The Application of Nanomaterials in Agricultural Field

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Abstract

Nanomaterials are considered as materials having external dimension of 1-100 nanometers. Nanomaterials can be formed naturally or as by-products of combustion reactions or directly designed for a particular purpose. These materials can differ in their physical and chemical characteristics from their counterpart. Nanomaterials of various sizes and shapes have been created as a result of recent technological advancements. These breakthroughs will serve as the foundation for future engineering to produce new properties tailored to particular applications. Nanomaterials have been used successfully and safely in a variety of areas in the past, including food production, environmental science and medicine. Nanomaterials have the capacity to improve pathogen identification, plant safety, seed growth and germination, as well as detection of the herbicide residue or pesticide, according to the preliminary research. This paper summarizes nanomaterials' agricultural applications and their potential role in future agricultural development.

Keywords: Agriculture, Germination, Nanomaterials, Nanoparticles, Nanotechnology.

Introduction

The important technical advancementhas been made in the field of agriculture in recent years to overcome the rising problems of sustainable development and food security. The use of natural and synthetic materials, such continuous agricultural advancements are vital in meeting the rising food demand of the world's booming population. Nanotechnology, in particular, has the ability to offer useful alternatives to a variety of agriculture-related issues. Nanoparticles are of considerable scientific importance because they cross the distance between bulk materials and molecular or atomic structures. A substantial amount of study has been done on nanotechnology in the past twenty years, with a focus on its various uses in the agriculture field. Fertilizer use is critical for increasing agricultural productivity; nevertheless, excessive application of fertilizer permanently changes soil chemistry and reduces the amount of available soil for agricultural production. In order to conserve the environment and save numerous species from extinctions, sustainable farming involves the use of as few agrochemicals as possible.

For instance, nanomaterials increase crop yield, enabling a controlled site-oriented delivery of nutrients with a restricted use of the agri-based input by improving the efficiency of agricultural input. Nanotechnology has actually skyrocketed, which may result in higher crop yields in plant protection items. Furthermore, a big challenge in agricultural development is allowing plants to respond more quickly to progressive climate change variables including high temperatures, water scarcity, alkalinity, salinity, and radioactive metal waste without endangering existing vulnerable habitats. Furthermore, in order to measure and monitor crop growth, soil, pest and agrochemicals, penetration and environmental degradation the production and usage of nanosensors in precision farming have dramatically improved. Sustainable agriculture and environmental systems are heavily influenced by the inspection and quality control, soil and plant health and protection. Nanomaterials engineering is a state-of-the-art field of science that contributes to the development of high-tech agricultural fields by developing a broader region which is crucial to the survival of agricultural systems over time. As a result, nanotechnology will not only minimize confusion, but also organize agricultural production management methods as a substitute to traditional methodologies. In some cases, agro-nanotechnology advancements have quick solutions to problems that plague contemporary industrial agriculture.

Materials with a particle size below 100nm in one dimension are characterized as materials. The combination of nanotechnology and biotechnology has greatly extended the range of applications for nanomaterials in a variety of fields. Nano-sized polymers and bio-composites nanomaterials based on carbon, metal, and metal oxide is being developed. Wastewater disposal, water purification, food processing as well as packaging, industrial and household use, environmental remediation, smart sensor production and pharmacy, are all examples of general applications for these products. The majority of these implementations have emphasized the importance of nanomaterials for increased performance and productivity. These products are also used in crop protection and agricultural processing.

Water disinfection, the food industry, non-point source emissions management, environmental waste disposal, and the construction of trace concentration monitoring systems arestudied in this paper. The use of nanomaterials in agriculture, on the other hand, is comparatively recent and requires further study. As a result, the discovery and implementation of novel nanomaterials in agriculture issummarized in this paper. The following are among the topics covered in this paper: germination and growth of plants, protection and processing, pesticide or herbicidal residues detection and pathogen recognition.

1. *Nano-Farming: AnInnovative Leading Edge inAgricultural Growth:*

Nanoparticle engineering is a recent technical advancement that demonstrates unusual focused characteristics as well as increased power. A professor named Norio Taniguichi, at Tokyo University of Science, invented the word "nanotechnology" in 1974[1]. Although Nanotechnology has been used for years in a number of fields, it is still a relatively recent technological breakthrough that nanoparticles (NPs) could be useful in agricultural production. Due to the progress in their manufacture the nanomaterials of different sizes and forms have a numerous applications in agriculture, medicine, food production and environmental science. Over the progress of history, agriculture has benefited from these inventions. In addition to this, nanotechnology has emerged as a potential application for accurate agriculture, because farmers face numerous and unknown thresholds, such as a decline in crop production as a result of biotic and abiotic stresses, nutrient shortages and pollution (Figure 1).

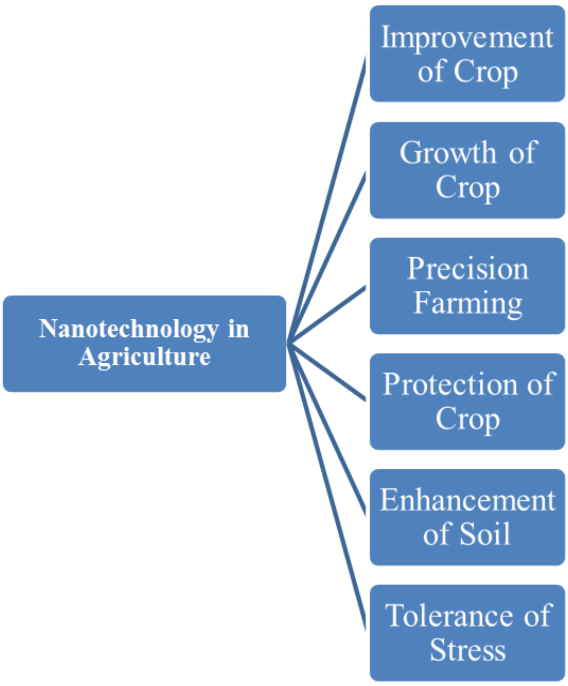

Figure 1: The Usage of Nanotechnology in Farming. Nanotechnology Has Emerged as A Potential Application for Precision Agriculture.

In recent years, the term "precision agriculture" or "farming" has become popular, referring to the innovation of wireless networking and sensor miniaturization for tracking, assessing, and regulating agricultural practices. It is linked to the site-specific plant management system, which includes a wide variety of farming pre- and post-production aspects, from plants to field plants. Recent developments in the engineering of tissues and the engineered selective delivery of CRISPR-associated protein (Cas), sgRNA and mRNA for genetic modification

(GM) of the seeds have been notable scientific achievements. Nanotechnology also offers outstanding solutions to a growing host of environmental problems. The production of nanosensors, for example, has a lot of promise for tracking environmental stress and developing plants' disease-fighting abilities. As a consequence, continuous progress in nanotechnology, with an emphasis on problem identification and collaborative approaches to sustainable agricultural development, has the capacity to deliver substantial social and equal value.

2. *Plant Growth and Germination:*

The scholars have been reviewing the impression of nanomaterials on development and plant germination in recent years in order to encourage their use in the applications of agricultural field. Zheng et al. analyzed the properties of Nano as well as non-Nano TiO_2regarding development of naturally-aged seeds of spinach [2]. Over the course of a 30day germination cycle, seeds treated with Nano-TiO_2 provided plants with three times higher photosynthetic rate, 73% more dry weight, and 45% more chlorophylla formation than control seeds. The scale of the nanomaterials had an inverse relationship with the rate of growth of spinach seeds, meaning that the larger the size of nanomaterials leads to increase in germination process. A major clarification for the augmented growth rate may be due to photo-sterilization as well as photo-generation of active oxygen such as superoxide and hydroxide anions by Nano-TiO_2, that improves the resistance of seed stress and promote piercing capsules designed for oxygen intake and water required to enhance germination process. The scholars approved that TiO_2Nano-sizes might boost the absorption of inorganic nutrient and accelerate organic material breakdown, resulting in an increase in photosynthetic rate, leading to oxygen-free radicals generated during photosynthetic processes.

Increased seed germination rates are important for penetrating nanomaterials into the semis. Multi-walled carbon nanotubes (MWCNTs) have been found to penetrate tomato seeds and to increase their germination rate through increased seed water absorption [3]. In just 20 days MWCNT's seed germination and plant biomass increased by up to 90 percent. The authors however underlined the importance of a further study on the tolerance of carbon nanotubes germinated tomato plants and their toxic effects on other field plants before direct use in this ground. The consequence of metallic nanoparticles on lettuce germination is analyzed, as shown by the root shooting ratio and seedling growth, and nanoparticles have positive effect on seed germination. Many scholars have tried to find out whether the nanoparticles have some impact on soil microorganisms, but they couldn't find something definitive.

Nanoparticles have both positive as well asadverse effects on plants. The phytotoxicity of nanomaterials used in seed germination is one of the issues. Phytotoxicity levels is varied on the basis of Nanomaterial types and its intended application. It is observed that the potential of photostable Cadmium-Selenide (CdSe) and fluorescein isothiocyanate-labeled silica nanoparticles quantum dots to functions as biolabels and enhances the germination of seed. The nanoparticles of FTIC-labeled silica were found to cause germination of seed in corn, on the other hand quantum dots stopped it.

Lin and Xing studied Nanomaterial phytotoxicity as well as its effect on rates of germination in canola, radish, rapeseed, ryegrass, corn, cucumber and lettuce [4]. The germination at 2000 mg/L were inhibited by higher Zn and ZnO concentrations in rye grass and maize. Nano-Zn as well as ZnO usage of 200 mg/L inhibited the root length of the plants under study. The phytotoxicity of both Nano-Al and Al_2O_3 has had a substantial effect on the elongation of root in ryegrass and rice, respectively.

The results of four oxide nanoparticles on the species of plant such as radish, tomato, rape, lettuce, cabbage, wheat, and cucumber were investigated by Ma et al. [5]. They discovered that root growth was influenced by nanoparticles and their concentration, similar to the study of Lin and Xing. Except for lettuce at a concentration of 2000 mg/L, it is observed that Nano-CeO_2 has little impact on the elongation of root in species of plant. However, at the same concentration, the three nanoparticles forms i.e.La_2O_3, Gd_2O_3, Yb_2O_3 had a major impact on root formation. Furthermore, the nanoparticles' inhibitory activity was observed at numerous phases of root development. The nanomaterials phytotoxic behavior must therefore be methodically understood in advance before implementing nanomaterials in the arena. Plant seedlings which are grown in a greenhouse, and later transferred to the field can be castoff as a way of protecting other species from phytotoxicity. Ornamental and specialty crops will benefit from this.

The Environmental Protection Agency (EPA) is debating the phytotoxicity and applicability of silver nanomaterials in agriculture. M. Murphey et al. finds out that silver is present in over 100 pesticides in arrears to its antimicrobial properties[6]. On the other hand poisonousness of Nano-silver to ecosystems and humans is a significant concern. According to Lu et al. silver with citrate-coated nanoparticles present in the shape of powder were phototoxic and genotoxic [7]. This may be due to the chemical transition of the spherical silver nanoparticle in the powder form to create silver ions or oxides. Surprisingly, coating nanoparticles of powdered silver with biocompatible polyvinylpyrrole reduced their photoxicity. Biocompatible coatings can increase the probability of use of nanomaterials to reverse plant germination and growth by exploring nanomaterial toxicity. The harmful effects on desired seed properties and nanomaterial efficacy of such coatings are also studied.

Oancea et al. concludes that the regulatory release in Nano composition composed of double layered hydroxides present in active plant along with other chemicals helps in the growth of stimulants [8]. In contrast, leading organic food certifiers reject the use of agri-foods based on nanomaterials as organic. Naturland and the IFOAM, both based in Germany, have been banning the food products labelling which are produced with the help of artificial nanomaterials and consider them as organic. The following issues should be discussed in nanomaterials future research work for the growth and germination of plants:

a. Unpredictability of nanomaterials' reactions to various species.

b. Phytotoxicity as a result of higher concentrations, and

c. Decreased photosynthesis as a result of larger nanomaterials.

3. Smart Delivery Options Enabled by Nanoparticles:

Nanotechnology is regarded as one of the most important developments of the twenty-first century, with the potential to advance conventional farming activities and provide sustainable production by enhancing management and recycling strategies and reducing agricultural input waste. Agrochemical and organic molecule delivery systems, as well as the transfer of DNA molecules or oligonucleotides into plant cells, are critical aspects of sustainable agricultural processing and precision farming. Agrochemicals are usually added to crops using standard techniques such as broadcasting or spraying. As a result, just a small percentage of fertilizers and pesticides reach crop destinations far below the minimum efficient concentration for plant growth predicted. Chemical leaching, hydrolysis, photolysis, and microbial decay are all factors that contribute to the losses. For example, the bioavailability of nutrients due to soil cheling, degradation of microorganisms, hydrolysis and runoff problems should be more carefully taken when applying fertilizer. The emphasis should be on the improvement of efficacy by spray drift control in pesticide applications. Recent nanotechnology synthesis of slow and controlled release fertilizers, herbicides, and pesticides has gained a great deal of interest in agriculture in order to guarantee environmentally sustainable agricultural activities. From laboratory studies, nanotechnology has advanced to practical applications with time span. In order to achieve the full biological skill while minimizing losses and negative effects, the aim of controlled distribution techniques is to release a regulated amount of necessary and sufficient agrochemicals over time. Because of their wide surface area, ease of binding and quick mass transfer, nanoparticles provide efficient agrochemical distribution. Micronic or submicronic particles are introduced into agrochemicals by a number of processes, including entrapment in the Nano-matrix of active ingredients, absorption, capsulation andweak bond attachments or surface ionic. In large scale growth, the encapsulation of potassium nitrate with graphene oxide movies greatly delays fertilizer release, which appears to be feasible at a low cost. Nanomaterials increase agrochemical stability and protect against oxidation and subsequent atmospheric release, resulting in better effectiveness as well as lower volumes of agrochemical.

Other than agricultural uses, the nanotechnology integration along with biotechnology opens up new avenues for gene modification and even the development of new species as new molecular transporter methods (Figure 2). Nano-biotechnologies, for example, use nanocapsules, nanoparticles, and nanofibres to transport chemicals and foreign DNA that help alter target genes. During the delivery of genetic materials, viral genetic delivery vectors face different obstacles, including a limited host selection, a limited injection size genetic material, cell membrane transportation, and nucleus trafficking. Recent breakthroughs in Nano-biotechnology give researchers more chances to fully substitute the genetic material of one animal with that of another. Nanoparticles with silicon dioxide have been formed in genetic engineering to transfer fragments of deoxyribonucleic acid (DNA) to targeted species such as tobacco and maize plants without having adverse side effects. Insect tolerant novel crop varieties are also developed using the NP-assisted delivery method. For instance, DNA coated NPs are used to bombard cells and tissues as bullets in gene-gun technology in order to transfer the requested genes to target plants. With an efficient ribonucleic acid (RNA) binding capability and the capacity for the pull of cellular membranes, a further plot of crop improvement that allows targeted, precise control of insect pests has been generated recently by the creation of SiRNA-entangled NPs. A new era of genetic engineering is beginning to improve the CRISPR/Cas single-guide RNA selective nanomaterial delivery. CRISPR/Cas is a prokaryote RNA-directed defense mechanism commonly used in plant genome processing. It includes repeat spacer arrays of CRISPR and proteins of Cas. However, the poor distribution reliability remains a significant impediment to its use. Nanomaterials, it turns out, could lessen off-target consequences with enhancing the precision and reliability of CRISPR/Cas systems.

4. *Detection of Pathogen present in Plants:*

The Smart field systems identify, diagnose as well as report pathogens, and later apply fertilizers and pesticides as appropriate before symptoms appear, according to the researchers. Although this research is still in its early stages, nanoparticles may be used as biomarkers for identifying bacterial, viruses and fungal plant pathogens in agriculture or as a rapid diagnostic process. Nanoparticlebased sensors could be able to identify viral pathogens in plants with higher detection limits. Nanoparticles may be specifically modified to detect pathogens or used as a screening tool to identify substances that indicate a state of disease. Nano-chips are micro-arrays containing fluorescent samples for the detection of hybridization. Yao et al. utilized the nanoparticles of fluorescence silica along with antibodies to discover Xanthomonas axonopodis pv. vesicatoria, a bacterium which causes a disease named bacterial spot in Solanaceae plants, suggesting that nanoparticles may be useful in detection of disease [9]. Singh et al. utilized surface plasmon resonance (SPR) to discover disease named Karnal bunt in wheat with the help of Nano-gold Immunosensors[10]. The study focuses on the use of an SPR sensor that diagnoses the disease for seed and quarantine in wheat plots. For the rapid detection and control of disease pathogens sensing nanosensors for infield use can be extremely helpful.

Physiological modifications occur in plants in response to various stress conditions. Systemic protective activation is one such reaction that the plant's hormones like methyl jasmonate, jasmonic acid, and salicylic acid are thought to regulate. Using this stimulus indirectly to produce a delicate electrochemical sensor, Wang et al. used modified golden electrode with copper nanoparticles to test the levels of salicylic acid in oil seeds in order to detect fungi [11]. Using this sensor, they were able to reliably test salicylic acid. The sensors and various sensing methods should be studied further for detecting pathogens and their byproducts, as well as tracking physiological changes in plants.

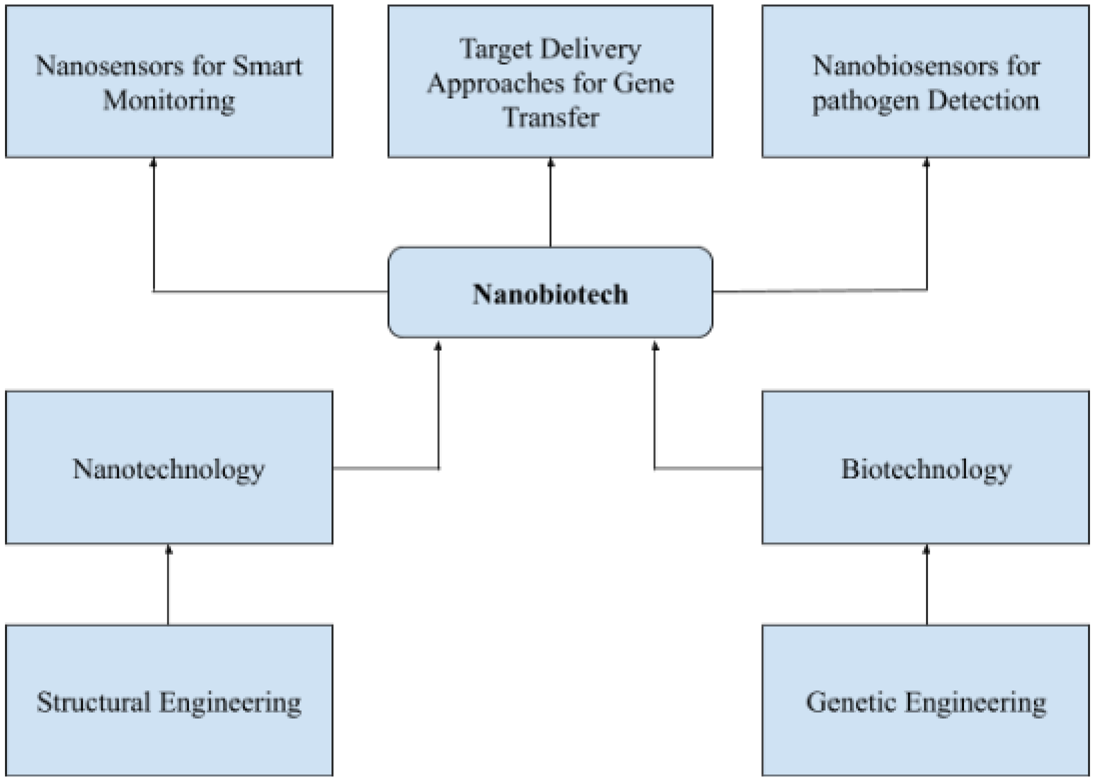

Figure 2:The Integration of Nanotechnology and Biotechnology. Nano-Biotechnologies Uses Nanocapsules, Nanofibres and Nanoparticles to Transport Chemicals and Foreign DNA that Helps in Altering Target Genes.

5. *Drawbacksand Future Research Requirements:*

Any of the main issues for using nanomaterials in agriculture include ecosystem toxicity, possible residual carry-over in crops, and Nanomaterial phytotoxicity. Bouwmeester et al. examined the health risks of nanomaterials used in plant processing in depth[12]. The health risks of multiple nanomaterials have also been explored by Kahru and Dubourguier[13]. Furthermore, the “toxicodynamics and toxicokinetics” of nanomaterials used in agricultural processing must be measured. According to R. Jayakumar et al. the same nanomaterials have differing effects on different agricultural plants and, if not degraded rapidly, would have a significant impact on alternate cropping systems[14]. Until using nanomaterials in agricultural production processes, research on these subjects must be undertaken and their effects fully understood. Site-specific Nanomaterial application technology will mitigate any of these threats. The following are the main concerns concerning the applications of nanomaterials in crop protection and agricultural processing:

a. Precise nanomaterial characterization in biological matrices to ensure that their toxicity is fully understood in biological environments.

b. The interactions of Nanomaterials with biology.

c. Considerations of Dose response.

d. Research on characterization and exposure measurement.

e. Commodity factors of life cycle.

f. Context nanomaterials amounts in feed and food matrices, and

g. As a consequence of use in agricultural and crop safety of nanomaterials number and form in foodstuffs.

For agricultural applications, low-cost nanomaterials and field applications, like other technologies, are required. In order to improve the effectiveness of Nanomaterials/Nano-pesticides on their desired targets, existing implementation approaches must be checked. According to Navarro et al. extensive research is carried out in the different environments of nanomaterials, such as nanoparticle dosage, their physical and chemical characterizing, mechanisms for passing through cell membranes and cell walls, basic characteristics associated with nanoparticles toxic effects as well as the mechanism behind the nanoparticle trophy [15]. Many scholars, including Suh et al. have demonstrated the dangers of nanomaterials to human health[16]. Nanomaterials are absorbed into the human body by inhalation, swallowing, and dermal absorption. Xu et al.emphasized the importance of investigating factors like surface structure, Nanomaterial size, solubility, chemical composition, and aggregation for risk associated with their exposure to humans[17]. This chance of exposure could be reduced if efficient nanomaterials application technologies were used in agricultural processing. Finally, nanomaterials that are highly dispersed and wettability are biodegradable, less harmful and less photo-generative in the atmosphere, well-understood toxicodynamics, and toxicokinetics and smart and durable, easy to manufacture and use in agriculture, that are ideally suited for their operational use throughout the production in agriculture.

CONCLUSION

The study is focused on fundamental uses of nanomaterials like pesticide residue detection, pathogen detection and plant protection in the agriculture. In comparison to conventional methods, nanomaterials provide faster plant germination as well as production, better plant safety, and decreased environmental effects. Smart nanosensors may also be an effective way to identify residues of pesticide present in the field. This study moreover addressed some issues and questions related to particular applications of Nanomaterial, as well as a few potential solutions. Nanomaterials improves the germination process in plant while damaging other plants. In these situations, nanomaterials must be utilized in controlled manner, like in greenhouse plants for promoting the plants which requires germination. The nanomaterials' applications in agricultural field as well as their potential role in future agricultural development are discussed in this paper. While this work demonstrates the promising role of nanomaterials for a variety of farm applications, further research and study are necessary for the development of agricultural application possibilities and methodologies.

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