A Comprehensive Review on Nanomaterials and Diverse Agricultural Applications

Abstract

Climate change, the population explosion and the growing demand for good food and health require better, more reliable and more efficient. The differe nt shape, size, composition and ability to interact with organic compounds make nanomaterials and technology widely used. Nano formulations and their applications in agriculture in the form of agrochemicals for crop protection, toxicity identification by nanobiosensors, genetic manipulation of plants treated by nanodevices, and rapid and efficient diseases of plants. The delivery of genetic material and proteins via nano-arrays has been proven in crop engineering, drug delivery and environmental monitoring. Nanotechnology also benefi ts the food industry by improving all stages of food production from food processing to production, processing, packaging, safety, extending shelf life, testing for disease and creating smart foods.Therefore, technology can meet the needs of most consumers, including the improvement of foo d products and their sensations, and can improve product quality, texture soft and nutritious food with out affecting its natural properties.

Keywords: Nanomaterial's and Diverse Agricultural applications

Introduction

The use of technology in the synthesis, characterization and use of nanoscale materials is fascinating. Nanotechnology makes science more interactive and application-oriented. Nanomaterials are materials with at least 1 size reduction from 1to100 nanometers. They have unique properties different from bulk materials. Their high volume ratio and related molecular reactivity make them into chemical, optical, electrical and mechanical and biomedical applications. Due to the unique properties of nanoparticles, nanotechnology has become a rapidly growing industry with high financial impact. While some nanoscalematerials (window glass and sunglasses) have been used for decades, some are newly discovered (sunscreens, cosmetics and textiles) and some are still under development (fat cells and bioanalysis). The translation of nanotechnology advances to human and natural health is fascinating.Climate change, the population explosion and the growing demand for good food and health require better, more reliable and more efficient [1]. This is why the quality of nanoscale materials depends on size and shape. Many surface areas complicate their work and therefore their application. For this reason, nanomaterials are used in almost every area of life, from medicine to water and air purification, from food and development to cosmetics, from fabrics to various household products. Nanoparticles are classified in various ways according to their morphology, size and chemical properties [2-5]. These include carbon-based nanoparticles, metal nanoparticles, ceramic nanoparticles, semiconductor nanoparticles, polymers, lipidbased nanoparticles, and more. Fullerenes and surface-functional fullerenes find applications in optics, electronics, cosmetics and biomedicine. The different shape, size, composition and ability to interact with organic compounds allow them to push the boundaries of colloid science. In carbon nanotubes, atoms are arranged in a hexagonal shape, similar to graphite. The ends can be opened and closed with a fullerene cap. Tubes with two or more layers are called multi-walled carbon nanotubes (MWCNTs), single-walled nanotubes (SWCNTs). Just one layer SWCNTs have electronic properties that make them efficient and their properties differ from MWCNTs. Metal nanoparticles are produced from metal precursors and have unique optoelectronic properties due to surface plasmon resonance (LSPR). They can be modified with various functionalgroups or combined with drugs such as antibiotics, antibiotics, ligands and drugs and have many applications. Ceramic NPs are usually prepared from oxides, carbides, phosphates and carbonates of metals and metalloids and have properties such as heat resistance and chemical inertness. They are used for medicine, energy and storage. Polymeric nanoparticles are nanoparticles suitable for certain applications.

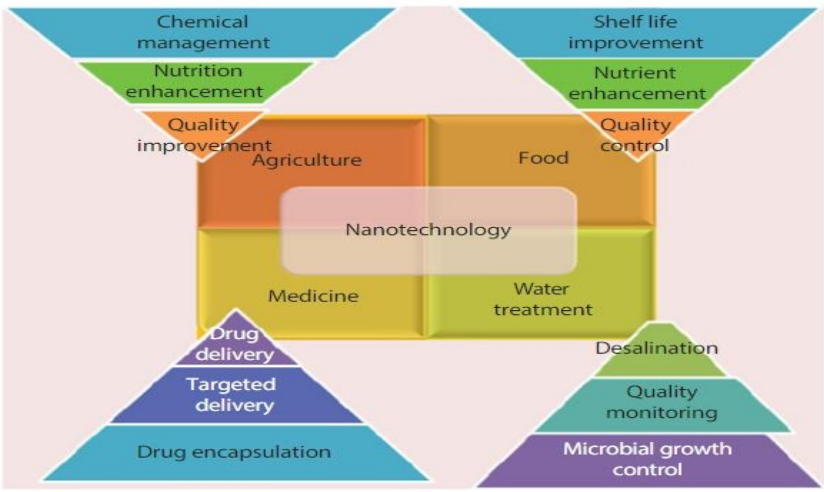

Fig 1: Application of nanomaterial in different aspects of life.

The basic approaches to nano fabrication are bottom-up and top-down. The following method involves assembling atoms into crystal planes that continue to form nanostructures. This synthetic process produces uniform and defect-free nanostructures. Meanwhile, the top-down method synthesizes nanostructures by removing crystal faces that already exist in the substrate. Nanoparticles can be synthesized by chemical, physical or biological methods. In physical coupling, larger particles are ground/sized to obtain nanoscale particles. Chemical synthesis is the most commonly used method. Here, nanoparticles are grown on a liquid medium containing various reactants and reducing agents. It has some disadvantages such as contamination from the precursor, use of toxic solvents and production of harmful products. Biosynthetic methods have been introduced to overcome the disadvantages of other methods such as low yield, high cost, toxicity and environmental concerns. For this purpose, biological products such as plants, bacteria, fungi, algae, yeasts and bacteria are used. In our previous research, we reported the synthesis of bioactive AgNPs u sing various microbial and plant species.

The size of the feature shape affects the properties of the nanoparticle. Microscopy techniques such as Polarized Optical Microscopy (POM), Scanning Electron Microscopy (SEM), Transmissive Electron Microscopy (TEM/HRTEM), Scanning Tunnel Microscopy (STM) and Atomic Force Microscopy (AFM) are used for habituation. Examine the composition and properties of materials with energy dispersive Xray (EDX), Xray diffraction (XRD), Raman spectroscopy, Xray photoelectron spectroscopy (XPS), particle size analyzers and dynamic light scattering (DLS) [6-8].

Nanotechnology and Agriculture

Agricultural products appear in our lives in many forms such as food, oil, furniture, textiles and raw materials. However, agricultural production is very difficult due to the lack of space, diseases and changes in agroclimatic conditions. Many methods of increasing the crop, including the use of fertilizers and pesticides, have proven extremely dangerous and lifethreatening. For this reason, it is necessary to update agricultural practices and methods brought by new technologies. Such is the importance of using nanotechnology in agriculture. It has been proven that various nanotechnology techniques can be applied in agriculture to increase productivity. These include the creation of nanoformulations of agrochemicals for plant protection, toxicity analysis of nanobiosensors, genetic manipulation of plants mediated by nanodevices, and rapid and effective diagnosis of plant diseases. The delivery of genetic material and proteins via nanoarrays has been proven in crop engineering, drug delivery and environmental monitoring. Binding of nanoparticles to DNA has been shown to protect DNA from DNase-mediated degradation and sonication. These positive results encourage the use of ultrasound programsto introduce genetic material containing nanosystems into plants. In this way, the seeds can turn into good plants. Mesoporoussilica nanoparticles (MSN) have been shown to be effective for gene delivery by controlled release from gold nanoparticles. Here, genes and their chemical inducers are transported to MSNs and coated with gold nanoparticles to ensure minimal leakage. Drug release and gene expression occur with the removal of the cap, which allows regulation of gene expression. Biolistic conversion based on seed payment with gold nanoparticles has been shown to be successful in tobacco and tissues. Here it also utilizes and target-specific DNA and effector molecule delivery. Nanotechnological methods for the distribution of fertilizers, nutrients and pest control, as well as advances in the production of nano pesticides, nano fungicides and nano herbicides, show their great applications on the farm. Therefore, nanotechnology is used in many applications in agriculture, from biomass conversion technologies to precision agriculture and other fertilizers. Nanotechnology has many applications in agriculture and processing of agricultural products. This is because the physical properties of plant nanomaterials, their role in pesticide bioremediation, smart packaging and product tracking reduce the negative impacts on the environment than currently practice. Nanoscale food, micronutrient fertilizers, nanoemulsions, etc., coated with zinc oxide nanoparticles. Many nanotechnology products have been approved for application in agriculture, including the inclusion of antibiotics and antibiotics in the food supply has become a major concern for human health. Bioremediation of compounds with nanomaterials can degrade completely or turn into non-toxic products. Due to progress in bioremediation of uranium, hydrocarbons, soil treatment, groundwater and wastewater, these problems can be solved with nanotechnology. When plant cell walls limit the entry of other substances, nanoparticles can pass through the pores. Engineered nanoparticles have also been shown to cause pore swelling or induce new pores associated with their absorption. While still in contact with the leaves, the nanoparticles were found to be taken up into the stomata and the base of the trichomes and then transported throughout the plant. Monitoring these processes and generating molecular insights for such processes could lead to the development of nanotechnology as an advancement in agriculture. Once thenanoparticle enters the cells, it changes its effects on the whole plant. Their function can be determined by size, shape, chemistry, and location [9-11].

1.1 Precision Farming and Nanotechnology

Precision farming techniques using nanotechnology should provide greater yields with reduced agrochemical inputs and thus limit the accumulation of large amounts of agrochemicals in soil and water. With the advancement in nanotechnology, precision farming has become more important because there is a better way to control soil health and diseases. This is achieved through the slow release of agrochemicals and the use of nanomaterials for the control of plant diseases. Precision farming can be developed by exploring the growth-controlling role of nanomaterials, the use of water retention in the soil, and their function to transport nutrients and improve production. In this context, the future will be in the development of agricultural nanotechnology approaches to manage challenges related to food, food security, sustainability and climate change in an environmentally friendly way.

Nanotechnology approaches to improving photosynthesis, food and biofuel production, and crop disease prevention and nanobionics have proven very promising in agriculture. Advances in plant nanobionics show the promise of bio-inspired materials for light harvesting and biochemical research. This has been reported to be an effective way to improve photosynthesis and biochemical sensing using a single-walled carbon nanotube-chloroplast assembly. The nutritional quality of food products can also be achieved with nanotechnology to control the nutritional value of foods by improving their nutrition from plants.

Some nanomaterials have also been reported to support the growth of many plants. Advances in nanofabrication and characterization methods have allowed technology to better understand disease and develop disease treatment strategies. Nanofabricated xylem vessels with biomimetic capillary action demonstrated colonization, film formation and forward movement and replication of the new xylem living organism in situ. Nanoscale lignocellulose crystals are used as a high-strength polymer and find uses in construction and body weight as well as food and other packaging. Cellulose nanowhistles made from rice straw should make biocomposites to replace glass fibers and plastic. Preventing the release of nutrients into the soil, reducing leaching, improving the capacity of plants and reducing eutrophication are some of the advantages of smart nano systems [12-15].

1.2 Control Release Formulations.

Nanoencapsulation of pesticides or active ingredients consists of coating with other materials of different sizes. For controlled release of active ingredients to ensure longl-asting performance. The potential of nanotechnology to reduce pesticide misuse and increase their safe application has been explored through nanoencapsulation. Encapsulation provides multiple pesticide levels and slow release prevents premature spoilage and builds up over time. This reduces the amount of pesticides required, human impact, and is more environmentally friendly than conventional methods.
The table1 below shows the most commonly used controlled release formulations. In the case of clay minerals, the nanoscale structure determines their properties. Because they have better storage options to control the distribution of compounds, they can be adapted to take advantage of plant growth regulators, pesticides, and herbicides, reducing the use of chemical and anti-loss drugs.

1.3 Nano-agrochemicals

The development of nanotechnology in agriculture includes the use of nanoscale agrochemicals, the development of plant protection systems, and the management of agricultural crops after harvest. Nanotechnology promotes limited use of natural resources, providing better and safer soil, water and environment. However, balancing the use of nanotechnology against environmental concerns may now lead to better acceptance in agriculture.
The preparation of polymeric nanoparticles containing encapsulated herbicides provides a friendly method for weed control. It also focuses on the specific application of insecticide-loaded nanoparticles to plant roots to directly eradicate the plant.
Various metal nanoparticles have been used as pesticides in commercial vegetable crops. Producing the maximum amount of crops with great care with the use of few chemicals can give a

good idea about nanotechnology.

Table 1. Comparison of some common control release formulations used in agriculture.

SNo	Type	Classes	Properties	Examples
1.	Polymer based encapsulation • Nanoparticles or nano-fillers dispersed within a solid matrix • Eco friendly and biodegradable • No degradation byproduct	Nanocapsules	○ Polymer membrane encapsulating the active compound as the inner liquid core	○ Carbaryl, ○ Bifenthrin, ○ Etofenprox ○ Acephate ○ mMethomyl
		Nanosphere	○ Active compound uniformly distributed and embedded in the polymeric matrix	○ Carbaryl ○ Azadirachtin
		Micelle	○ For water insoluble agents ○ The amphiphilic properties helps in self assembling to form a spherical micelle	○ Carbofuran, ○ Rotenone ○ Imidacloprid
2.	Lipid based encapsulation • Better encapsulation • Low toxicity	Nanoliposomes	○ Increased surface area, solubility and bioavailability than liposomes. ○ A bilayer lipid with a watery interior at nanoscale level	○ Etofenprox.
		Solid Lipid Nanoparticles (SLN)	○ Colloidal carrier for controlled delivery ○ Can retain the beneficial properties of other colloidal carriers	○ The ecological pesticide *Artemisia arborescens L.* essential oils
3	Porous Inorganic Nanomaterials	Porous silica nanoparticles	○ Mesoporous silica nanoparticle (MSN) or porous hollow silica nanoparticles (PHSNs or HSNs) ○ Controlled morphology ○ High level of biocompactability ○ Ease of functionalization	○ Imidacloprid ○ Metalaxyl ○ Avermectin ○ Validamycin
4.	Clay based nanomaterials and layered double hydroxide (LDH)	Clay nanomaterials	○ Fine grained materials belonging to naturally occurring aluminium silicate or hydrous silicates	○ Ethofumesate ○ Alachlor
		Layered double hydroxides (LDH)	○ Natural and synthetic materials of anionic lamellar compound made of positively charged layers and mixed metal hydroxides – magnesium and aluminium.	○ 2,4-D ○ MCPA ○ Picloram

1.4 Nano-pesticides

Pesticides and other agricultural chemicals are used to increase crop yields. However, the use of safe, simple and degradable pesticides for agriculture is still very difficult. Therefore, there is currently emerging interest in nanopesticides to overcome the harmful effects of conventional pesticides. It has been reported that nanoemulsions are prepared by encapsulating functional groups in water droplets to reduce the desired drug concentration. The nanomaterials provide greater stability to the active compound and also reduce its leaching from the leaf. Nano pesticides and colloidal formulations of insecticides could have important applications as they reduce the dose of drugs, reduce the number and frequency of applications, which in turn reduces the risk of human exposure. The environmental safety of nanoformulations can be further enhanced by using biocompatible and biodegradable polymers. Petroleum-derived or microbial-derived biopolymers are environmentally degradable and may release encapsulated components during degradation. A schematic diagram of the release of active ingredients from nano emulsion degradation is shown in Figure 2.

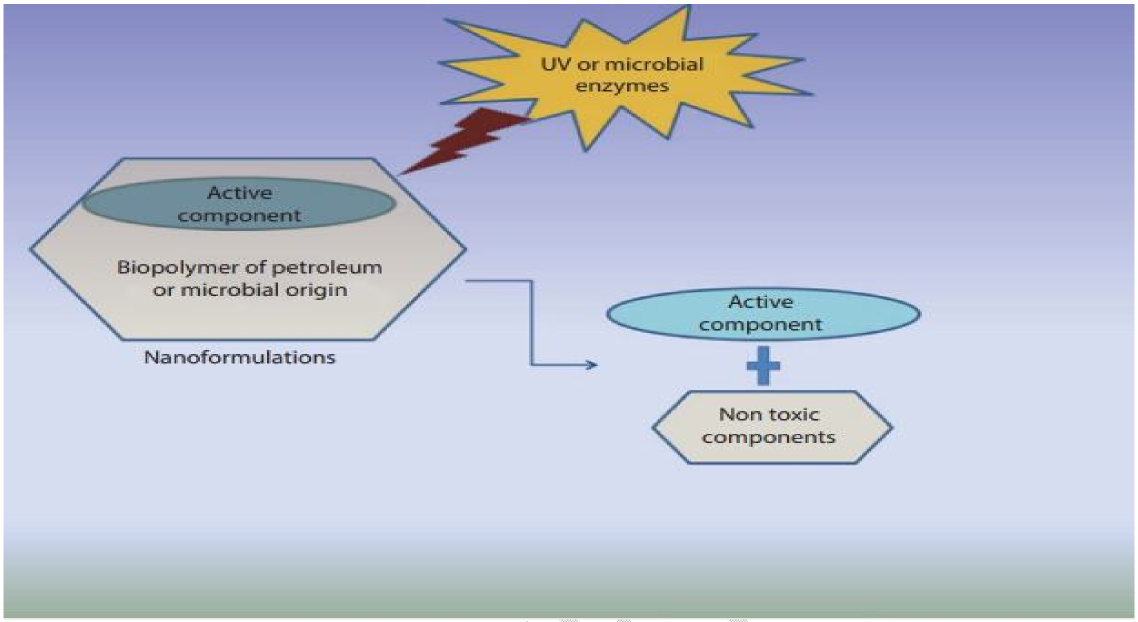

Fig2. Schematic representation of the degradation of the nano emulsions leading to the release of the active ingredients.

Nanoencapsulated insecticides also have slow release, so they can be used for a long time. Various nano-based carrier systems have been used to produce encapsulated insecticides or herbicides. Several companies have developed microencapsulated pesticides for field applications. Nanotechnology also has important applications in pest control. The antibacterial properties of Phyto formulations also increase in the presence of nanoparticles. The development of clay nanotubes as an insecticide provides long-term release and good contact with plants, reducing the need for pesticides by 70-80%. Recent advances in pesticides introduce controlled release technology, in which active ingredients are combined with an inert substance to prevent, control and control release. The benefits of nano formulations include improved performance, durability and less need for active ingredients. The formulations may be made in a form such as nanoemulsions, nanocapsules, or formulations containing the first engineered nanoparticles. These allow efficient and effective interaction with the line while minimizing moisture and leakage issues. Polycaprolactone and polylactic acid are used to encapsulate the etiprol insecticide. Encapsulation makes it more accessible to plants. Further controlled release studies show that these formulations are more effective than many commercial formulas. [16-21]

Aluminum-silicone nanotubes are used as effective insecticides because they are easily absorbed by insect hairs when sprayed on plants. They cause less harm to the environment because they are more fun and goal-oriented. This indicates that more technological advances in nanotechnology are expected to replace existing agriculture in the coming years.

1.5 Nanofungicides

As fungal diseases pose a major threat to agricultural production, the development of anti-bacterial properties of nanomaterials has important applications. The threat of fungicide is significant because it has both harmful and beneficial effects. Besides phytochemicals and biocontrol agents, nanoparticles have also been recognized as an alternative to fungicides. The potentials of silver, carbon, silica and aluminosilicate nanoparticles as antimicrobial agents have been investigated. It has been reported that silver and TiO_2 nanoparticles prevent various plant diseases. The nanosilica treatment was also found to improve plant phenolics, indicating good protection.

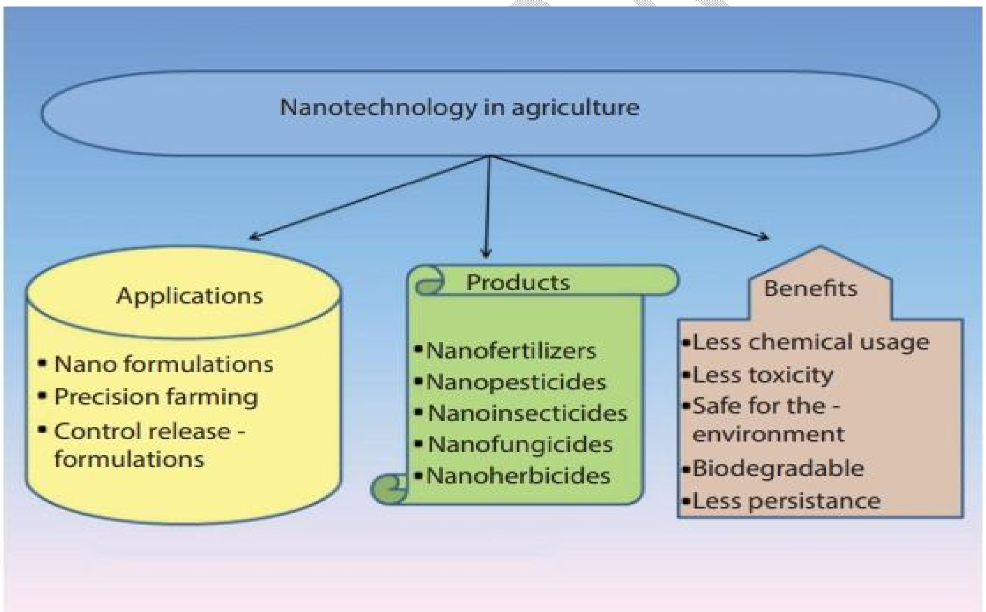

Fig3. Role of nanotechnology in agriculture.

Silver nanoparticles are one of the most studied nanoparticles for their many applications. There is increasing interest in its application in plant disease control. Many studies have shown that this can improve seed germination and seedling weight. Nanosilver emulsions have been shown to adhere to fungal or bacterial infections and are very effective in providing rapid response . Despite the great potential of silver nanoparticles to control fungal pathogens, their effects on phytopathogenic fungi are poorly understood.

The issue of toxicity of nanomaterials and their effects on animals is important to explore their applica tion areas. Although the amount is usually obtained as an agrochemical for plants, soil and hydroponic organisms, it can be toxic in a concentration-dependent manner (Figure 3) [21-25].

1.6 Nanofertilizers

Fertilization plays an important role in agricultural production. In general, they are applied to the soil by surface application, by placing in the soil or mixing with water. Many of these fertilizers are not available to plants and instead become a source of ecosystem pollution. This requires new nanotechnology techniques to improve nutrient utilization and reduce fertilization in plants. This has led to the use of technology in the production of smart fertilizers or nano fertilizers. Many types of Slow Release Fertilizers (SRF) and Controlled Release Fertilizers are made from synthetic or biopolymers. Polymer nanoparticles are also used as a coating in biofertilizers to make them resistant to drying. Nanofertilizers include both materials in the size range of 1 to 100 nm and materials replaced by nanoscale materials. The effect of several nanomaterials on plant growth and productivity has been studied. Nanoparticles have also been reported as natural biofertilizers due to their ability to promote plant growth in vitro. The nanofertilizer properties of various nanomaterials were investigated. These include carbon-based nanoparticles, TiO2, iron oxide, zinc oxide and urea hydroxyapatite. The overall benefits recommended for its use include promoting good nutrition, maintaining soil health and microbial diversity, and ultimately increasing crop yields. Nanoscale data shows plants grow better than large scale data. This was reported by the germination percentage and germination power index of various plants such as spinach. It has been reported that the photosynthetic rate, chlorophyll content, dry weight and seed stress of plants are also improved with the use of nanomaterials. The nanotechnology approach has been specifically used to provide nutrients to plants. Report on the Development of Urea Hydroxyapatite Nanoparticles Provingis an efficient way to transport Nitrogen and Phosphorus Field experiments confirmed the stable release of the nanohybrid and improved the results. Similarly, the growth of carboxymethylcellulose based hydroxyapatite nanoparticles has proven effective in promoting the growth of soybean seeds. Application of nanomaterials to soil causes significant changes in morphological parameters and yields. Ultrasonic dispersion based methods have been reported for the production of phosphorus (P) nanofertilizers. Here, the application of nanoformulations enhances the growth of maize plants both in greenhouses and fields. The truth is that the application of nanotechnology has been proven to improve the utilization of plant micronutrients. Both nanoformulations and micronutrients have been shown to improve soil health. In the case of zinc oxide nanoparticles, it has been shown to have multiple effects on plant growth and secondary metabolite composition. Foliar spraying of ZnO nanoparticles increases phosphorus uptake by plants. Phosphatase and phytase can be activated to work effectively by the application of zinc oxide because these enzymes require zinc as a cofactor. Enhancement of plant growth based on this zinc oxide nanoparticle via increased phosphate mobilization has also been reported in many other plants. This has important implications for the development of nutrients from plants in different soils, as phosphorus is usually present in the soil but not available to plants. Application of ZnO nanoparticles in tomatoes causes an increase in lycopene content [26-27].

Conclusion

In addition, nanomaterials can protect crops from various stresses such as drought, salinity and pests. This can help farmers increase yields while reducing dependency on harmful chemicals such as pestic ides and herbicides.Nanomaterials have also been shown to be effective in providing nutrients necessary for plant growth and development. With their ability to penetrate cell membranes, nanomaterials can deliver nutrients such as micronutrients and fertilizers directly to plants, enabling them to grow and use. This can help farmers use less fertilizer while maintaining the same yield level.In addition, nanomaterials show soil remediation potential, which is an important topic in today's agriculture. Nanomaterials can improve soil quality and fertility by helping to remove pollutants and heavy metals from the soil. This can increase the sustainability of agriculture while reducing the environmental impact of agriculture.

Despite the benefits of nanomaterials in agriculture, there are also possibilities to be considered. More research is needed to understand the potential environmental and health effects associated with nano materials.This includes their effects on soil microbes, water quality and human health. Additionally, the production and disposal of nanomaterials will have an environmental impact that must be addressed.

In conclusion, nanomaterials have the potential to transform agriculture and contribute to sustainable and profitable agriculture. Although there are still challenges and risks to be overcome, the benefits of using nanomaterials in agriculture are enormous. More research is needed to better understand the ris ks and benefits of using nanomaterials in agriculture.

In this way, we can generate new solutions that help solve the problems facing agriculture and promote sustainable agriculture.

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