Science Academique

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Popular Article

Nanotechnology Based- Sustainable Agriculture: Scope and Applications

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Citation: Paul S, Kumari P, Kumari G, Sahu PK, Singh UB, et al. (2022) Nanotechnology Based-Sustainable Agriculture: Scope and Applications. Sci Academique 3(1): 12-15

Received: 11 March, 2022; **Accepted:** 25 March 2022; **Publication:** 28 March 2022

Abstract

Due to low agricultural production, degradation of natural resources, significant post-harvest losses, little or no value addition, and population surge, ensuring food security in developing nations is extremely difficult. Researchers are attempting to incorporate modern technology in order to boost supply and minimize the gap between production and consumption. Nanotechnology is one of the most promising technologies that could boost agricultural productivity by developing nano fertilizers, using more efficient herbicides and pesticides, regulating soil characteristics, managing wastewater, and identifying diseases. Nanotechnology has the potential to have a positive impact on the agri-food sector, reducing the negative effects of agricultural practises on the environment and human health, increasing food security and productivity and promoting social and economic equity.

Introduction

Agriculture is the economic backbone of developing countries, providing food for a better living. This sector is currently experiencing a number of issues, including unexpected climate change, soil pollution from different devastating environmental contaminants such as fertilizers and pesticides, and, most importantly, rising food demands due to escalating population worldwide [1]. In the current situation, meeting the nutritional requirements of the world's fast-growing population is a major concern. Pest infestations, microbiological attacks, natural disasters, poor soil quality, and nutrient availability all cause harm to almost one-third of crops grown conventionally. Sustainable and profitable agriculture is the need of hour.

Hence, in the modern, it is imperative to develop novel technology that will enhance production while reducing food waste in order to maintain the country's sustainable living standards and improve food security. As a result, one step that has been taken is the introduction of nanomaterial (NM)-based products to revolutionise present agricultural techniques. Due to their enormous surface area–to–volume ratio and new physicochemical features, these materials have a high reactivity, allowing for easy change in response to rising demand. Nanotechnology has the potential to produce foods of outstanding quality in a highly

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practical form while also increasing nutrient bioavailability. The use of NMs in agriculture aims to boost yields by reducing nutrient losses, reducing the number of products used for plant protection [2], and lowering production costs to maximise output.

Applications of Nanotechnology in Agriculture

Stimulation of plant growth

Carbon nanotubes and Au, SiO_2, ZnO, and TiO_2 nanoparticles can help plants develop better by increasing elemental intake and nutrient utilisation [3]. The true influence of nanomaterials on plants, however, is determined by their composition, concentration, size, surface charge, and physical chemical properties, as well as the plant species' vulnerability.

Boost agricultural productivity

Nano particles play a very important role in agriculture by enhancing the production of crops. Slow-release or chromium fertilizers based on nanotechnology have the potential to improve nutrient uptake efficiency. Engineered nanoparticles can help to solve the long-standing problem of moisture retention in arid soils and improve crop yield by boosting nutrient availability in the rhizosphere. The use of Nano fertilizer increases element efficiency, reduces soil toxicity, and reduces the frequency of fertilizer application, to at least reach the negative consequences produced by excessive fertilizer use. Foliar application of zinc oxide (20 mgL^{-1}) nanoparticle solution on tomato showed enhanced growth and biomass production as compared to untreated plants [4]. The favourable effect of zinc oxide nanoparticles on tomato plants suggests that they could be used as a future nano fertilizer.

Detection of plant pathogens

Nanotechnology can be utilized as a quick diagnostic tool or a biomarker against a variety of plant pathogens, and they can be used either directly or indirectly for pathogen detection or as a disease indicator. Using surface plasmon resonance, AuNP-based immunosensors were used to detect Karnal bunt (*Tilletia indica*) disease in wheat [5]. *Xanthomonas axonopodis* pv. *vesicatoria*, which causes bacterial spot disease in Solanaceae plants, was detected using fluorescence SiNPs in combination with Ab [6].

Post-harvest management

Nanotechnology play a vital role in post-harvest management of horticultural crops by minimizing post-harvest losses and enhancing the quality of produce. Nano-ZnO, nano-silicon, and nano-$CaCO_3$ are currently employed in post-harvest fruit preservation. The effect of a chitosan coating containing 1% chitosan and 0.04% nano-silicon dioxide on the qualitative properties of harvested jujube at ambient temperature was studied by [7]. They reported that the titratable acidity, vitamin C content was higher in the fruit coated with nano-CaCO3 than the fruit coated with chitosan.

Mitigation of abiotic stress

Plants benefit from NPs because they help them grow while also protecting them from abiotic stress. Because of its huge surface area and small size, toxic metal binds to the surface of the NP, decreasing its availability. Drought, salinity, alkalinity, temperature variations, and mineral and metal toxicity are all examples of abiotic stress. NPs can mimic the activity of antioxidant enzymes in the form of nano-enzymes that may protect the plants from oxidative stress [8].

Mitigation of biotic Stress

Plant performance is also harmed by various biotic stresses such as microbes and pests. Plants are protected from pathogen invasion and insect- pest attack by using engineered metal nanomaterials such as Ag-based nanoparticles, Cu-based nanoparticles, Ce-based nanoparticles, and even C- and Si-based nanoparticles. Furthermore, they reduce the number of toxic substances released into the

environment. As a result, this technology aids in the reduction of environmental pollutants. The vast surface area given by small nanoparticles, in particular, makes them appealing for addressing difficulties that are not addressed by physical, chemical pesticides, or biological control approaches [9].

Heavy metal remediation

Heavy metal pollution in soil has resulted from the intensification of agricultural land usage and changes in farming practices, as well as technological advancement. Metal/metalloid concentrations in soil are rapidly rising, posing a threat to plant growth, food safety, and soil microbiota. Nanotechnology has emerged as a promising method in the decontamination of heavy metals in recent times. Heavy metal removal is a hot topic in research, and nanomaterials have a special affinity for heavy metal adsorption as well as a large surface area Figure 1.

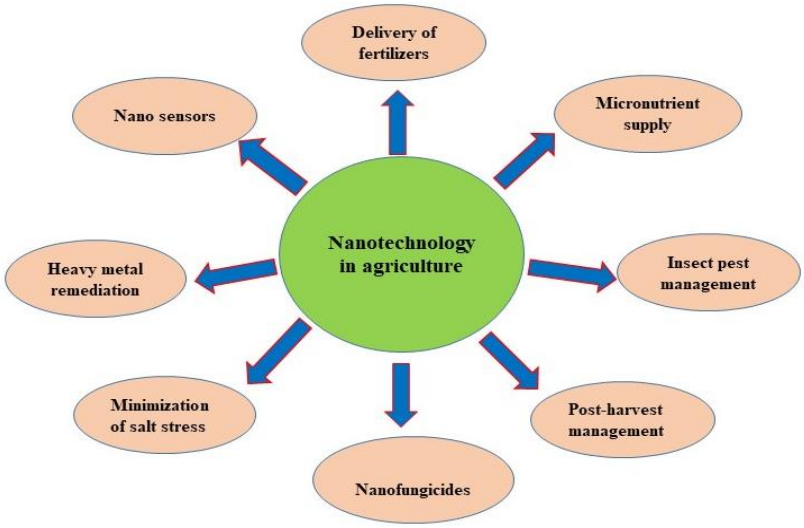

Figure 1: Applications of Nanotechnology in Agriculture.

Conclusion

In view of the great challenges we are facing, particularly as a result of population explosion and climate change, nanotechnologies and the use of nanomaterials in agriculture have the potential to make a significant contribution to addressing the issue of sustainability. Additionally, it is crucial to involve all stakeholders in an open discourse, including non-governmental and consumer organisations, in order to gain consumer acceptance and public support for this technology.

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