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Nanotechnology in Agriculture: Mini Review

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Abstract

In order to increase agricultural yields, new technologies are frequently used in agriculture. Using nanoparticles in farming, known as nano-agriculture, can provide crops with a number of advantageous impacts. Potential new uses in biotechnology and agriculture are made possible by the advent of nanotechnology and the creation of new nanomaterials and gadgets. Materials that fit into the nanometric range and have at least one dimension less than a few hundred nanometers are referred to as nanoparticles. These substances would discharge fertilizers or insecticides at predetermined times and locations. Chemical discharge into the environment and harm to other plant tissues may be minimized by using nanoparticles labelled with agrochemicals or other compounds. The important function that nanoparticles play in plants is highlighted in this review. Furthermore, nanoscience offers fresh perspectives that help us comprehend the most effective way for nanoparticles to function in plants. Better plant growth and development result from the proper understanding of the physiological, biochemical, and molecular mechanism of nanoparticles in plants.

Keywords: Agricultural; Nanoparticles; Nanotechnology

Abbreviations: OFRS: Oxygen Free Radicals; NPS: Nanoparticles.

Introduction

The biggest interaction between humans and the environment is agriculture, which also contributes significantly to ecosystem degradation and climate change. Specifically, the usage of fertilizer causes the pools to undergo significant modifications. In contemporary agriculture, fertilizer is widely used to enhance crop yield and food quality, to encourage plant development, and to supply soil nutrients. As a result, the use of fertilizers to agricultural areas has a significant impact on crop productivity and global food security. Thus, coordinated research and technological development are needed for the selection and implementation of goals in stressed ecosystems [1].

The majority of countries' economies are based mostly on agriculture, which is also seen as the primary driver of globalization, industrialization, and progress. Although agriculture has come a long way in recent decades, it still has to grow sustainably in order to feed the world's growing population. The use of large amounts of pesticides and fertilisers in conventional agriculture has had a negative impact on ecosystems and living things alike. Agrochemical usage should be kept to a minimum in sustainable agriculture as a fundamental principle to protect the environment and preserve different species. Furthermore, low input 16 systems with reduced production costs and better net yields are ideal for sustainable agriculture. The usage of pesticides has serious repercussions in both industrialised

and underdeveloped nations [2]. The long-term preservation of natural resources and agricultural output with the least amount of negative environmental effect is the goal of sustainable agriculture. Chemicals included in pesticides have the potential to cause oxidative stress, which can result in the production of free radicals and changes to antioxidants or enzymes that scavenge oxygen free radicals (OFRs). The use of synthetic or fumigant insecticides in shops to control pests and protect plants typically results in the development of pest resistance [3].

Recent years have seen a sharp increase in interest in nanotechnology because of its numerous uses in fields such materials science, health, pharmaceuticals, energy, and catalysis. These nanoparticles, which range in size from 1 to 100 nm, may find use in industry, medicine, and agriculture. Researchers have worked hard to create nanoparticles using a variety of techniques, such as chemical, biological, and physical ones. Comprehending the pathophysiological processes of complex biological systems remains a formidable obstacle. Biological systems are made up of hundreds of thousands of difficult-to-identify genes and proteins, whose behaviour is challenging to connect, comprehend, and forecast. Synthetic biology is a new approach that may be used in addition to standard approaches. Additional research is necessary to identify the most suitable treatment strategy for each of the disease's individual processes that operate at the beginning, middle, and advanced phases [4-7].

Nanoparticles (NPs) are used in imaging and diagnostics due to their optical scattering capabilities, and in numerous therapeutic applications due to their photothermal properties [8,9]. Using cell-specific compounds (peptides, antibodies) linked to NPs and connecting to cognate receptors at the membranes of particular target (diseased) cells improved the situation. Currently, the most common methods for applying fertilisers, herbicides, antibiotics, and nutrients to agricultural soil and plants include spraying or soaking them, or giving animals feed or injections. Pesticides and medications are either delivered as "preventative" therapy or after the disease-causing organism has grown and the plant is exhibiting symptoms. In this regard, nanotechnologies provide a fantastic chance to create novel pest-repelling solutions. Through improvements in patient adherence, safety, efficacy, and cost-efficiency, nanotechnology raises their acceptability and performance. It is envisaged that nanoscale devices would be able to identify and cure infections, nutritional deficiencies, and other health issues well in advance of macroscale symptoms. With a better understanding of the risks involved in using synthetic organic pesticides, this kind of therapy might be applied directly to the afflicted region. It has become imperative to look at appropriate substitute solutions for pest management. The discipline of Diagnostics was revolutionised by the wide use of Molecular Biology [10].

Scope and developments of Nanotechnology in India

Scope

Since agriculture makes up the majority of India's economy and there is a huge population to feed, applications of nanotechnology in the food and agricultural sectors are particularly relevant and important. This raises severe concerns about food security. The diversity of soils and agroclimatic conditions, which in turn leads to crop diversification and production fluctuations, are further characteristics of the Indian agricultural scene. This presents both opportunities and difficulties for the industry [11].

- The majority of industrial and agricultural processing and packing creates environmental concerns that, if left unchecked, may exacerbate long-term ecological issues like global warming.
- India is urbanizing fast but still faster is the level of pollution because of urban waste, untreated water etc.
- The agricultural sector provides employment for 60% of India's population, yet productivity is low due to cheap inputs, pests, illnesses, and losses. As a result, income levels are low.
- India gets excellent solar radiation, every roof top can become a power house, but solar energy is not generated because right and affordable technology is not in place.

Developments

With over a billion people, a vast terrain, and a varied socioeconomic basis, India has enormous opportunities for any kind of technological intervention, including nanotechnology. India has been sluggish to experiment with new technology and to accept them. This has mostly occurred as a result of people, institutions, and governments having poor risk-taking abilities. Furthermore, there has been little faith in the inventions due to a lack of connection with the outside world. In India, nanotechnology is being pushed by the general public. Participation from the industry is quite new. With very few exceptions, most nanotechnology research and development is carried out in research organisations and universities that receive public funding [12].

Applications of Nanotechnology in Indian Agriculture

Important connections between nanotechnologies and the science and engineering of agriculture include disease treatment delivery systems, new tools for molecular and

cellular biology, new materials for pathogen detection, and environmental protection.

Nanotechnology has the potential to provide extremely early diagnosis and eradication since it functions at the same scale as a virus or disease-infecting particle. The potential for "Smart" therapy delivery systems to be triggered well in advance of the onset of macro symptoms is presented by nanotechnology. One example of a smart therapy delivery system would be a tiny implanted device that collects saliva samples from the animal on a regular basis. The integrated sensing, monitoring, and regulating system might identify the sickness long before a fever appeared, alert the farmer, and turn on bioactive systems including medications, insecticides, nutrition, probiotics, nutraceuticals, and implantable cell bioreactors.

Nano Fertilizer

Up to 35–40% of agricultural output is derived from fertiliser, making it a crucial component of production. The greatest solution to address the long-term issue of eutrophication may be nano fertiliser, which improves nutrient usage efficiency. In addition to reports that nano fertiliser is more effective than regular fertiliser, attempts have been made to synthesise nano fertiliser in order to control the release of nutrients based on crop requirements [2].

In Nano fertilizer technology, the primary factors that led to India's increased food grain output from 55mt in the 1960s to 254mt in 2011—which coincided with a remarkable rise in fertiliser usage from 0.5mt to 23mt, respectively—were fertilisers, high-quality seed, and irrigation. Fertiliser has a definitively shown impact on crop productivity, accounting for around 35-40% of total yield. The Indian government is extensively subsidising the cost of fertilisers, especially urea, given their significance. As a result, there has been an uneven distribution of fertiliser and, in certain places, excessive nitrogen application has caused nitrate contamination of groundwater. The usage efficiency of N, P, and K fertilisers have stayed steady over the past few decades at 30–35%, 18–20%, and 35–40%, respectively. This has allowed a significant amount of additional fertilisers to build up in the soil or seep into aquatic systems, where they can cause eutrophication. It's critical to develop a multipurpose fertiliser formulation based on nanotechnology to solve problems with poor fertiliser usage efficiency, uneven fertilisation, multi-nutrient shortages, and the reduction of soil organic matter. Although incredibly creative, there is little information on nano-fertilizer technology in the literature. On the other hand, a number of publications and patents provide a compelling case for the broad potential in creating nano-fertilizers. Application of nanoparticles as fertiliser on leaves has resulted in a notable rise in yields. It was demonstrated that in a dry environment, 640 mg ha-1 of foliar application of nano phosphorus (40 ppm concentration) produced 80 kg ha-1 P equivalent yield of cluster bean and pearl millet. Research is now being done to create nanocomposites that can distribute all the necessary critical nutrients in an appropriate amount using a smart delivery mechanism. Based on preliminary results, nanotechnology may be able to accomplish balanced fertilization [11].

It is necessary to determine how metals, such as micronutrients, that are administered as nano-formulations by foliar and soilborne application or in other ways, are metabolised inside the plant biomass. Furthermore, careful consideration must be given to the nanocomposites that are being considered as a way to distribute all the nutrients in the proper amounts using "smart" delivery methods. Because 50–70% of the nitrogen provided by traditional fertilisers is lost during application, the efficiency of nitrogen usage is currently poor. By boosting plant absorption, innovative nutrient delivery methods that take use of the porous nanoscale portions of plants may be able to decrease nitrogen loss.

Nutrient intake can be enhanced by fertilisers enclosed in nanoparticles. The nutrients in the next generation of nano fertilisers can either be delivered at a particular moment or in response to an environmental event. In cluster bean and pearl millet grown in a dry climate, foliar application of nanophosphorous fertiliser (640 mg ha-1) and soil application of phosphorous fertiliser (80 kg ha-1) produced equivalent yields.

Nanosensors

Biosensors have been present since glucose monitors were made commercially available in the 1970s, but the field of biosensors has not benefited from the laboratory research and many research papers that have been produced on the subject.

The use of nanoscale materials in electrochemical biosensors has increased dramatically as a result of their great sensitivity and quick reaction times. In these applications, the creation of robust and well-structured electrode materials for biosensor platforms requires the efficient immobilisation of biomolecules without compromising bioactivity. The created biosensor system is a perfect instrument for online pesticide and nerve agent monitoring of organophosphate compounds. In agriculture and food systems, bioanalytical nanosensors are used to identify and measure trace levels of pollutants such as bacteria, viruses, toxins, and biohazardous materials. The majority of these poisons' analyses are still carried out with traditional techniques; however biosensor techniques

are now being developed as screening instruments for analysis in the field [13].

Seed Technology

The most crucial component in determining a crop's production is its seed. Traditionally, seeds are sent to farmers for planting after being examined for germination. Even though seed testing is conducted in state-of-the-art laboratories, the lack of moisture in rainfed environments makes field reproduction of the tested seed difficult. Since rainfed agriculture accounts for more than 60% of the net area cultivated in India, developing solutions for rainfed agriculture makes sense. In an effort to increase the germination of crops that are rainfed, a team of researchers is now working on carbon nanotubes and metal oxide nanoparticles. According to Khodakovskaya [14] tomato seed germination can be enhanced by using carbon nanotubes to improve moisture penetration. According to their research, carbon nanotubes (CNTs) transport water from the substrate into the seeds by acting as new holes for water permeation caused by seed coat penetration. These procedures speed up germination, which rainfed agricultural systems may take advantage of. By improving moisture penetration, the use of carbon nanotubes promotes germination.

Nano Pesticides

The use of pesticides during the early stages of crop growth aids in keeping the number of pests below the level of economic threshold and provides longer-lasting, effective control. Therefore, one of the most practical and affordable ways to get rid of bug pests is to employ active substances on the applied surface. Utilising a nanotechnology method called "nano-encapsulation," the active component may be shielded from unfavourable environmental conditions and given more persistence. This will increase the insecticidal value. A thin-walled sac or shell (protective covering) enclosing nano-sized particles of the active substances is known as nano encapsulation. A number of research studies on the encapsulation of pesticides have been released recently. Insecticides, fungicides, or nematicides can be nanoencapsulated to create a formulation that effectively controls pests without causing residues to build up in the soil [15].

Impact of nanoparticles as plant growth enhancers: In addition to NPs intended for interaction with plants, the latter are also subjected to extensive human manipulations that unintentionally add a spectrum of engineered NPs (ENPs). The various routes that engineered NPs can acquire to reach the plants include direct application, release via accidents, contaminations in soil, sediments or water, and atmospheric outcomes. Plants are one of the fundamental components of the environment and perform essential functions in maintaining equilibrium across the ecosystem including the food chain and food web through the translocation of minerals and nutrients. Higher plants work in network with their soil, water, and environmental chambers supporting NPs through all the specified routes.

Despite the fact that research on plant-NP interactions has been conducted, their influence on the general growth of plants has not been clearly defined. According to reports, under certain growing conditions, plants may absorb different necessary and non-essential elements in varying amounts, above which they may represent harmful dangers to the plants. Regarding the effect of NPs on plants, scientists throughout the world are split into several camps. A growing body of research demonstrates that NPs can have both harmful and helpful effects. For instance, Canas JE, et al. [16] found that whereas tomato root length decreased across the same size range, SWCNTs lengthened the roots of cucumber and onion.

Conclusion and Future Aspects

Although NPs have advanced to state-of-the-art levels in the field of nano-technological applications, their uses in agriculture and crop development are still in the early stages. To fully take use of the benefits that NPs are supposed to offer, we need to improve our comprehension of about the relative phytotoxic features and their characterisation in relation to plant-NP interactions. How to distinguish between the modes of NP uptake and translocation by plants is still a significant issue. On the basis of growth conditions, plant species, and the size and concentration of NPs, several approaches have been suggested, but the outcomes have varied. Investigating the NPs' uptake kinetics in relation to particle size, agglomeration, and compositions becomes crucial as a result. Another strategy to be considered is their transport, accumulation, and biotransformation in various plant sections. A growing body of research points to the potentially harmful consequences of NPs; nonetheless, by altering their surface, some favourable effects have been observed. This review clearly explained about the Nanotechnology can be utilised in agricultural goods to preserve plants, monitor growth, and identify infections. Researchers are exploring novel applications of nanotechnology in agriculture and the food business. The agriculture and food industries are expected to undergo significant positive developments in the next years.

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