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Review Article

Agro-nanotechnology: A Future Technology for Sustainable Agriculture

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A B S T R A C T

Nano-technology is making its way in agriculture throughout the world. Traditional farming techniques have attained saturation and are neither able to increase productivity nor able to restore ecosystems damaged by existing technologies. The global requirement of food is increasing gradually. Nanotechnology would prove a boon for modern agriculture farming by improving the efficiency of nutrient uptake employing nano-fertilizers, control of pest and pathogen using nano-pesticides, etc. Nano-sensors are being developed that spread throughout the farming fields for monitoring agro-climatic conditions required to increase productivity of quality food crops and proper management of fertilizers, pesticides and herbicides, etc. requirement. Thus, agro-nanotechnology would be an eco-friendly, cost effective green technology for sustainable agriculture.

Keywords

Agriculture; Ecosystem; Food crops; Nano-fertilizers; Nanotechnology

Introduction

Agriculture is the major source of income in developing countries, it provides food and fodder. Indian agriculture suffers from low productivity due to conventional farmers' practices. Indian population is increasing at alarming rate. Therefore, it is crucial time to use modern technology such as bio and nanotechnology to maintain the ever increasing demand of food crops. Nanotechnology is defined as the branch of the science that deals with the understanding and control of matter at the dimensions of about 1-100 nm, and their implications for the welfare of human beings (US Environmental Protection Agency). Globally, a large proportion of people face daily food shortage due to changing agro-climatic conditions particularly in developing countries. The situation is even poor in developing countries. Thus, there is need to develop drought and pest resistant crops with increased minerals uptake to maximize production level. Alfadul (2017) and coauthors have reviewed that nanotechnology will increases the crop yield by withstanding environmental conditions, detection and control of crop diseases, improved crops with efficient capabilities for mineral uptake from the soil. 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. Nanotechnology gained attention in agriculture with the reports published by Roco (1999), the United States

Department of Agriculture (2002), the Nano-forum (2006), etc. These reports focused on nanotechnology research in agriculture applications.

It has been envisioned that the novel properties of nano-scale biomaterials combined with indigenous technologies would have many innovative applications for agriculture (Scott and Chen 2013). In India, applications of nanoparticles could be in the areas of nano-inputs, nano-food systems, Nano-biotechnology, and nano-remediation (Subramanian and Tarafdar 2011). However, nano-technology is likely to overwhelm all spheres of agricultural activities from tillage to sillage, presowing field preparations to post cooking and food serving, and seed germination to germplasm manipulation (Mukhopadhyay 2014).

The nanoparticles show extraordinary features which are not exhibited by the materials otherwise. For example, surface area, cation exchange capacity, ion adsorption, complextion, many more properties of clays would multiply if they are brought to nano-size (Mukhopadhyay 2014). Nanoparticles may have different surface composition, types, densities, and reactivity with respect to processes such as adsorption and redox reactions. These particles have high proportion of atoms present on their surface which could be used in synthesizing nano-materials of agricultural use (Maurice and Hochella 2008; Waychunas *et al.*, 2005).

The purpose of using fertilizers is to provide macro and micro nutrients absent/less in soil. The fertilizers directly affect the plant growth and crop productivity. However, use of chemical fertilizers is not an economically sustainable solution to crop productivity, while, it damages the soil health due to generation of toxic compounds by chemical reactions. Nanotechnology may answer these shortcomings of chemical fertilizers/pesticides and other agricultural conditions. The advanced technologies of 21st century are making a very significant impact on the world's economy, industry and people's lives (Guere *et al.*, 2011; Scott and Chen 2013).

The nanotechnology in agriculture would be benefit in different ways for increasing yields of crops such as (i) to produce high temperature tolerant crops, (ii) development of specialized pesticides for specific insects, (iii) overcome the problems of global warming, (iv) development of nanotubes that store rainwater in the soil so that plants can use it in drought.

The nanotechnology has helped in making efficacious pesticides and prevention of dangerous dissemination in environment by placing these pesticides in nanometer capsules which can accurately control the rate of pesticide release from the capsule as per need of crops (Alfadul *et al.*, 2017). In this paper, few applications of nanotechnology in agriculture are discussed.

Applications of Nanotechnology

Detection and control of the plant diseases

Nanoparticles may be useful in the treatment and monitoring of food crops diseases by targeting pathogens (Philip, 2011). Some of the nanoparticles are nano-forms of carbon, silver, silica and alumina silicates that are use in control of crops diseases. Singh *et al.*, (2014) reported that nano silver is the most exploited nanoparticles in biological system.

The capsulated nano silver removes unwanted microbes in planting soils and restricts several other plant diseases (Bhattacharyya 2010; Singh *et al.*, 2014).

Food crop production

Globally, there is increasing demands for safe food due to the ever increasing population. Thus, technological advancement is necessary for completing demands of healthy food. Nanotechnology can be boon in current scenario and used in the crops production and their processing. Several studies have been carried out to determine the applicability of nanotechnology in the detection of chemical and biological compounds in many types of food crops (Alfadul *et al.,* 2017). Agro-nanotechnology focus on the sustainable food production and protection of food crops for both human nutrition and animal feeding and against pests and diseases (Khot *et al.,* 2012).

Food security is one of the biggest issues for every country. In future global need of food and nutrition by 2050 will be increased by 70% from current levels in a sustainable way (Chen and Yada 2011). Thus, farmers must have new and innovative technologies and adopt modern farming practices to meet out the future challenges of agriculture based food production (Mukhopadhyay 2014).

Nano-fertilizers

The augmentation of fertilizers in soil is essential to supplement the soil fertility for better yield of food crops (Barker and Pilbeam, 2006). However, the use of chemical fertilizers cause many adverse environmental effects and damaged the soil health. Thus, there is requirement a new cost effective ecofriendly technique for better crop production. In this context, the use of nano-fertilizers instead of using conventional fertilizers will assist in controlled release of nutrients in soil and prevent loss due to chemical fertilizers (Naderi and Abedi, 2014; Moaveni and Kheiri, 2011).

In nano-fertilization, nutrients may be entraped using nano-materials coated with a thin film or delivered as emulsions. The slow release of nutrients from nanoparticles coated fertilizers increase the use efficiency of nutrient by crops. El- Ramady (2014) reported the impacts of nano-fertilizers in sustainable agriculture. Several other researchers reported the possible use of nano-fertilizers as an alternative to conventional fertilization processes at low cost and in smaller quantity (Naderi *et al.,* 2011; Prasad *et al.,* 2012; Batsmanova *et al.,* 2013).

Nano-pesticides

In agriculture, pesticides or weedicides are used to control pests or weeds for increasing crop yield. However, they also damage the soil health. Nano-pesticide is an agro-chemical combination used to overcome the problems caused by conventional pesticides (Sasson *et al.,* 2007). Several types of materials viz., surfactants, organic polymers and mineral nanoparticles that fall in the nanometer size range are used in formulation of nano-pesticides (Alfadul *et al.,* 2017). The new generation of nano-pesticides will be specific in action against insects and does not have any harm to other important insects of soil (Kah *et al.,* 2013).

Nano-sensors

The crops growth depends on proper agro-climatic conditions. For effective protection of crops, the fast and sensitive sensors are required to detect plant pathogens. Nano-sensors can be use all over the agricultural fields for monitoring the fertility of soil and other agro climatic conditions (Alfadul *et al.,* 2017). Such measures will lead to

enhanced crops yield at very low economy (Rai and Ingle, 2012). Researchers are working on nano systems for the release of fertilizers and pesticides as per agro-climatic conditions monitored by nano-sensors.

Nanotechnology is an eco-friendly and cost effective technology for agriculture. It offers several benefits in agriculture such as detection of pathogens, delivery of nano-pesticides to the specific target sites, and enhanced absorption of nutrients in plants. The applications of nanotechnology have great potential to meet out the future agricultural challenges such as food security.

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