



## Nanotechnology Agriculture: An Overview

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**Abstract:** *Nanotechnology is the production of new devices, materials, and structures by manipulating matter on a near-atomic scale. It has become a promising solution to many problems faced by human society. It has been invading and penetrating every aspect of our life, and the agricultural sector is no exception. Nanotechnology has the potential to positively impact agriculture and farming, minimizing adverse problems of agricultural practices on environment and human health, while promoting social and economic equity. The incorporation of nanotechnology in modern agriculture helps in uplifting the global economy by providing support and advances in different ways. Nanotechnology also increases the quality and quantity of yields. This paper provides an overview on the use of nanotechnology in agriculture.*

**Keywords:** *notechnology, agriculture, farming.*

### INTRODUCTION

Nanotechnology is a newly emerging multidisciplinary field integrating several disciplines such as engineering, physics, chemistry, and biotechnology. It refers to the purposeful manipulation or engineering of materials at the nano (one nanometer is one billionth of a meter) scale. It is the science of the very small things. It helps us understand nature well in the nanometer scale. It enables development of novel materials (nanomaterials) with a wide range of potential applications in a variety of consumer, medical, commercial, and industrial products. Nanomaterials are designed to have at least one dimension (length, width, height) in range from 1 to 100nm. For humans, cell membranes, hormones, and DNA are typical examples of structures that measure in the nanometer range. Some industries such as microelectronics, aerospace, and pharmaceuticals have already begun manufacturing commercial products of nanoscale size [1]. Attempts to apply nanotechnology in agriculture began with the realization that conventional farming technologies would neither be able to increase productivity any further nor restore ecosystems damaged by existing technologies.

Agriculture is the only provider of human's food. It is considered the backbone of most developing countries, with more than 60% of the population dependent on it for their livelihood. It serves as the primary pillar of the developing economy and provides food for a better life. Currently, agriculture around the world faces a several challenges such as increasing population, plant diseases, animal diseases, unpredictable hazards, global climate change, nutrient deficiency, stagnation in crop yields, diminishing soil organic matter, low water availability, macro and micronutrient deficiency, overuse of chemical fertilizers and pesticides, nutrient deficiency in the soil, decreased land area due to urbanization, land degradation, and labor shortages. Using conventional agriculture, nearly one third of crops get damaged, mainly due to pest infestation, unpredictable climate change, natural disasters, poor soil quality, environmental pollutants, and lesser nutrient availability. More innovative technologies are currently required to overcome these problems and meet the nutritional demands of the rapidly growing global population. Nanotechnology has emerged with imminent potential to reform the resilient agricultural system while promising food security. Modern



agriculture is being transformed into precision agriculture with the help of new-age nanomaterials [2].

## WHAT IS NANOTECHNOLOGY?

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as nanotechnology, the materials or objects themselves are called nanomaterials, and the study and discovery of these materials is known as *nanoscience*. The word “nano” comes from the Greek for “dwarf.” Nanotechnology involves the manipulation of matter at the molecular scale. It can work from the top down (by reducing the size of the smallest structures to the nanoscale) or the bottom up (by manipulating individual atoms and molecules into nanostructures) [3]. Nanotechnology refers to the design, fabrication, and use of nanomaterials whose nanoscale structures range from 1 to 100 nm. In other words, nanomaterials are the natural or engineered substances with dimensions between 1 and 100 nm [4]. Figure 1 shows some applications of nanomaterials in agriculture [5].

Nanomaterials (NMs) include carbon nanotubes, nanowires, nanoparticles, quantum dots, nanorods, and nanofibers. They can be classified into three groups: nanoparticles, nanofibers, and nanoplates. Nanoparticles can occur naturally or man-made in food. They are added to many foods to improve flow properties and color during processing, or to increase shelf life. They can enter the body by inhalation, ingestion or by dermal penetration. Nanofibers have diameters of less than 100 nm, are produced by the electrospinning process, and are used in food [6]. A wide range of nanomaterials have been applied in food industry.

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. Nanotechnology is revolutionizing many fields including the military, mechanical industry, electronics, biotechnology, medicine, energy, communication, solar, optics, agriculture, and food [7,8]. Nanotechnology is regarded as a transformative technology, which can stimulate scientific innovation and greatly benefit the society. Research on nanotechnology has skyrocketed over the last decade, leading to numerous applications in virtually every segment of the economy. All potential applications of nanotechnology significantly affect our lives, our health, our convenience, and our environment [9].

## NANOTECHNOLOGY IN AGRICULTURE

Nanotechnology in the modern era has greatly affected the agricultural sector, which is why nanotechnology is regarded as the 6th most revolutionary technology in the contemporary world. Nanotechnology is poised to help modernize the agricultural process on a global scale and propel farming efficiency into a new age. It will do this by offering new techniques for fertilizer delivery, waste reduction, creating sustainable water use, controlling pest problems, remediating heavily polluted soil, etc. Water is a commodity that will need to be used sparingly as the world’s population continues to grow. So nano-polymer hydrogels are being used in agriculture in the effort to create more sustainable water use. Hydrogels, nanoclays, and nanozeolites have been reported to enhance the water-holding capacity of soil. The automation of irrigation systems is also a crucial requirement of smart agriculture in view of water shortage. Nanotechnology treatment of seeds will see seeds germinating faster and steadier with increased resilience to environmental stressors [10].

In agriculture, nanotechnology has implications on every stage of farming, including seed germination, growth, harvest, processing, storage and transport of agricultural products. The potential benefits and uses of nanotechnology in agri-food industry are enormous, which can heighten global food production and trim the abysmal usage of agrochemicals. Nanotechnology can

contribute to a greater extent in achieving the target of zero hunger, which is one of the 17 sustainable development goals proposed by the United Nations. Nanotechnology has the potential to revolutionize agriculture and food systems in the areas of nano-fertilizers, pesticide career, microfluidics, nucleic acid bioengineering, smart treatment delivery systems, nano bioprocessing, bio analytical nano sensors, bio selective surfaces, environmental processing, pathogen detection, plant/animal production, biosecurity, molecular and cellular biology, and environmental protection through the reduction and elimination of pollutants [11]. Figure 2 illustrated nanotechnology in agriculture [12].

## APPLICATIONS OF NANOTECHNOLOGY IN AGRICULTURE

Nanotechnology strikes at an indispensable part of numerous domains of agriculture without any doubt. A wide range of potential applications of nanotechnology has been envisaged in agriculture. Nanotechnology-based products and its applications in agriculture include nano-fertilizers, nano-herbicides, nano-pesticides, recalcitrant contaminants from water, nano-scale carriers, nanosensors, veterinary care, fisheries and aquaculture, detection of nutrient deficiencies, preservation, photocatalysis, nanobarcode, quantum dots, etc. [13]. Figure 3 shows some of these applications [14]. Some of the applications are explained as follows.

- *Food Industry:* In the food industry, maintaining some important factors such as quality, safe, freshness, taste, etc. in whole supply chain requires producers to package and label their products. Nanotechnology is an emerging technology with a great potential for generating absolute new products and certain processes in the food sector. Nanotechnology led significant advances in the food safety field. It is being used to increase food safety by detecting contaminants and pathogens in food. Nanotechnology boosts food quality with stronger packaging and sensors detecting safety, preventing foodborne illnesses. Figure 4 shows some applications of nanotechnology in the food industry, while Figure 5 depicts nanofood packaging [15].
- *Food Production:* Nanotechnology has been developed and integrated into agriculture and food. It can transform conventional agricultural systems and make them smart. It has been applied in food machinery mainly as food machinery lubricants and nano magnetic refrigeration. Use of nanotechnologies is also being explored for use with livestock, animal breeding and genetics, and identity preservation and tracking. Nanotechnology has also been proposed for water treatment and bioremediation of irrigation water [16,17]. It has been used to alter the genetic structures of crop plants.
- *Food Manufacturing:* The food manufacturing industry has been using nanotechnology to change the way we grow and maintain our food. Food manufacturers have invested a lot in order to develop novel nanotechnology based products in food industry. Manipulating food at this scale allows manufacturers to pack more pack more nutrients and make the food taste great. Some companies are willing to invest in nanorobots that can make food by assembling atoms and molecules of different nutrients. Public acceptance is an important issue that is often ignored by a food manufacturer. Public voice is either assent or dissent (altruism or skepticism) with nanotechnology in food industry [18].
- *Wood Industry:* Preservation of wood is one of the problems faced by the wood industry, which is now solved by nanotechnology. Conventional wood preservation includes thermal modification in which wood is treated at a particular temperature and chemical modification in which wood is treated with certain chemicals to form a bond between the chemical used and wood. Wood preservative systems treat wood with chemical substances or give pressure treatment to protect the wood from insects and fungi. Nanotechnology in the wood-based industry can be applied in two types, one being the derivation of nanomaterials from the forest



and the other being the use of nanomaterials for wood-based products. In nanotechnology, nanotubes, nanosized metals, and polymeric nanocarriers are used [19].

- *Nano-fertilizers*: Fertilizers are necessary for enhancing soil fertility and crop productivity. Nanofertilizers are mineral nutrients manufactured mainly by encapsulation with nanoparticles and can be classified into macronutrients and micronutrients. They can be tuned to have specialized delivery to plants. Conventional fertilizers can be dangerous to the environment because of the sheer amount of runoff that stems from their use. Due to the poor efficiency of the chemical fertilizer, its usage is reduced. Studies have shown that, greater than 50% of the amount of fertilizer applied to soil is lost to the environment. This poses extremely negative environmental implications, while also demonstrating the high waste associated with conventional fertilizers. On the other hand, nanofertilizers are able to amend this issue because of their high absorption efficiency into the targeted plant, which is owed to their remarkably high surface area to volume ratios. Another beneficial aspect of using nanofertilizers is the ability to provide slow release of nutrients into the plant over a 40-50 day time period, rather than the 4-10 day period of conventional fertilizers [20].
- *Nanopesticide*: Using a pesticide in agriculture is part of their regular practice for getting greater yield. Less amount (0.1%) of pesticide is reaching the targeted pests. The other remaining 99.99% of the applied pesticides are contaminated. Human health and the food chain are severe consequences of contaminated pesticides in the environment. All these harmful effects can be overcome by using nanopesticides. The nanopesticides can offer effective pest control for a long duration by releasing the active components slowly and closely controlled. Nanopesticides are essential for sustainably and efficiently managing different pests [14].
- *Crop Production*: One of the primary applications of nanotechnology in agriculture is to improve crop yields. Agriculture is confronted with unprecedented challenges, including increased food demand and a decline in crop production. Nanotechnology has been used in various aspects of agricultural production, such as seed germination and plant growth, to increase crop yields and quality. It is a promising way to boost crop production, enhance crop tolerance, and decrease the environmental pollution. The advancements in nanotechnology can be explored to enhance sustainable crop improvement. Enhancing the quality and quantity is the main focus of crop improvement, which can be achieved by nano biofortification [21].

Other areas of application include crop breeding, plant transformation, food packaging, food processing, precision farming, plant disease diagnostics, animal health, animal breeding, poultry production, postharvest management, etc. Potential applications of nanotechnology to food and agriculture are limited only by the imagination.

## **BENEFITS**

Nanotechnology is widely used in our everyday life and is changing the entire society. The benefits of applying nanotechnology in agri-food sector are many and are expected to grow with time. The unique properties of materials at nanoscale make them suitable candidates for the design and development of novel tools in support of a sustainable agriculture. The application of NMs in agriculture reduces nutrient losses to increase yields, reduces the amounts of products for plant protection, and minimizes the cost of production to maximize output. The advancement in nanotechnology is rapidly contributing to the digitalization of agriculture also. Figure 6 displays some benefits of using nanotechnology in agriculture [15].

## **CHALLENGES**

While the potential benefits of food nanotechnology are exciting, its potential risks are not well understood as with all innovations. Various issues have been raised by nanotechnology as any new technology. There are concerns about the potential safety risks of nanomaterials (NMs) to non-



target organisms as well as to humans. As agriculture is closely related to food safety, people are likely to be sensitive to the application NMs in agriculture [20]. There may be the direct release of NMs into the environment from agro-nanotechnologies. There is the potential migration of NMs through the food chain, so safety assessment is urgently required. While the majority of public fears and concerns are unfounded, it is the result of poor communication and lack of public awareness of introducing novel technology to a traditional industry such as agriculture.

## CONCLUSION

Nanotechnology focuses on the creation, fabrication, and manipulation of biological and nonbiological materials at dimensions of roughly 1 to 100 nanometers. It has made a lot of advancements over the past decades and fairly in the field of agriculture. An increasing number of government, scientific, and independent institutional bodies have seen the potential of nanotechnology in making significant contributions to alleviating the burden of the global food supply.

Nanotechnology can be widely used to address various agricultural problems. Nanotechnology applications in agriculture exhibit great potential for improving the environment and increasing the production crop plants. Research involved in nanotechnology applied in agriculture has increased exponentially. So the future of agriculture looks promising with all the new nanotechnological developments. More information about nanotechnology in agriculture can be obtained from the books in [23-34] and also from the following related journals:

- Foods
- Food Nanotechnology
- Nature Nanotechnology
- IEEE Transactions on Nanotechnology
- Journal of Nanobiotechnology
- Journal of Food Chemistry & Nanotechnology.

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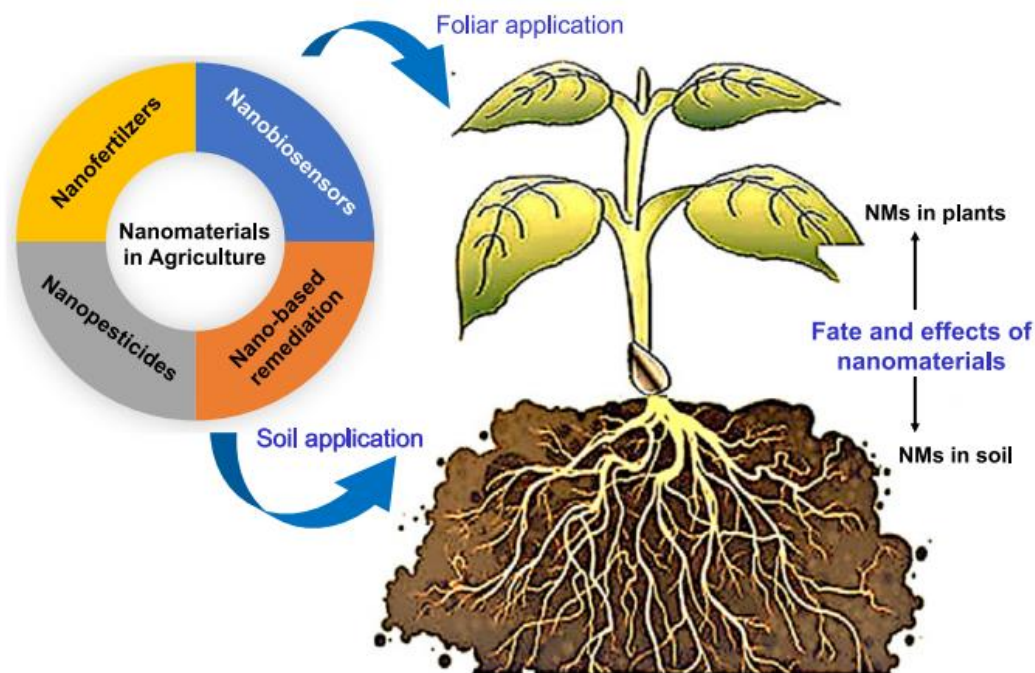


Figure 1 Nanomaterials in agriculture [5].

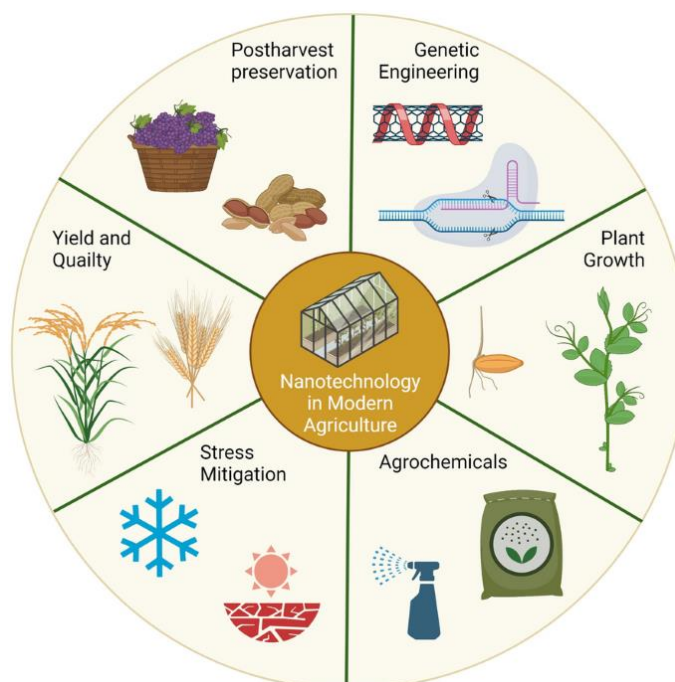


Figure 2 Nanotechnology in agriculture [12].

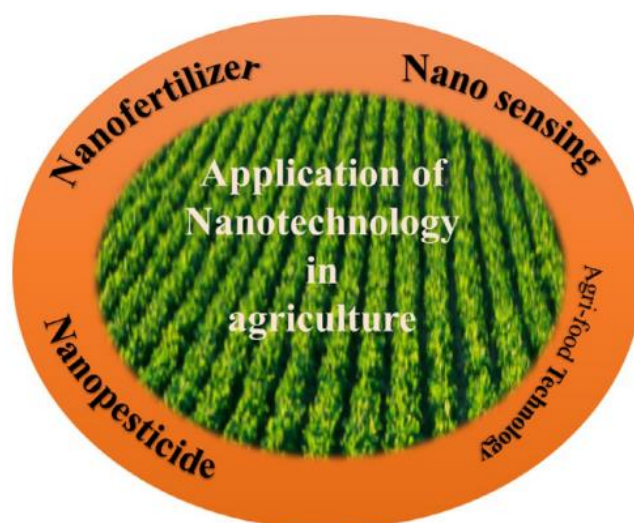


Figure 3 Applications of nanotechnology in agriculture [14]

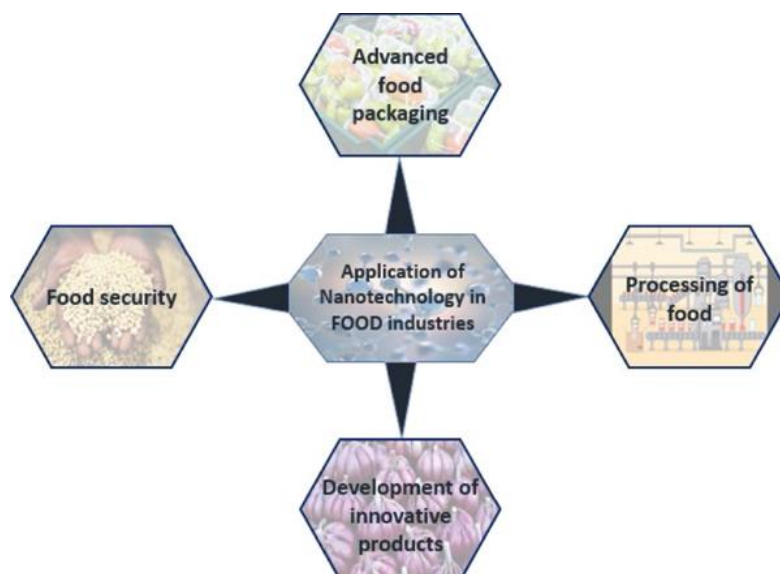
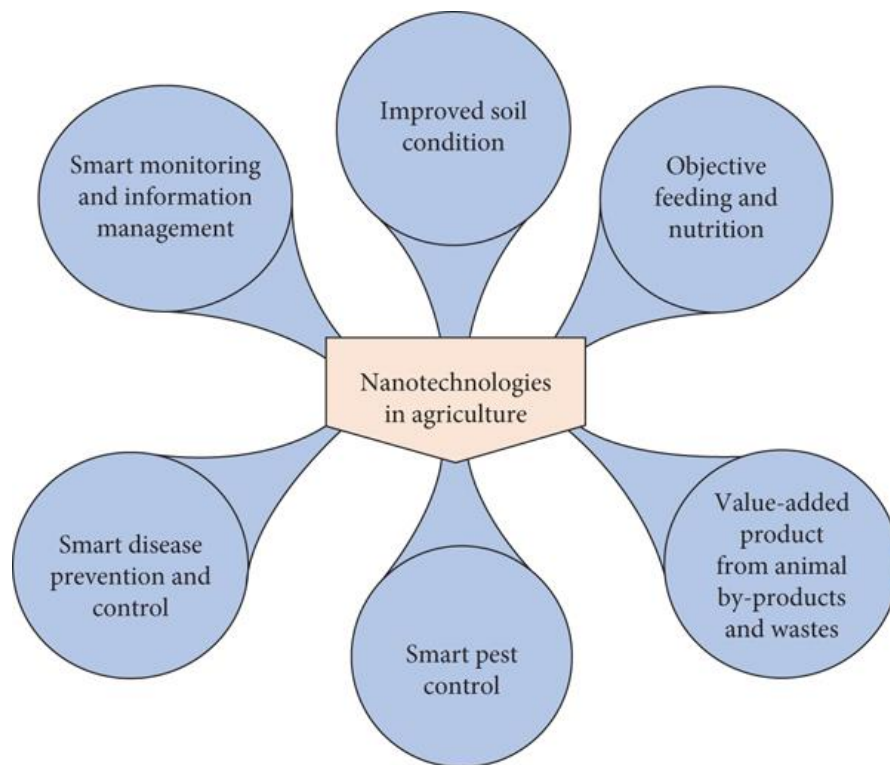


Figure 4 Some applications of nanotechnology in the food industry [15].



Figure 5 Nanofood packaging [15].





**Figure 6** Some benefits of using nanotechnology in agriculture [15].