Review Article

A Review about Perspectives of Nanotechnology in Agriculture

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Abstract | Nanotechnology plays a significant role in promoting agriculture and agricultural products. Agriculture and food industry aims for the sustainability and the protection of agricultural products, including crops for human and livestock. Nanotechnology helps in the manufacturing of innovative agrochemicals and novel delivery mechanisms to enhance crop production and decrease in pesticide use. Nanotechnology also contributes in increasing the crop yield in agriculture. One of the major contribution of nanotechnology in the field of agriculture is the formulation of nano based pesticides and fertilizers for increased crop production. Precise farming techniques can promote crop production without damaging soil and water, reducing losses due to leaching of nitrogen and enhancing long lasting incorporation of nutrients by micro-organisms present in the soil. Another major breakthrough of nanotechnology for improvement in agriculture production is the development of insect-resistant varieties by DNA transfer in the plants or nanoparticle-mediated gene. Biofuel production from biomass is estimated to speed up using nanotechnology. Researchers and manufacturers have to demonstrate that the application of nanotechnologies have no harmful effect on the atmosphere against the anomaly based only on small amounts of toxicological research and concerns about the safety of nanomaterials.

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Introduction

The agricultural practice, also called "farming", include raising of certain plants and livestock to produce food, feed, fiber and many other desired products. Agriculture is backbone of the most developing countries, providing food directly and indirectly to mankind. Because of climate shift, resource and energy constraints, and rapid increase in population, food and water resources are under unprecedented stress, and agricultural processes are often seen in the eyes of the public. Agriculture as a food source is becoming more and more important in the world of resource depletion and global population growth (Brennan, 2012). Given the growth of the world's population, modern technologies are necessary in agriculture and food science, such as nanotechnology and nano-biotechnology. Nanotechnology has the ability to transform agriculture and related disciplines, including aquaculture and fisheries. Nano-agriculture is at present focused on target farming and requires the utilization of nanoparticles with exceptional properties to increase crop yields and livestock productivity (Batsmanova et al., 2013). Protection of plants, monitoring plant growth, identification of diseases related to plants and animals, increase in overall

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food production, improving quality of food and reduce "sustainable intensification" of waste are the areas of interest in nanotechnology. Food and agricultural production is one of the main applications of nanotechnology.

Current Status of Nanotechnology in Agriculture

Above 60% of world's population depends on agriculture for their livelihood as it is the backbone of most emerging countries. Nanotechnology is considered as a novel technology in agriculture due to its ability to provide appropriate delivery of nutrients and pesticides resulting in improving yields or nutritional values of the crop. Moreover, it helps in environmental remediation and provides pathway to value added crops. One of the common applications of nanotechnology in agriculture is particle farming, in which plants are grown in defined soils to yield nanoparticles for industrial use. A study was conducted to extract gold nanoparticles by growing the plants in gold rich soil. The plant tissues of these plants accumulated gold nanoparticles which were absorbed through their roots. After harvesting these plants the gold nanoparticles were mechanically separated from the plant (Kalaugher, 2002).

Researches had also been conducted to study the effect of nanoparticles on the growth and development of plants. Some of the studies suggested a positive effect while other found out a negative response of plants applied with nanoparticles. The composition of nanoparticles applied as well as size, concentration and its physical and chemical properties affected the response of the plants (Siddiqui et al., 2015). Application of calcium carbonate nanoparticles enhanced formation of soil macro aggregates and micro aggregates (Liu and Lal, 2012).

Improvement in plant genetic material can also be achieved through nanotechnology by delivering the drug molecules and genes to precise location at a cellular level in animals and plants (Kuzma, 2007). Conventional fertilizers have been replaced by nano fertilizers with the help of nanotechnology. Nano fertilizers tend to enhance the fertility of soil and ultimately helping in eliminating eutrophication and ground water contamination (DeRosa et al., 2010; Bhalla and Mukhopadhyay, 2010; Mukhopadhyay and Sharma, 2013).

Nanopesticides

In agriculture, crop yield and efficiency are improved by the use of pesticides. Nanopesticides cover extensive variety of products, few of which already are available in the market (Nuruzzaman, 2016). Nanomaterials comprising polymeric nanoparticles, silver ions, gold nanoparticles and iron oxide nanoparticles are used as pesticides. Researchers reported different methodologies for nanoparticle formulation, characterization, their effect and their application in plant disease management (Al-Samarrai, 2012).

The potential of nanoparticles in insects and their use in pest control has been reported (Bhattacharyya et al., 2010). Nanotechnology has been reported in the control of polyphagous pest *Helicoverpa armigera* (Vinutha et al., 2013). Aqueous leaf extract of *Tinospora cordifolia* (commonly known as heart-leaved moonseed) utilizing synthetic silver nanoparticles reported highest mortality against the head louse. Synthetic silver nanoparticles possess excellent anti-lice and mosquito larvicidal activity (Jayaseelan et al., 2011).

Nanofertilizers

Discharge of nutrients into the soil in a controlled way can be achieved by the utilization of nano-fertilizers, thereby avoiding water pollution (Naderi and Abedi, 2012). Treatment of TiO_2 nanoparticles on maize considerably affected growth, while the TiO_2 bulk treatment effect was found insignificant. TiO_2 nanoparticles increase light retention and light diffusion in the plant. Researchers also found that the compounds of Silicon and Titanium nanoparticles enhance the nitrate reductase action and enhanced absorption capacity of soybean plants, increasing their water and fertilizer use efficiency. Nano fertilizers have unique characteristics such as ultra-high absorption, increased production, increased photosynthetic activity and considerable increase in the surface area of leaves (Iran Nanotechnology Initiative Council 2009). The use of nano-fertilizers results in increased elemental efficiency, reduced soil toxicity, at least to the harmful effects of extreme intake of fertilizers, and lessened frequency of fertilizer utility (Naderi and Shahraki, 2013). In a recent study Sadaf et al. (2017) investigated that wheat productivity and soil quality can be improved by the co-application of biochars and chemical fertilizers (Sadaf et al., 2017).

Nanotechnology and Agri-environment

Utilization of agro-chemicals to enhance crop yield results in improper release of undesirable compounds into the atmosphere. Today, nanotechnology has a potential to increase crop yield and repair polluted groundwater and soil. Researchers have found that current use of nanotechnology in agricultural environment research, with specific consideration to the destiny of nanomaterials in soil and water. Application of nanomaterials improves environmental quality and facilitates in detection and repairing of contaminated areas; only a few nanomaterials display a possible toxic effect (Mura et al., 2013).

Generation of destructive free radicals is catalyzed by a free ion of copper as it plays an important role in the electron transport chain of cell. Some scientists reported that use of synchrotron microanalyses, *Phragmites australis* and *Iris pseudoacorus* common wetlands plants changed Cu into metallic nanoparticles in and close to the root zone with the support of endomycorrhizal fungi when cultivated in polluted soil (Manceau et al., 2008).

Nanotechnological Applications in Agro-waste Reduction and High value Products such as Bio-fuels

Right now, depressing energy patterns and problems are the consequence of over-dependence on restricted amount of fossil fuels associated with escalating energy requirement. The answer is a nanotechnology technique which facilitates in smooth conversion to biofuels. Application of nanotechnology in pyrolysis, hydrogenation, transesterification and gasification, and addition in the transformation of compounds of biomass was recorded (Ramsurn and Gupta, 2013). Nanomaterials can stimulate microbial metabolism. In this case, the utilization of nanomaterials can enhance the effectiveness of lipid extraction and even achieve it without harming microalgae. Calcium oxide and magnesium oxide nanoparticles can be used as biocatalyst carriers for transesterification of oil to biodiesel (Zhang et al., 2013).

Nanotechnology is one of the suitable advancement for future biofuels, of which current endeavors of the second generation is to convert liquid biofuels to ethanol and biodiesel depends on biomass cellulose (A polysaccharide, ($C_6H_{10}O_5$), which is composed of glucose monomers and is a major component of the plant cell wall). The potential way to obtain biofuels should be of such anextent that nonfood feedstock's and innovative systems should be used in a focused manner (Trindade, 2011).
Spent tea (solid waste) is utilized to produce bio-ethanol, biodiesel and biogas. Scientific studies have revealed three steps in converting of spent tea (*Camellia sinensis*) to bio-fuels. The first step included the gasification of spent tea at 300 ^{0}C. Spent tea was gasified at 300 °C under atmospheric pressure using cobalt nano-catalyst. This gasification of spent tea yielded 60% liquid extract, 28% fuel gases, and 12% charcoal. The gaseous products contained 53.03% ethene, 37.18% methanol, and 4.59% methane. The second step includes the transesterification reaction of liquid extract of spent tea which produced 40.79% ethyl ester (biodiesel). The development of *Aspergillus niger's* on spent tea produced 57.49% bio-ethanol in the third step. The modern world utilizes millions of tons of tea a year. This procedure can be utilized to produce alternative energy (Mahmood and Hussain, 2010).

Nanotechnology for Crop Improvement

Improved production was reported by foliar use of the nanoparticles as fertilizer (Raliya and Tarafdar, 2013). Numerous nano-materials, generally metal-based nano-materials and carbon-based nano-materials are produced for their assimilation, translocation, storage, and specifically, for their impacts on development and improvement in crop yield (Nair et al., 2010). In many crop plants, due to the positive morphological impacts of nanotechnology improved germination percentage, root and shoot length, and its proportion; and vegetative biomass of seedlings were observed. It has also been reported that metal-based nano-materials enhance numerous physiological parameters such as increased photosynthetic rate and nitrogen assimilation in some crops including soybean (Agrawal and Rathore, 2014), spinach (Gao et al., 2006), and peanut (Giraldo et al., 2014).

Nano-biotechnology provides tools and technology platforms to improve agricultural productivity by genetically modifying plants and transporting genes and drug molecules to particular locations on the cellular stage. In agriculture, smart delivery systems for fertilizers and pesticides timely detection of pathogens and contaminants can be achieved through the availability of suitable technologies and sensors (Ahmed et al., 2013).

Nanotechnology in Hydroponics

Growing of soil-free plants is called hydroponic. This technique is broadly used to grow crop plants (Seaman and Bricklebank, 2011). Hydroponics techniques are less well-known in food production, although many of the hydroponically produced fruits and vegetables are displayed at supermarkets. Different applications include feed and biofuel crop production. Researchers have created hydroponics in nanotechnology by "growing" metal nanoparticles in different plants (Schwabe et al., 2013).

Particle Farming

Researchers have figured out a technique to develop and gather gold from plants. Nanoparticles can be produced industrially. Researchers observed that alfalfa plants in rich environment of $AuCI_{-4}$ shows that plants absorb gold. Mechanical separation of Gold nanoparticles is achieved by dissolving the organic material (plant tissue) after harvesting (Gardea-Torresdey et al., 2002). Absorption of silver by alfalfa plants grown in medium rich in silver and the successive development of silver nanoparticles was observed by some scientists (Gardea-Torresdey et al., 2003).

Conclusions

Much more opportunities for nanotechnology exist in agriculture and food production. The potential applications and advantages of nanotechnology are vast. Increasing crop yield through precision agriculture driven by nanotechnologies is desirable for maximizing output and reducing inputs through improved monitoring and targeted action. Nanotechnology empowers crops to use water, pesticides, and fertilizers more effectively. The application of nanotechnology can possibly convey advantages to farmers through food production. Expected agronomical nanotechnology applications include nanoporous zeolites for slow release and effective doses of water and fertilizers for plants, nanocapsules for agrochemical delivery, biofuel generation and improved plant breeding. Even so, the use of nanotechnology in the agriculture is retreating. In addition, present efforts are likely to reduce the negative effect of agrochemicals on the atmosphere and health of humans, relatively the use of nanotechnology to enhance their properties for crop production.

Author's Contribution

Dr. Safdar Ali, Dr. Tariq Mehmood and Dr. Ijaz Ahmed wrote the abstract and conclusion sections, whereas, Mr. Bashir Ahmad Khan, Mr. Muhammad Amir Hanif and Mr. Obaidullah Shafique compiled the introduction and references sections of this review article

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