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REVIEW ARTICLE **OPEN ACCESS**

Nanotechnology and its applications in Crop Improvement

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ABSTRACT
In recent times nanotechnology is an interdisciplinary area of science that has encountered immense progress due to its applications. The nanoparticles synthesized from different processes involved in many ways to improve the production and quality of crops. Nowadays, many biochemical companies are trying to make some potential pesticides at the nanoscale level as nanopesticides to increase the effectiveness of pesticides. Nanoencapsulation is a potent carrier for these nanopesticides to the target position and nanoparticles are also used to prepare the resistant plants and eco-friendly pesticide development. Some plants absorb Silicon nanoparticles which then lead to increased disease and stress resistance. Nanoparticles also play a major role in removing pathogens and other contaminants and its early detection through the application of nanobiosensor. Delivery of DNA into plant cells is another promising area of nanotechnology to alter the expression profile of plants. Application of nanotechnology in agriculture is increasing day by day ranging from crop production to insect and pest management (Rai M. and Ingle A., 2012). Silver and TiO_2 nanoparticles are common nanoparticles having the antimicrobial effect. Problems regarding crop improvement solved with the help of nanotechnology which included new methods to modernize agricultural research and development i.e. by molecular treatment and rapid detection of diseases and by enhancing the ability of plants to absorb nutrients etc. Smart delivery systems and smart sensors will help the agricultural industry combat crop pathogens and other contaminants.
Keywords: *Nanotechnology, Nanoherbicides, Nanopesticides, Nanobiosensors, Nanoencapsulation*

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INTRODUCTION

The word "Nanotechnology" coined by Norio Taniguichi at the University of Tokyo. The term nanotechnology is derived from a greek word 'nano' means 'dwarf '. Nanotechnology, therefore, refers to the creation and utilization of materials, devices and systems through the control of their properties and structure at a nanometric scale [22]. It is the creation of devices and systems at a length scale of ~1–100 nm. On this scale, structures have been shown to have some unique functional properties. According to the National Nanotechnology Initiative [18], Nanotechnology is the science of understanding and control of matter roughly at 1 to 100 nanometers dimensions [8]. Nanotechnology is a permitting technology that has opened new paths of research and development in many fields, including medicine, agriculture and food etc.

Agriculture is the pillar of developing countries, with more than 60% of the population depending on it for their livelihood [5]. Nanotechnology has the potential to transfigure the agricultural industries with innovative tools for the management, detection of diseases and for enhancing the ability of plants to absorb nutrients. Instead, nanobiotechnology can also improve our knowledge of the biology of various crops and thus can probably enhance the yields or nutritional values, as well as refining the systems for monitoring environmental conditions and enhancing plants ability to absorb nutrients or pesticides [25]. Among the latest scientific inventions, nanotechnology occupies a prominent position in improving agriculture and food production. The use of nano-devices and nano-materials could open innovative applications in the field of biotechnology and agriculture. Presently, the main aim of research in nanotechnology emphases in the field of electronics, medicine and life sciences [23].

This review is focused on the potential use of nanomaterials in sustainable agriculture management. Some of the recent developments in agriculture and food systems that covers the application of nanoparticles for more effective use of chemicals for plants. The effects of different type of nanoparticles on the growth and metabolic functions of different plants and nanoparticle-mediated plant genetic transformation. Although nanotechnology potentially has numerous applications in the food and agriculture industry, interested readers required more information about nanotechnology in food and agricultural systems which might additionally publish by CSREES, USDA [9].

Potential Applications of Nanotechnology

Nanotechnology has the potential to influence many aspects of food and agricultural systems [6, 7, 12].Important examples of nanotechnology are Food security, disease treatment delivery methods, tools for molecular and cellular biology, and protection of the environment [10]. Other examples of nanotechnology as a means for achieving additional improvements in the food and agricultural industry are as follows:

- Nanocapsules for delivery of pesticides, fertilizer and other agrichemicals more efficiently and to improve the bioavailability of neutraceuticals in standard ingredients.
- Nanoparticles to deliver DNA to plants (targeting genetic engineering) and nanocapsules to deliver vaccines.
- Nanosensors for monitoring soil conditions, crop growth and for the detection of animal and plant pathogens.
- Nanoparticles are used to selectively bind and remove chemicals or pathogens from food.
- Nanoemulsions and particles used for better availability and dispersion of nutrients.
- Devices to maintain ancient environmental records of a product and tracking its shipments.
- To enhance the efficiency and safety of food processing and transportation by the integration of sensing, localization, reporting, and remote control of food products.

Food processing is a multi-technological manufacturing industry which involves a wide variety of raw materials,high biosafety necessities, and well-regulated technological processes. The major areas in food production may benefit from nanotechnology is the development of new functional materials, microscale and nanoscale processing, development of product and methods/instrumentation design for enhanced food safety and biosecurity. Figure 1 depicts possible applications of nanotechnology.

At the nanoscale level, material properties of foods have been influenced their bioavailability and nutritional value [2, 3].

Nanotechnology in Crop improvement

Due to the new challenges in agriculture, the interest is rising to use nanotechnology. Goals of applying nanotechnology in agriculture are to increase crop production or yield and to increase use efficiency.

The specific application of Nanotechnology in Agriculture includes:

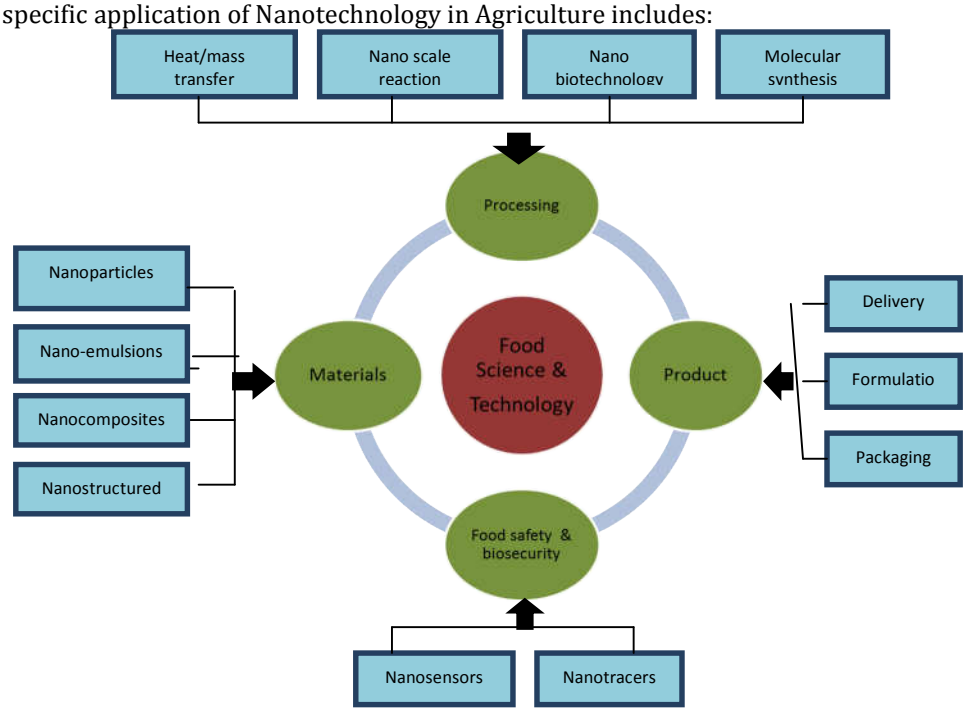

Fig 1. Nanotechnological applications

Nanogenetic manipulation of agricultural crops

Manipulating genes of crops by using nanoparticles, nanofibers and nanocapsules. Nanoparticles carry several genes that trigger gene expression in plants and Nanofibers with the potential of drug delivery can be used for quick and efficient delivery of genetic materials to plant cells. Today, DNA is being delivered into plant cells by use of gene guns or particle bombardment.

Agricultural Diagnostics and Drug Delivery

Accurate delivery of drugs, nutrients or other agrochemicals which is required for the plants. Control of plant diseases with the help of nanotechnological systems e.g. carbon, silver, silica and aluminosilicate nanomaterials. Carbon nano-fibers can be used to strengthen natural fibers. On the other hand, silver nanoparticles have significant consideration as a pesticide for various agricultural applications [1] that is used to extend the pot-life of cut gerbera flowers.

Controlled release of nano-fertilizers and nano complexes

Nanomaterials are used to control the effective release of the right doses of plant nutrients which makes the fertilizer nutrients more available to the nanoscale plant pores. The application of TiO_2 was reported to increase the yield by promoting growth, photosynthetic rate, and by reducing disease severity. Application of TiO_2 with aluminium and silica showed effectiveness in controlling downy and powdery mildew of grapes [4].

Nanobiosensors

These are nanosensors with bioreceptors probes, which are selective for target analyte molecules. Its application includes the detection of analytes such as urea, glucose and pesticides. It is also included the monitoring of metabolites and various pathogen detection. It also detects crop harvesting time, crop growth and microbial or chemical contamination [15]. Nano sensors detect soil diseases caused by soil microbes such as bacteria, fungi and viruses. Some of the types and application of nanobiosensors depicted in fig. 2. Eventually, precision farming, with the help of smart sensors primes to boost up the productivity of agriculture by providing accurate information, thus helping farmers to make better decisions. Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens [16].

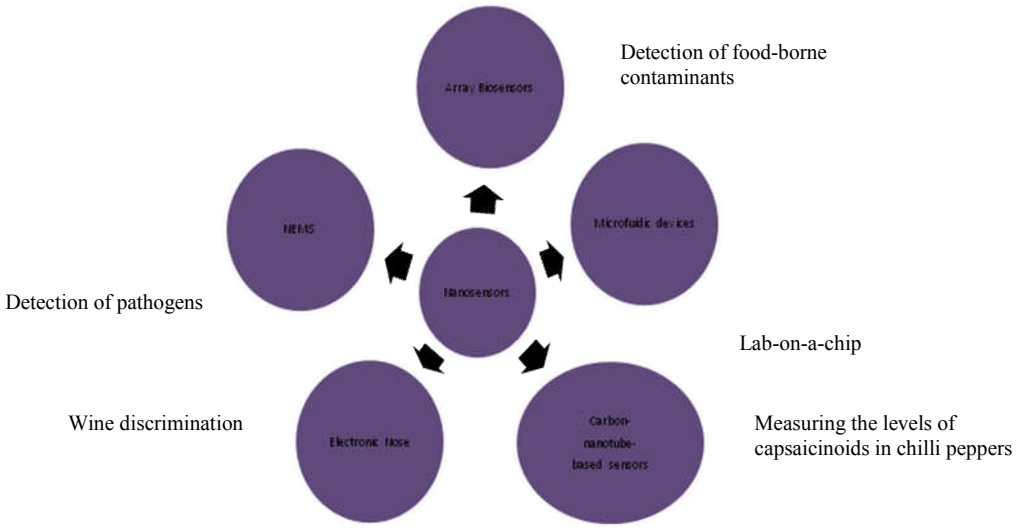

Fig 2. Types of nanosensors and their application

Nano-pesticides

Pests are the most important limiting factors to crop yields and need to be efficiently controlled. Pest control by traditional means involves the use of large quantities of pesticides, which results in environmental problems and increased cost production [24]. Pesticides dilution with the nano-treated water could greatly improve their efficiency and reduce the quantity of chemicals used. Nano-pesticides are more efficient than the conventional pesticides in controlling pests. It also reduces the cost by half of the conventional pesticides [13].

Insecticidal value can also be improved using nano- encapsulation. In this technique sealing of the nano-sized active pesticide ingredient carried out by a thin protective coating. This approach greatly improves effectiveness and decreased a number of pesticides and associated environmental hazards. For example, "Halloysite" (clay nanotubes) have been developed as carriers of pesticides which will greatly reduce the required amount of pesticides.

Nano-fertilizers

Nanourea increased grain yield by 10.2 % and efficiency of nitrogen fertilizer by 44.5 % than normal urea [13]. Conventional urea is only 58.3-87.6 % of those of the nanometer urea. 70 % nitrogen nano fertilization treatment yielded 11.6 % higher than that of the conventional fertilization [26]. Encapsulation of fertilizers within a nanoparticle is done by encapsulating nutrient inside nanoporous materials, coated with thin polymer film and delivered as particles of the nanoscale level. [20, 21]

Nano-herbicides

Weed infestation of field crops can also lead to a tremendous yield reduction if not eliminated. Nanoherbicides eradicates weeds in an eco-friendly way, without releasing any toxic residues in soil and environment [19]. Nanoherbicides blend with soil particles and prevent the growth of resistant weed species. Nanoherbicides kill viable underground ground plant parts like rhizomes or tubers, which act as a source for new weeds. They target the specific receptor in the roots of target weeds and inhibit glycolysis of food reserves in the root system.

Nanofibers and Nanotubes

Applications of nanotechnology are having an impact on the food industry are nanofibers and nanotubes. Among them, nanofibers are not usually composed of food-grade substances and have only a few potential applications in the food industry and have small diameters ranging from 10 to 1000 nm in size, which makes them ideal for serving as a platform for bacterial cultures. As with nanofibers, the use of nanotubes has predominantly been for nonfood applications and these carbon nanotubes are widely used as low resistance conductors and catalytic reaction vessels. Under appropriate environmental conditions, certain globular milk proteins can self-assemble into similarly structured nanotubes [11, 14].

Nano scale carriers

These are “smart” nano scale devices which can be positioned for the efficient delivery of fertilizers, herbicides, pesticides and plant growth regulators etc. For this, the nano scale carriers are designed in such a way that they can anchor the plant roots to the surrounding soil and organic matter, leading to improving stability against degradation in the environment.

Smart dust

Several nano-sensors will be scattered across the fields and these tiny wireless sensors are capable to communicate the information they sense. These are planned and designed in such a way that they respond to various parameters like temperature variation, humidity and nutrients. The distributed of smart particles can be networked to giving an alert in advance to devise ways and means to deal with environmental variations. By smart dust and gas sensors, it is possible to evaluate a number of pollutants in the environment [17]. The most efficacious approach in this sense is the real-time detection of parameters using autonomous sensors connected to global positioning system (GPS).

CONTROLLED ENVIRONMENT AGRICULTURE (CEA)

Smart sensors and smart delivery systems will help the agricultural and food industries combat crop pathogens and other contaminants. In near future, nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly using alternative energy supplies and filters or catalysts to reduce pollution and clean-up existing pollutants. An agricultural practice which is widely used in the USA, Europe and Japan efficiently utilizes recent controlled environment agriculture (CEA) technology for crop improvement and management. CEA is an advanced and intensive form of hydroponically-based agriculture. Plants are grown within a controlled environment so that production practices can be optimized. The computerized system monitors and regulates localized environments for crops. Today, CEA technology provides an outstanding platform for the introduction of nanotechnology to agriculture and its development.

POTENTIAL RISKS OF NANOTECHNOLOGY

Nanoparticles may enter the human body by four major paths; through inhalation, swallowing, skin absorption and deliberate injection during medical processes. Once they have entered the human body, they have a high degree of mobility, being small. In some cases, they can even cross the blood-brain barrier. Therefore, the potential danger to human and animals of nanoparticles should not be neglected. Nanoparticle residue is very difficult to be cleared away by common methods of rinsing.

CONCLUSION AND FUTURE DIRECTIONS

Conventional farming practices are becoming increasingly inadequate, coupled with increasing demands of the terrestrial ecosystem. There is need to adopt the new technologies to enhance the production of

food, fodder and fiber as for demand. Nutrient use efficiency can be enhanced by using applying nanoformulation technology in fertilizers, including breaking barriers of nutritional quality and yield through nanotechnology, surveillance and control of pests and diseases, understanding the mechanism of host-parasite interactions at the molecular scale and so on. However, requires a detailed understanding of science, as well as fabrication and material technology, in combination with knowledge of the agricultural production system. For it to flourish, continuous funding and understanding on the part of policy makers and science administrators, along with reasonable expectations, would be crucial for this promising field. In food and agriculture sector, the remarkable potential role of nanotechnology is to facilitate the next stage of precision farming techniques. It will increase the agricultural potential to harvest higher yields in eco-friendly way even in challenging environment [24].

The future belongs to new products and new processes with the goal to customize and personalize the products. Improving the safety and quality of products will be the first step. Designing and producing products by shaping molecules and atoms is the future of the food industry worldwide.

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