, and pesticides [13].

EFFECT OF NANOPARTICLES IN DISEASE MANAGEMENT

All over the world human population is increasing in uncontrobly, depleting natural resources and emergence of new resistant pathogens has made the supply of sufficient and healthy food a daunting task. This problem might be magnified several folds in near future. Now, there is a need to increase production efficiency and decrease post-harvest wastage with application of emerging technologies like biotechnology and nanotechnology in post-harvest products. Nanotechnology has been effectively applied in agricultural and horticultural products by increasing shelf life, controlling growth of microorganisms by nanofilms and coatings, controlling influence of gases and the harmful rays (UV), using nanobiosensors for detection of quality and spoilage. Nanotechnology can be applied in postharvest operations such as drying, storage and preservation of agricultural products. Chitosan, a deacetylated derivative of chitin, is found to be very effective in reducing postharvest decay of fruit and vegetables [21]. Engineered nanoparticles, due to their unique electrical, mechanical, and catalytic properties, are presently found in many commercial products and will be intentionally or inadvertently released at increasing concentrations into the natural environment. Metal- and metal oxide-based nanomaterials have been shown to act as mediators of DNA damage in mammalian cells, organisms, and even in bacteria, but the molecular mechanisms through which this occurs are poorly understood. For the first time, we report that copper oxide nanoparticles induce DNA damage in agricultural and grassland plants. Significant accumulation of oxidatively modified, mutagenic DNA lesions (7,8-dihydro-8-oxoguanine; 2,6-diamino-4-hydroxy-5-formamidopyrimidine; 4,6-diamino-5-formamidopyrimidine) and strong plant growth inhibition were observed for radish (*Raphanus sativus*), perennial ryegrass (*Lolium perenne*), and annual ryegrass (*Lolium rigidum*) under controlled laboratory conditions. Lesion accumulation levels mediated by copper ions and macroscale copper particles were measured in tandem to clarify the mechanisms of DNA damage. To our knowledge, this is the first evidence of multiple DNA lesion formation and accumulation in plants. These findings provide impetus for future investigations on nanoparticle-mediated DNA damage and repair mechanisms in plants [21].

NANOTECHNOLOGY: NEW ERA OF GREEN NANOTECHNOLOGY

Nanotechnology has emerged rapidly as a Green technology in multidisciplinary field of developing research area, serving as an important technique that emphasize on making the procedure which are clean, non-hazardous, and especially environmentally friendly, in contrast with chemical and physical methods currently employed for nanosynthesis [31]. The biogenic routes could be termed green as these do not involve the use of highly toxic chemicals or elevated energy inputs during the synthesis. Differences in the bio-reducing agents employed for nanosynthesis can lead to the production of nanoparticles (NPs) having distinct shapes, sizes, and bioactivity. The exquitiveness of the green fabricated NPs have capacitated their potential applications in various sectors such as biomedicine, pharmacology, food science, agriculture, and environmental engineering. The present review main emphasis has been given on the current status and future challenges related to the wide-scale fabrication of nanoparticles for environmental remediation, pathogenicity and agricultural applications.With the potential adverse effects of agro-chemicals on human health and ecosystem the use of green technology to prevent the environmental damage has become major concern by research community. Nanotechnology is an important contribution to green chemistry; it helps in development of microscopic and sub microscopic devices with less cost and provides huge savings in materials [5]. A group of research hers have successfully used, photosynthesis is protein units (PSI) isolated from leafy vegetables and plants to form a bio hybrid photo electrochemical cell that converts light energy into electrical energy, it was interesting to note that this bio hybrid devices display remarkable stability at ambient conditions up to one year [9].

According to Emmert [11], biological control offers an environment friendly alternative to use the pesticides for control of plant diseases. Unfortunately, growers continue to use chemical control over biological agents and lack of knowledge often contributes to the downfall of a bio control agent. Knowledge of the biological environment in which the agent will be used and of how to produce a stable formulation both is critical to successful bio control. Certain Gram-positive bacteria have a natural formulation advantage over their Gram-negative counterparts: the spore. Although the Gram-positive bacteria have not been as well represented in the bio control literature, their spore-forming abilities and historical industrial uses bode well for bio control success. Here we describe several systems utilizing Gram-positive bio control agents that have been researched in depth and provide models for the future of bio control.

ROLE OF NANOPARTICLES IN FOOD PRODUCTS

Natural food products are made up of natural biopolymers like carbohydrates, proteins, lipids etc. These products should have at least one dimension in the nanometre range or nanostructures introduced by processing or cooking (e.g. emulsions such as mayonnaise). These biopolymers can also be used to design new food structures, e.g. fat reduced emulsions, nano encapsulations of nutrients (e.g. vitamins). The risk assessment has to consider that the biokinetics and toxicity profile in target tissues may be different from non-nano counterparts [19]. Some of these materials are often not intentionally produced in the nanosized range, but may contain a fraction in that size range, as for example titanium dioxide (TiO_2) as white pigment [27]. They are only weakly soluble and their components are not or slowly dissolved during digestion [6,10]. Hence these NMs may be absorbed, retained and accumulated within the body [23]. In food packaging applications nano polymer composites offer new lightweight properties and at the same time stronger materials that can keep food products secure during transportation, fresh during long storage and safe from microbial pathogens [7]. Metal oxide nanoparticles such as nano-silver or nano zinc oxide in "active" packaging and nanocoatings on food contact surfaces serve to prevent microbial growth and keep food fresher over relatively longer periods. "Smart" packaging can either slowly release food preservatives and/or incorporate nano-sized (bio) sensors to monitor the condition of food. The main concern about (any) food contact materials, is their (potential) migration into foodstuffs which is addressed by specific legislation e.g. European Commission, [12]. The safe use of all these applications is ensured by specific legis [2].

Ma [21] reviewed that rapidly increasing demand and use of engineered nanoparticles (NPs) in agriculture and related sectors, concerns over the risks to agricultural systems and to crop safety have been the focus of a number of investigations. Significant evidence exists for NP accumulation in soils, including potential particle transformation in the rhizosphere and within terrestrial plants, resulting in subsequent uptake by plants that can yield physiological deficits and molecular alterations that directly undermine crop quality and food safety. A clear understanding of nano-impacts, including the advantages and disadvantages, on crop plants will help to optimize the safe and sustainable application of nanotechnology in agriculture for the purposes of enhanced yield production, disease suppression and food quality. Application of nanotechnology in agricultural field and food products is shown in figure-1 below.

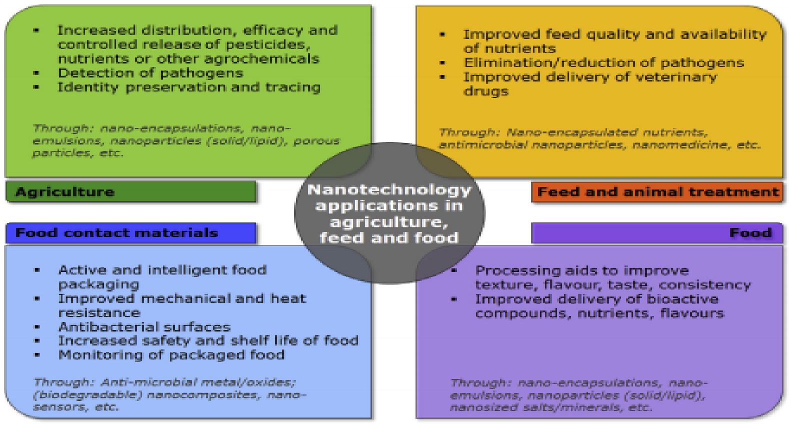

FIGURE-1 Application of nanotechnology [2]

EFFECT OF NANOPARTICLES ON PLANT GROWTH

In recent practices nanoparticles are used to check the growth of plants and for the control of plant diseases caused by different type of pests. The amount of research has been increasing on the biological effects of nanoparticles on higher plants. It was observed by Savithramma [32] that nanopartcles of size below 100 nm fall in the transition zone between individual molecules and the corresponding bulk materials, which generates both positive and negative biological effects in living cell. Biologically synthesized SNPs were employed to improve the seed germination and seedling growth of *Boswellia ovalifoliolata* an endemic, endangered and globally threatened medicinal tree species. The maximum height (10.6 cm) observed in seedlings treated with SNPs 4 mg/ml. The possible contribution of SNPs is to facilitate the penetration of water and nutrients through seed coat and accelerate the seed germination and seedling growth of *Boswellia ovalifoliolata*. Effect of biologically synthesized silver nanoparticles on seed germination and seedling growth of (*Boswellia ovaliofoliolata*) is shown in figure 2.

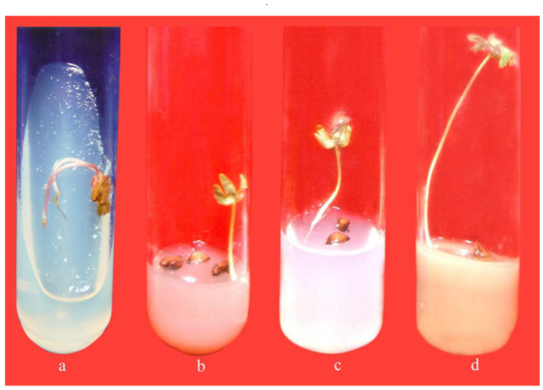

FIGURE-2. Effect of silver nanoparticles on seed germination and seedling growth of *Boswellia ovaliofoliolata* a) Control, b) SNPs 10 mg/ml, c) 20 mg/ml and d) 30 mg/ml [32]

Studies also indicate that metal nanoparticles can be used in plant cultivation as fungicides and growth stimulators. Olchowik [26] evaluated the effect of silver (AgNPs) and copper nanoparticles (CuNPs) on the growth parameters, on the extent of leaves infected by powdery mildew and on spontaneous ectomycorrhizal colonization of English oak (Quercus robur L.) seedlings growing in containers. Nanoparticles were applied to foliage four times during one vegetation season, at four concentrations: 0, 5, 25 and 50 ppm. The adsorption of NPs to leaves was observed by microscopical imaging (TEM). TEM results showed disturbances in the shape of plastids, plastoglobules and the starch content of oak leaves treated with 50 ppm Cu- and AgNPs, while no changes in the ultrastructure of stems and roots of oak plants treated with NPs were observed. No significant difference in powdery mildew disease intensity was observed after NP foliar app lication.

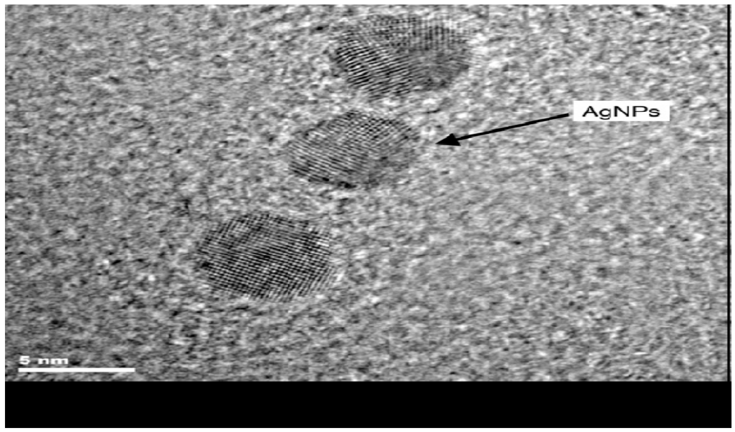

FIGURE - 3. Transmission electron micrograph of silver nanoparticles [26]

Marek and coworkers studied a significant reduction in mycelial growth was observed for spores incubated with silver Nanoparticles. The sporulation test showed that, relative to control samples, the number of spores formed by mycelia increased in the culture after contact with silver Nanoparticles, especially on the nutrient-poor PDA medium. The 24 h incubation of FC spores with a2.5 ppm solution of silver Nanoparticles greatly reduced the number of germinating fragments and sprout length relative to the control.

SIGNIFICANCE AND LIMITATIONS OF NANOTECHNOLOGY

Nanotechnology has a significant role to play in agriculture, food processing, food packaging, food security and water purification. But it may pose negative effects on the environment, ecosystem, and humans. The potential risks associated with releasing nanomaterials into the environment (soil and water organisms) are still unclear by scientists. Recent findings showed the potential harmful effects of nonmaterial's on the digestive systems of a beneficial soil organism–earthworm [29]. Xu [35] summarized the increased safety concerns over application of nanomaterials in food and agriculture. They emphasized their study on main exposure routes and determinants of nano toxicities involving particle size, surface, structure, chemical composition and dosage.

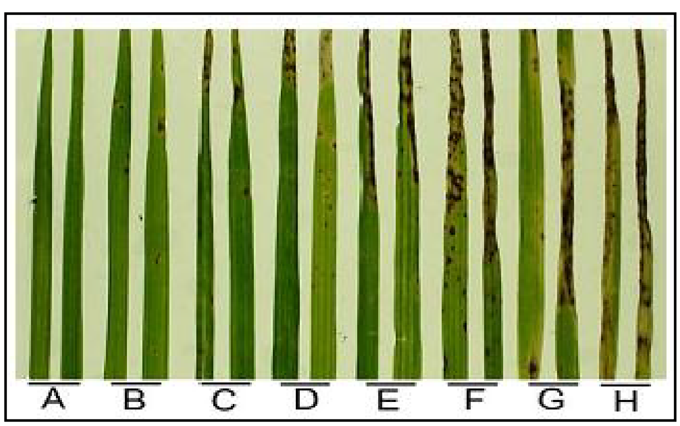

FIGURE - 4 Reduction in mycelial growth for spores incubated with silver Nanoparticles [1]

CONCLUSION

From the existing review it is concluded that nanotechnology have multiple applications in research area of agriculture, medical, microorganism, food, feeder, packaging, polymers etc. and more work has to be carry out in these fields for future aspects of human and environmental health .

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