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"ROLE OF NANOTECHNOLOGY IN AGRICULTURE"

Shahid Raza[1*], Saima Hanif[2] and Arifa Tahir[2]

[1]Lahore Garrison University, Lahore, Pakistan.
[2]Lahore College for Women University Lahore, Pakistan.

***Corresponding Author: Dr. Shahid Raza**
Lahore Garrison University, Lahore, Pakistan.

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ABSTRACT

An emergent technology involving different interdisciplinary field of science is the 'Nanotechnology'. Its wide applications used in various fields like medicine, pharmaceuticals, electronics, biotechnology and agriculture. The use of nanoparticles (NPs) in the field of nanotechnology have impact on plant growth, cell structure, and physiological and biochemical functions due to their unique physicochemical properties like high surface area and reactivity, its pore size and particle morphology. Nanoparticles pose potential risks to the organisms when released into the environment. Their adverse effects have been investigated in recent years like it is believed that NPs reduce plant biomass, water and chlorophyll content, inhibit root growth, photosynthesis, and transpiration. It is also investigated that, nanoparticles containing nano-pesticide fertilizers, herbicides or genes can serve as "magic bullets", which target specific cellular organelles in plant to release their content. Therefore, the present review highlights the key role of nanoparticles in plants. Even now, the share of publications on nanotechnology in agriculture remains diminutive. However, the accelerating hop reflects a growing recognition of the numerous potential agricultural applications of nanotechnology. It is evident from compiled information that depending upon the mode of application, size, and concentrations of NPs, its effect varies from plant to plant. The outcomes also suggest that plants as an important element of the ecosystems need to be included when assessing the overall positive and negative impact of nanoparticles in the environment because few studies also shown the positive impact of NPs on plant growth and development.

KEYWORDS: An emergent plant growth and development.

INTRODUCTION

Nanotechnology: The prefix 'nano' is the 10^{-9} or one billionth part of a meter from the Greek word meaning 'dwarf'. So, the term nanotechnology, generally used for materials having size range between 1 and 100 nm; however, it is also essential that these materials as a result of their size should display different properties from bulk (micrometric to larger) materials. These differences include chemical reactivity physical strength, magnetism electrical conductance and optical effects.

Adverse impacts of Nanotechnology in Agriculture

Nano as an enemy

Nanoparticles are the indispensable part of nanotechnology act as a mandatory constituents of nanotechnology exhibit a discrete property of larger surface-area-to-volume ratio, which makes them better than their bulk counterparts in the sense of their activity. Engineered nanoparticles (ENPs) can be carbon or metal-based. Carbon nanotubes mostly used in carbon-based and; while in metal-based metals, metal oxides, and quantum dots are in use (Peralta *et al.*, 2011). Among the most widely produced and used metal-based ENPs are, titanium dioxide ($nTiO_2$), copper (nCu), gold (nAu), silver (nAg), zinc oxide (nZnO) and cerium oxide ($nCeO_2$) NPs (Keller *et al.*, 2011). Other NPs like nMn, nFe_3O_4, nCuO, and $nCoFe_2O_4$ are also used. Studies have shown that these NPs are able to generate excess ROS (reactive oxygen species) to affect proteins, lipids, carbohydrates, and DNA in plants, also produce stress by affecting photosynthesis and chlorophyll content in different ways. Once entered inside cells, nanomaterials might aggravate alterations in cell structures, membranes, and molecules, as physical restraints, solubilization of toxic NP compounds, or production of ROS.

Toxicity of Nanoparticles

The effects of NPs on plants as producing oxidative stress using techniques that measure either just H_2O_2 or ROS in general have been broadly investigated. Cell death referred to as oxidative damage commonly measured by lipid peroxidation and electrolyte leakage. The ROS scavenging ability of $nCeO_2$, oxidative damage in rice seedlings germinated in $nCeO_2$ have been investigated widely (Rico *et al.*, 2013b). Results shown that $nCeO_2$ decreases the H_2O_2 concentration due to its radical scavenging ability (Heckert *et al.*, 2008; Horie *et* *al.*, 2011; Xia *et al.*, 2008). Similarly photo catalytic activity of ZnO making it able to generate free radicals contributing to toxic responses in plants (Xia *et al.*, 2008). The effect of 7-day treatment of *n*Ag on the H_2O_2 generation and lipid peroxidation in *B. juncea* determined Sharma *et al.*, (2012a). Toxicity study of graphene in cabbage, tomato, and red spinach was also performed. Results revealed increase in H_2O_2 production, electrolyte leakage and eventually cell death in graphene-treated leaves. Its negative impact was attributed to its aggregation on root surface (Begum *et al.*, 2011).

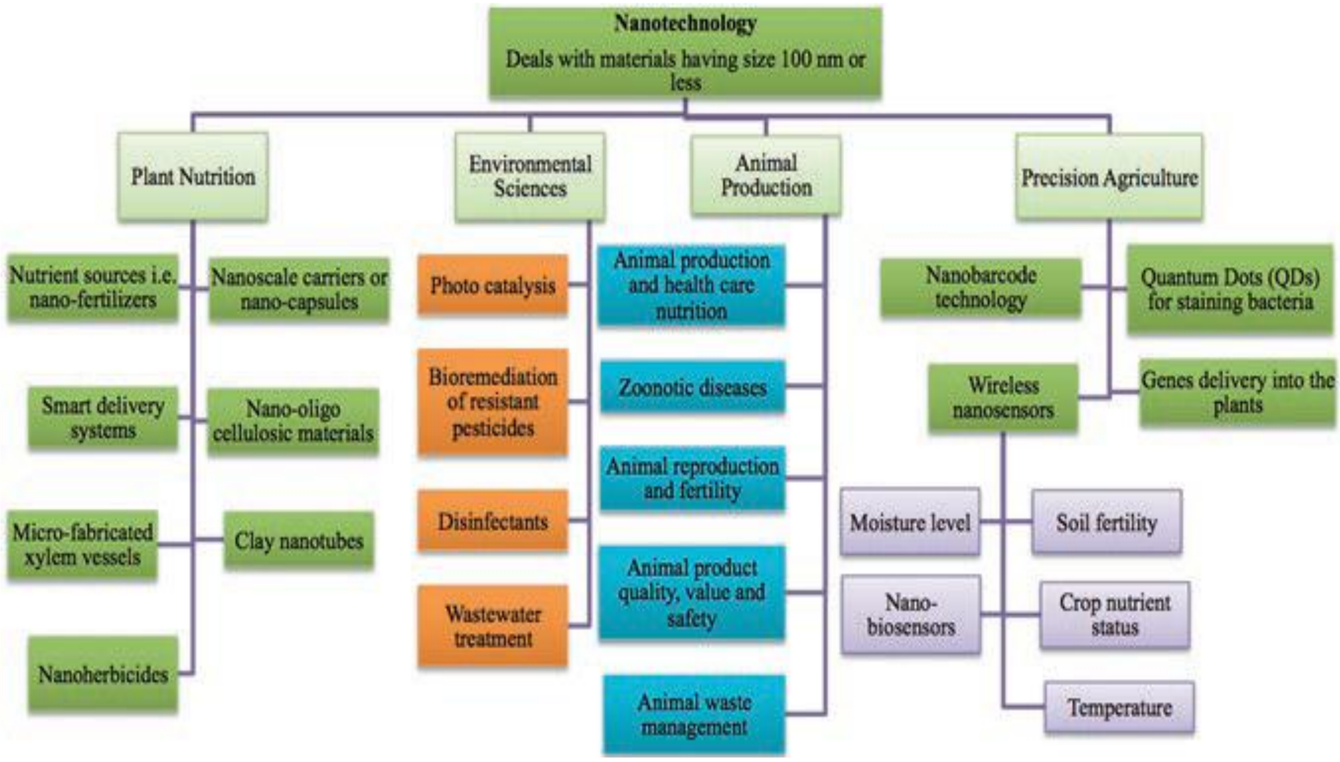
Antioxidant ability of Nanoparticles

The antioxidant ability of nanoparticles, and their mechanisms, that mimic the activity of natural enzymes reviewed which shows that various nanoparticles exhibit enzyme-like activities (Wei and Wang 2013). Unfortunately, if not impossible merely difficult to detect these mimetic activities by using NPs exposure to whole individual plant in different experiments. In fact, studies revealed irregular and erratic effects of NPs on enzyme activities. Earlier reviews have shown that the effect of important factors affecting the toxicity responses, including oxidative stress and anti-oxidative defense system in plants depends on type, concentration, properties, and exposure media of NPs. Thus, the chemical attributes of NPs on the variation of antioxidant defense system in plants is not clear, and a topic needed to be explored more.

Beneficial impacts of Nanotechnology in Agriculture

Nano as a friend

Nanotechnology has potentially change the entire scenario of agricultural and food industry by developing new tools for the treatment of plant diseases, rapid pathogen's detection using nano-based kits, improving the ability of plants to absorb nutrients, etc. Nano biosensors and other smart delivery systems will also help to fight against different crop pathogens in the agricultural sector. It is anticipated that nano structured catalysts will be available in the near future which will increase the efficacy of commercially available insecticides and pesticides and also reduce the doses level required for crop plants (Joseph and Morrison 2006). Depending on their properties, they induce many morphological and physiological changes by interacting with plants. Chemical composition of NPs, their size, reactivity, surface covering and most importantly the dose at which they are effective determined their efficacy (Khodakovskaya *et al.*, 2012). NPs also shown positive effects on germination of seeds, growth of seedlings, on fertilizing effects and on nitrogen assimilation. This was only obtained if the seeds were treated with specific NPs having specific dimension, concentration, and material. By using nanotechnology tools, the delivery systems for pests, nutrients, and plant hormones have been manufactured. It also facilitates the controlled release of agrochemicals by allowing direct delivery of various macromolecules at the predetermined sites for improving plant disease resistance, nutrient utilization, and plant growth. In terms of increasing efficiency, the usage and safe handling of pesticides nano encapsulation will play an important role (Nair *et al.*, 2010).



Role of nanotechnology in agriculture

Nanoparticles boosting Plant metabolism

Nanoparticles have potential to boost the plant metabolism by having unique physicochemical properties (Giraldo *et al.,* 2014). Siddiqui and Al-Whaibi (2014), investigated the lower concentrations of nano-SiO2 improving seed germination of tomato. According to Suriyaprabha *et al.,* (2012), seed germination enhanced by nano-SiO_2 which provide better nutrients availability to maize seeds, and pH and conductivity to its growing medium. Raliya and Tarafdar (2013) reported that ZnONPs induced a significant improvement in plant biomass, shoot and root growth, chlorophyll and protein synthesis, rhizospheric microbial population, acid phosphatase, alkaline phosphatase and phytase activity in cluster bean rhizosphere in *Cyamopsis tetragonoloba*. Kumar *et al*., (2013) reported that gold (Au) NPs have a substantial role on seed germination and antioxidant system in *Arabidopsis thaliana* and altered microRNAs expression's level that regulates various morphological, physiological, and metabolic processes in plants. Gruyer *et al.,* (2013) reported that depending on the plants species, Silver (Ag) NPs have both positive and negative effect on root elongation. They described that root length was increased in barley, but was inhibited in lettuce. TiO_2NPs improved wheat plant growth and yielded components under water deficit stress condition reported by (Jaberzadeh *et al.,* 2013). Crabtree (1998), investigated that TiO_2NPs also induces an oxidation-reduction reaction and acts as a photo catalyst.

Nanotechnology regulating photosynthetic activity

Researchers want to develop bionic plants with better photosynthesis efficiency and biochemical sensing using techniques of Nano biotechnology. Nano mesoporous silica compound (SBA) bound with photosystem II (PSII) induces stable activity of an oxygen-evolving photosynthetic reaction, indicating electron transport from water to the quinone molecules in light reaction, and they suggested that PSII-SBA conjugate might have properties to develop for photosensors and artificial photosynthetic system (Noji *et al.,* 2011). SiO_2NPs improving activity of carbonic anhydrase and synthesis of photosynthetic pigments by increasing the photosynthetic rate (Siddiqui *et al.,* 2014; Xie *et al.,* 2012). By supplying CO_2 to the Rubisco, carbonic anhydrase may also improve photosynthesis rate (Siddiqui *et al.,* 2012).

Nanotechnology for Crop Protection

Nanotechnology has also been extensively used in the field of plant protection against insects and pests. New formulations like pesticides, insecticides, and insect repellants prepared by nanoparticles could be effectively utilized (Barik *et al.*, 2008; Gajbhiye *et al.*, 2009).

Bhattacharyya *et al.,* (2010) reviewed that revolutionized agriculture including pest management will be possible in the near future by using nanotechnology. It is also anticipated that over the next two decades, nanotechnology would be responsible for the 'green revolution'. Nano-encapsulation is one of the important example of this technology which used as the most important and auspicious method for protection of host plants against insect pests. It includes the use of a different kind of nanoparticles with pesticide or insecticide. Nano-encapsulation with these nanoparticles allows for proper absorption of the chemical into the plants unlike the case of larger particles (Scrinis and Lyons 2007).

Today nano-pesticides, nano-fungicides and nano-herbicides are being used in agriculture sector (Owolade *et al.* 2008). Many formulations of nanoparticles within the 100–250 nm size range are made by different companies that are able to dissolve in water more efficiently than existing ones and thus increasing their activity. Nano scale particles suspensions (nano-emulsions) are suggested by some other companies, having multiple applications for preventative measures, treatment or preservation of the harvested product (Goswami *et al.* 2010; Rickman *et al.* 1999).

Carbon Nanotechnology for Crops Biotechnology

ENPs are able to enter into plants cells and can transport DNA and chemicals Galbraith (2007) and Torney *et al.* (2007). This area of research offers new potentials in plant biotechnology to target specific genes manipulation and expression in the specific cells of the plants. The engineered carbon nanotubes also have potential to boost seed germination, growth, and development of plants (Lahiani *et al.* 2013; Siddiqui and Al-Whaibi 2014). Applications in the nanotechnology-based development of agriculture is crucial to tackle many complications that farming and food industry face across the world. The challenge has always been how to detect plant diseases at appropriate timing, increase agricultural output and efficiently advanced treatment. The process of maximizing the agricultural production requires increased ability of plants to absorb nutrients from the soil. This nano agriculture science continues to advance and promises valuable technologies rapidly for enhancing the agricultural yield. In a recent study carbon nanotubes may be used as a potential nano-vector to transfect plant cells with genes of interest (Giraldo *et al.* 2014). Thus, Carbon nanotechnology has the potential to empower advanced application in agriculture. In the next coming year's carbon nanotubes are anticipated to show more opportunities in the agricultural sector that remained beyond technical awareness which starting from increased crops yield to organelles- targeted gene delivery and ending with wood and chloroplasts engineering.

Nanofiltration: Purification of irrigation water

By employing the process of nanofiltration instead of traditional methods of using UV light or chemicals irrigation water could be purified (Hillie and Hlophe 2007). In the process of nanofiltration, the use of the nanofilters with nanopores have not only the ability to remove the water borne pathogens but also heavy metals like lead, uranium, and arsenic (Gao *et al.* 2014; Zhu *et al.* 2014).

Nanomaterials: antimicrobial and antifungal agents for plant pathogens

Some researchers also investigated the antimicrobial and antifungal activities of different metal nanoparticles particularly copper and silver nanoparticles against the plant pathogens. Antifungal activity of polymer-based copper nano-composite against plant pathogenic fungi reported by Cioffi *et al.* (2004).

Clay Nanotube

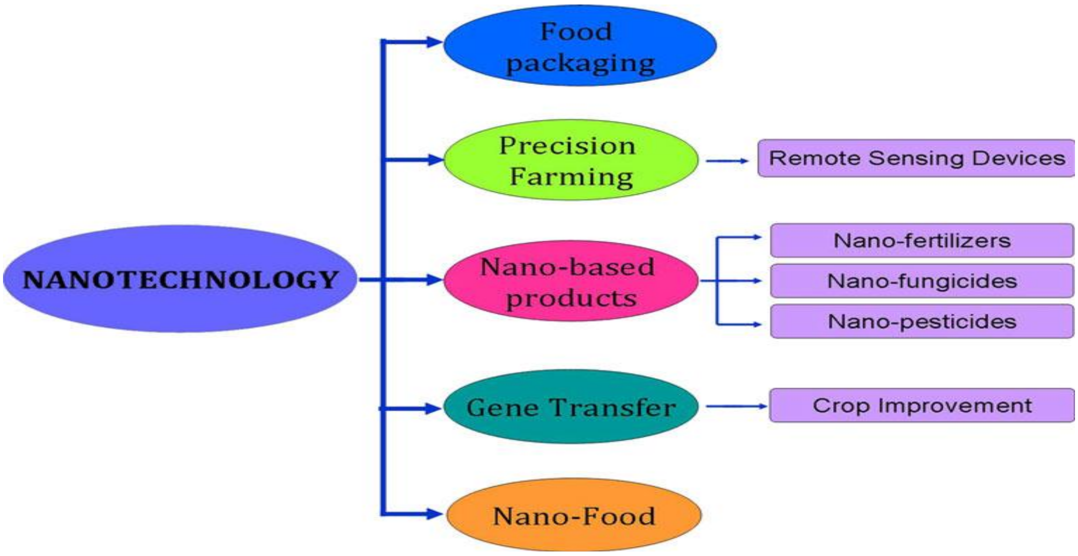
Another important achievement is the development of clay nanotubes in the field of plant protection. This will reduce the amount of pesticides by 70–80 % developed as carriers of pesticides for low cost, extended release and better contact with plants and hence will reduce the cost of pesticide and also the impact on water streams (Murphy 2008).

Nanobarcode Technology

Identification tags have been applied in wholesale agriculture and livestock products in our daily life. Due to the small size of NPs, these are applied in many fields ranging from advanced biotechnology to agricultural encoding. Their possibility of formation of large number of combinations that made them attractive for this purpose, nanobarcodes (>1 million) have been applied in multiplexed bioassays and general encoding. Optical microscope and UV lamp are used to identify the micrometer sized glass barcodes with rare earth containing a specific type of pattern of different fluorescent materials which are formed by doping (Mathew *et al.* 2009). The utilization of these particles in nanobarcodes should be sub-micron sized particles, easily encodable, machine-readable, and durable. Economically this technique has been proved proficient, rapid, and easy technique in decoding and recognition of diseases as several pathogens in a farm could be labelled and detected at a time using any fluorescent based tools (Li *et al.* 2005).

Conclusion and Future perspective:

Now in a general sense, exposure to nanoparticles is not a new problem. Nano-sized particles have been exposed to human beings since immemorial time as natural sources of nanoparticles such as forest fires and anthropogenic sources such as industrial pollution.



In various sectors including agriculture, nanotechnology has the potential to revolutionize the existing technologies. It may have concrete solutions against many agriculture-related problems by using traditional methods for insect pest management, adverse effects of chemical pesticides, development of improved crop varieties, etc. Recently, it has been proved that nanoparticles are present in 'Bhasmas' used in Ayurveda and homeopathic medicines. Nanoparticle-mediated gene transfer would be potentially useful for the development of new insect resistant varieties. There is a need to explore more studies on the mode of action of NPs, their interaction with biomolecules, and their impact on the regulation of gene expressions in plants. Nanomaterials can be used in different forms efficiently. Therefore, it can also be concluded that nanotechnology can provide green and eco-friendly alternatives in agricultural aspect without harming the nature.

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