The Production of Nanotechnology in Agriculture

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Nanotechnology has an extensive series of applications in agronomy and has an important role in the future of sustainable agriculture. The agricultural industries should be supported by innovative active materials such as nanofertilizers, nanofungicides, and nanopesticides.

Keywords: nanofertilizer ; nanosensor ; nanopesticide ; nanoproducts ; nanotechnology ; agriculture

1. Introduction

Nanotechnology is considered the potential solution for solving various agricultural problems. It has received more attention in the last few decades. This leads to the development of a new and unique method of farm production for improving agricultural productivity [1]. It provides new agronomical agents with a delivery method to improve crop yield. Nanotechnology increases agricultural productivity through various delivery agents like nanopesticides, nanofertilizers, nanofungicides, nanoherbicides, and nanosensors for the identification of disease in crops, genetic engineering, plant monitoring, animal health monitoring, post-harvest production management, etc. [1]. Nanotechnology is also utilized to improve crop health without causing damage to the soil. It also reduces nitrogen lost due to leaching and soil microorganisms. NPs afford 'magic bullets', which comprise chemicals, and herbicides or genes that target specific crop components for the proclamation of their content. Nanocapsules are very helpful in the effective dispersion of herbicides over the cuticles and tissues in plants via the deliberate and steady proclamation of the dynamic materials, spot-targeted distribution of several macromolecules required for enhanced plant disease resistance, effectual nutrients application, and improved plant growth [2].

Nanosensors (nano-based delivery systems) will possibly facilitate the effective utilization of agronomic natural resources such as nutrients, chemicals, and water over precise agricultural practices. The farm managers could gain the ability to distantly sense the infecting insects or facts of stress levels like drought with the help of nanomaterials and universe allocating arrangements through satellite imaging of the field [3]. Once the crop is found to be affected by pests or the soil is in drought conditions, the automatic modification of insecticide applications or an irrigation point scan be completed. It also perceives the occurrence of plant diseases and the level of nutritive components in the soil. The nano-encapsulated deliberate proclamation of fertilizers tends to store fertilizer utilization and reduce ecological contamination [4].

2. Nanoproducts

2.1. Nanofertilizer

Nano- and biofertilizers, which are more effective and environmentally friendly than the outmoded chemical fertilizers, are now an important part of agriculture [5]. Nanofertilizers will considerably help us reduce urea consumption, cut urea imports, and lower the cost of urea subsidies by improving nitrogen usage efficiency [6]. Nanofertilizers deliver nourishment in a regulated manner in response to a variety of cues, such as heat, moisture, and other abiotic stresses. With the help of various chemical, physical, mechanical, or biological procedures, nanofertilizers are created, or modified versions of traditional fertilizers, bulk fertilizer ingredients, or derivatives of various vegetative or reproductive portions of the plant [7]. Nanofertilizers are thought to be a cutting-edge strategy for preserving nutrients, particularly nitrogen, as well as the environment [8]. They are used to improve the fertility and productivity of the soil and the quality of agricultural output [9]. In nanoscale polymers, the release of nutrients and growth stimulants is controlled, gradual, and efficient [10]. Nanofertilizers have high surface areas and particles that are smaller than the pores of plant roots and leaves to promote penetration into the plant from the applied surface and increase uptake and efficient use of nutrients [11]. When the particle size of the fertilizer is reduced, the specific surface area and particle density increase, giving nanofertilizers more surface area to interact with and increasing nutrient penetration and uptake [12]. Nanofertilizers increase the availability of nutrients to growing plants, which improves plant growth overall by increasing the production of dry matter, chlorophyll, and photosynthesis [13]. The low cost of natural zeolites and the recent increase in public awareness of the phenomenon have evoked significant economic interest in the development of zeolite-based nanofertilizers [14]. Numerous studies have shown that nanofertilizers improve crop growth, yield, and quality, resulting in a higher yield and higherquality crop product for animal and human consumption [15][16][17][18]. Nutrients from nanofertilizer are transported and delivered to cells more efficiently through 50–60-nm-wide nanoscale passageways between cells. Nanofertilizers have increased cuticle absorption and are more soluble and reactive, allowing for targeted administration and control [19].

Copper belongs to the groupof metals recognized as trace elements. In general, these metals have high density and high atomic mass around a value of 20, which include metals like copper, zinc, nickel, and lead. Cu occurs through Cu^{2+} also Cu^{+}. It performs as a structural component in directing proteins and is one of the chief constituents in photosynthetic electron transport, oxidative stress, cell wall metabolism, etc. [20]. In plants, copper is one of the important elements for the manufacture of chlorophyll. Copper’s performance as a cofactor in enzymes includes superoxide dismutase (SOD), oxidation, polyphenol oxidase, plastocyanin, and amino oxidase [21]. Copper induces numerous enzymes and plays a role in RNA synthesis and the progress of the photosystems. It is an important component for plant growth and it is involved in several functional methods. It is a significant cofactor for metalloproteins [22]. Copper is essential for making biomass, chlorophyll production for photosynthesis, and the germination of seeds [23]. High-entropy-alloy NPs were found to be effective as nanofertilizes [24].

2.2. Nanopesticides and Nanofungicide

Nanopesticides have taken the place of traditional pesticides. Conventional pesticides deliver a nanoformulation with metal NPs or polymers, which is one of the most difficult areas of the pesticide industry [25]. Nanopesticide nanocomponents are quite small and additives that do not exist in conventional pesticides are typically very harmful in nanopesticides. The advantage of pesticide nanoencapsulation is the controlled and gradual release of the active component through manipulation of the nanocapsule’s outer shell, which delivers a small dose over a long period of time, reducing unwanted pesticide runoff. Nanopesticides have also improved plant pest and disease management [26]. To protect plants, the following nanopesticides are used: Ag, Cu, SiO_2, and Zn. Chemical pesticides and fertilizers increased food output significantly but at the expense of crop quality and soil fertility [27]. These nanopesticides increase solubility while decreasing soil runoff [28]. Target-specific nanopesticides should help to reduce non-target plant damage and the amounts of pesticides released into the environment. The nanomaterials used to make pesticides have a number of advantageous properties, including high stiffness, permeability, thermal stability, and biodegradability [29]. The use of pesticides is one of the most effective ways of protecting plants from insects, fungi, and weeds. To protect the environment and save non-target species, people must use natural and environmentally friendly pesticides as well as small amounts of chemical pesticides [30].

Copper is utilized as both a nanopesticide and nanofungicide. It is an imperative disease management device for both organic and conventional methods of cultivation. The pest-like arthropods include phytophagous insects and mites that destroy both the grown crops and stored agricultural products [31]. For instance, the red flour beetle *Triboliumcastaneum* is a pest that particularly affects the stored agricultural produce and foodstuff, damaging their quality and destroying them. This beetle also decreases the germination percentage of grains. Copper NPs have fungicidal and insecticidal activity against pests that affect the crop. Hence, they can be used as copper-based nanopesticides, nanofungicides, nanofertilizers, and nanoherbicides [32][33]. There are many other copper-based pesticides and fungicides such as copper ammonium complex, copper oxychloride, copper sulfate, copper hydroxide, and copper oxide [34]. The active form in all copper-based products is Cu^{2+} copper ions. Organisms like bacteria, fungi, algae, and molds that are sensitive to tiny amounts of copper ions have broad-spectrum activity against microorganisms. This occurs because of the interaction with nucleic acids that affect energy transportation, disruption of enzymes, and integrity of cell membranes [35].

Nanopesticides were developed to replace conventional pesticides [36]. The nanopesticide components in nanopesticides are extremely small and the additives in nanopesticides that are in common pesticides are often very toxic.

2.3. Nanoinsecticide

Among them, nanocapsules are by far the most popular method for releasing insecticides under control. It is also used to nanoformulate organic pesticides such as neem oil [37]. Food is a fundamental necessity for the world’s ever increasing population and, as a result, there is an ever increasing need to grow more food, prompting efforts to better protect agricultural crops from pest infestation. Polymer-based nanoformulations have been used to encapsulate the majority of pesticides. Nanoinsecticides have the following advantages over bulk substances: controlled release that increases the effectiveness of both natural and chemical insecticides, reduced rate of application, easy and safe handling, greater susceptibility to photodegradation, and lower toxicity to non-target organisms. Insecticides have been encapsulated in a wide range of polymer and non-polymer-based nanoformulations, including NPs [38]. Nanofibers, nanogels, nanospheres, micelles, nanoemulsions, and nanocapsules are all examples of nanomaterials [39]. The effective use of biodegradable polymers of natural origin rather than synthetic ones for encapsulation is a result of the current rise in environmental awareness. A commercial formulation of the pesticide bifenthrin is also used. These tests will establish a new benchmark for improved pesticide formulations capable of gathering plant-based systemic resistance. Synthetic pesticides may pollute the environment if used frequently due to their high residue levels. Because many insect pests are becoming resistant to insecticides, a new approach to pest control is also required.

2.4. Nanoherbicide

Herbicides are traditionally used to prevent the growth of undesirable weeds. Weeds planted alongside crops typically inhibit their growth [40]. Herbicide use may affect plant development and growth. Herbicides are a type of pesticide that is used to prevent or eliminate weeds. Herbicides can be injected into tissues and cuticles using nanocapsules, which have demonstrated delayed and continuous release of active ingredients. Herbicides that are more stable in the soil can reduce germination rates and fresh weights. Thus, pre-emergence herbicides with inhibitory effects that delay weed germination are desirable [41]. They are typically unaffected by conventional treatment, have high toxicity, and have a long half-life. Key nano-based materials, on the other hand, such as nanopolymers and nanoshells, have a wide range of scientific applications. Better soil motility, as revealed by the tobacco mild green mosaic virus (TMGMV), provides a potential platform for a medication carrier for agricultural applications. According to Santaella and Plancot [42], pesticides are delivered to plant parasitic nematodes using TMGMV as a nanocarrier. Carbon-coated AuNPs created via the simple heat treatment of intracellular biogenic NPs have been found to be an improved abiotic carrier for plant transformation [43].

Copper oxide NPs are utilized as nanoherbicides for controlling the weeds that affect plant growth. The copper-based nanoherbicides enter through the root, translocate in vascular bundles and to other parts like photosynthetic cells, and inhibit the glycolysis pathway and energy transportation through an electro chain that takes place in roots and parts of the plant. This affects the weed plant and causes starvation of the plant, reducingthe growth and development of the crops, which leads to the death of the crop [44].

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