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Role of Nanotechnology in Precision Agriculture †

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Abstract: Nanotechnology is an interdisciplinary study field that attempts to boost agricultural output through substantial nanotechnology. This study has been conducted because of the reckless use of pesticides and synthetic fertilizers brought on by the green revolution, which has diminished soil biodiversity and increased disease and insect resistance. Only nanoparticles or nano chips can produce sophisticated biosensors for precision farming and deliver ingredients to plants in a nanoparticle-mediated manner. The precise distribution of nutrients and agrochemicals to plants is made possible by nano-encapsulated versions of conventional fertilizers, insecticides, and herbicides. Nanotechnology-based tests for detecting plant viral diseases are also gaining popularity and are useful for making a rapid and accurate diagnosis of viral disorders. The advantages and future uses of nanotechnology in precision agriculture are covered in this article. Modern technologies and methods based on nanotechnology can solve many issues in traditional agriculture and could revolutionize this industry.

Keywords: precision agriculture; nanotechnology; nanoparticles; nanomaterial

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1. Introduction

Precision agriculture (PA), which has several potential advantages in productivity, crop quality, profitability, sustainability, environmental protection, food safety, on-farm quality of life, and rural economic development, is revolutionizing agriculture all over the world. PA has become a crucial part of the strategy to accomplish this aim [1]. Nanotechnology is already widely used in modern agriculture, and precision agriculture is now a reality. Nanotechnology includes particles with dimensions of 100 nm or lower. Nanomaterials are used in the protection of plants, and in feeding and farming technique management because of their small sizes, high surface areas, and distinctive optical properties [2]. Plants react differentially to the nanoparticles regarding growth and metabolic activities. Nanoencapsulation is crucial for environmental protection because it stops hazardous substances from evaporating and leaking into the environment. To solve this problem, more effective, non-persistent insecticides must be developed, such as controlled-release formulations [3].

2. Examples of Nanoparticles

The production of nanoparticles from several biological sources has been exploited in agriculture for precision farming [4]. Here are some examples of these nanoparticles:

- Silver nanoparticles: When compared with commercial silver, silver nanoparticles have a higher antibacterial impact because of their large surface area and atoms. A wide

variety of human diseases have been targeted by silver nanoparticles' antimicrobial properties [5]. As a result, there is increased interest in using silver nanoparticles' antibacterial properties to manage plant diseases [6].

- Zinc oxide nanoparticles: In alkaline soils containing calcium carbonate, zinc insufficiency is a prevalent micronutrient issue, negatively affecting agricultural productivity. To remediate the zinc shortage in soils, zinc fertilizers, such as zinc sulfate and zinc oxides, are often utilized.
- Titanium dioxide nanoparticles (TiO_2): Titanium is a sturdy metal that resists corrosion [7]. Titanium increases the formation of more carbohydrates, which promotes plant development and increases the rate of photosynthesis [8].

3. Nanotechnology and Its Role

- Fertilizer delivery: The massive volumes of fertilizers delivered have greatly enhanced yield but they also harm healthy soil microbiota. Run-off and pollution make fertilizers unavailable to plants. This issue can be resolved with nanomaterial-coated fertilizers (Figure 1).

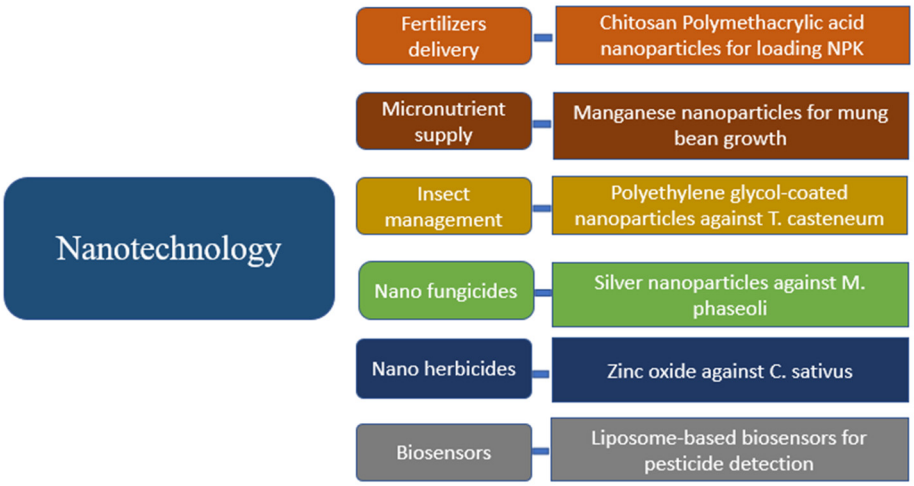

Figure 1. Role of nanotechnology.

- Micronutrient supply: Micronutrients, including zinc, iron, manganese, boron, copper, molybdenum, etc., are known to be crucial for growth and development. The green revolution's significant increase in crop yields and new agricultural techniques have led to a steady decline in soil micronutrients, including zinc, iron, and molybdenum. Micronutrient treatment on the leaves can improve absorption. Nano formulations of micronutrients can be applied as a spray to plants or added to the soil for root absorption to improve soil quality and strength [9].
- Insect pest management: Although synthetic agrochemicals have transformed agriculture, they have also created a new problem, namely insect pest resistance. For the control and supervision of insect pests in contemporary agriculture, nanoparticles hold enormous potential. PEG-coated nanoparticles have improved the insecticidal efficacy of garlic oil against Tribolium castaneum (the red flour beetle).
- Nano fungicides: Crop fungus infections significantly reduce crop productivity. Although there are several commercially accessible fungicides, their usage harms plants as well. Nanotechnology has significant potential to help with this issue. Antifungal drugs made of nanoparticles have been tested against harmful fungi. Silver nanoparticles showed a stronger antifungal impact with lower concentrations than titanium dioxide and zinc oxide nanoparticles [10].
- Nano herbicides: The largest challenge to agriculture is weeds, which reduce agricultural productivity by consuming nutrients that would otherwise be available to crop plants. Nano herbicides can play an influential role in the environmentally

benign removal of weeds from crops. Environmental safety is also achieved by the encapsulation of herbicides in polymeric nanoparticles [11].

- Biosensors: Utilizing computers, sensors, remote sensing tools, global positioning systems, and precision farming to locate environmental variables to ascertain if crops are growing as efficiently as possible or accurately pinpoint the type and location of issues.

4. Conclusions

When it comes to agriculture and agri-tech, nanotechnology is the key that unlocks the next revolutionary step. It has the potential to improve agricultural output while simultaneously fostering a more harmonious connection between chemical use and environmental equilibrium. Therefore, it has the potential to be employed as a state-of-the-art technology to assist in solving global hunger issues in the not-too-distant future. Several scientists believe that high-tech farms equipped with nanotechnology's smart nanotools will allow for greater productivity with fewer resources invested. It encourages the development of novel, effective agrochemicals for plants, such as nanofertilizers and nanopesticides, which help sustainably smart agriculture by inhibiting plant diseases and preventing crop failure.

5. Future Outlooks

- The use of nanotechnologies in agriculture could make a significant contribution by addressing the issue of sustainability and climate change;
- In reality, the use of nano-scale transporters and chemicals can improve the efficient use of pesticides and fertilizers, lowering the quantity that must be sprayed while maintaining yield;
- Nanosensor technologies can promote the spread of precision agriculture and have an influence on waste reduction, leading to both the reuse of waste and more production;
- To obtain consumer approval and support for this technology, it will be crucial to involve all stakeholders, consumer groups, and non-government sectors in an open discussion.

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