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Mini Review

Nanotechnology Application in Agriculture

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Abstract

Nanotechnology is emerging out as the greatest imperative tools in recent agriculture and predictable to become a driving economic force in the near future. At the same time Nanotechnology employs different chemical agents and novel delivery systems to implement crop productivity and potentials to decrease use of bulk agrochemicals, Nanotechnology may afford keener solutions for the current problems in the field of agriculture.

Direct applications of nanotechnology in agriculture include delivery of agrochemicals and nutrition, pesticides, nano-scale carriers, smart packing, nanosensors, veterinary care, fisheries and aquaculture, detection of nutrient deficiencies.

Nowadays Nano-fertilizers are increasingly been used as alternates to bulk fertilizers and reduce pollution of soil and water by different agrochemicals. Nano-fertilizers facilitate the slow and steady release of nutrients and thereby reduce the loss of nutrients and enhance the nutrient use efficiency.

Nanotechnology improves the nutrient use efficiency and reduces costs of environmental protection, slow-release fertilizers are the excellent replacement to soluble fertilizers.

This work focused on the applications of nanotechnology in agriculture sector improvement, especially in the area of plant nutrition and plant protection.

Keywords: Agriculture; Nano Application; Slow Release Fertilizers; Plant Protection; Smart Packing

Introduction

Agriculture is considered the backbone of most developing countries, with more than 60% of the population dependent on it for their livelihood. In the same times there are many challenges facing agriculture sector, like climate change, non-reasonable use of resources and usage too much chemical fertilizer [1].

"Nanotechnology is the art and science of manipulating matter at the nanoscale" the design, characterization, production, and application of structure, device, and system by controlling shape and size at nanoscale [2]. Nanotechnology is developing as the sixth revolutionary technology in the current era. It is considered as an emerging field of science widely subjugated in many scientific fields and supposed playing the main role in the field of agriculture and food science in next era, but till now there is lack in scientific studies about its application in agriculture in the worldwide [3]. Plant nutrition is crucial for agriculture production and crop quality, and about 40% to 60% of the total world food production depends on the application of fertilizers [4]. Nanotechnology is working with the smallest possible particles which increase hopes for improving agricultural productivity through encountering problems unsolved conventionally, the nanotechnology applications have the potential to change agricultural production by allowing better management and conservation of inputs of plant and animal production. Nanotechnology provide a great scope of novel applications in the plant nutrition fields to achieve the future request of the rising population because nanoparticles have exclusive physicochemical characters i.e. high surface area, high reactivity, and tunable pore size.

What is nanotechnology?

Nanotechnology is a new scientific approach that includes the use of materials and equipment capable of using physical and chemical properties of a substance at molecular levels to explore the biological and material worlds in nanometer-scale and use it in various carriers from medicine to agriculture [5]. Nanotechnology is the science and technology of tiny things, the materials that are less than 100 nm in size. One nanometer is 10 - 9 meters; Nanotechnology combines solid state physics, chemistry, chemical engineering, biochemistry, biophysics, and materials science.

Nanoparticles

Nanoparticle is defined based on the size at which fundamental characters different from those of the corresponding bulk material Nanoparticles overlap in size with colloids, which ranges from 1 nm to 1 mm in diameter [6] also, the physical properties of nanoparticles are different from the properties of the bulk material [7].

Methods of Nanoparticle Production

The Nanomaterials prepared through two basic methods (Top-down depending on size reduction from bulk materials) and Bottom-up system where materials are synthesis from atomic level (according to Royal Society and Royal Academy of Engineering).

"Top-down" systems: where tiny manipulations of little number of atoms or molecules fashion elegant patterns, through mechanical-physical methods like grinding, milling and crushing for producing nanoparticles, this method use for producing Nano composites and Nano-grained bulk materials like metallic and ceramic nanomaterials in extensive size distribution (10 - 1000 nm) as shown in figure 1.

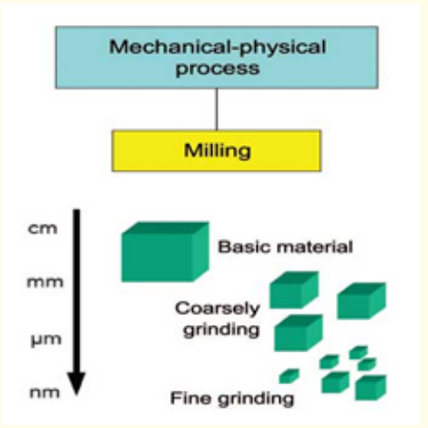

Figure 1: Schematic diagram for preparing nanoparticles by mechanical process (8).

Bottom-up system: in **'Bottom-up'** building up, numerous molecules self-assemble in parallel steps, as a function of their molecular recognition characters, this processing produces more complex structures from atoms or molecules, also, this method produce a uniform controlling sizes, shapes and size ranges of nano materials (Figure 2).

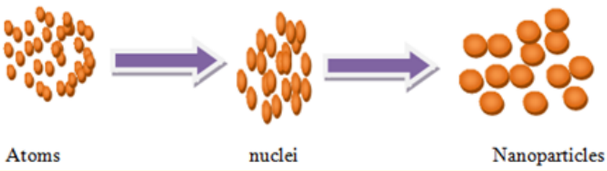

Figure 2: Structures of Nano particles are fabricated by chemical procedures (9)

Usually this method used for preparing most of the nano-scale materials (1 - 100 nm), it is plays an essential role in the production of nanostructures and nanomaterials.

Also, there are some other methods for produce Nanomaterials like attrition and pyrolysis, and biological synthesis of nanoparticles.

Some unique features of nanoparticles

In nano-world, materials less than 100-nanometer size behave completely different, the rules that manage the behavior of the elements of our known world start to give way to the rules of quantum mechanics, and everything changes. There are various advantages that nanotechnologies offer due to the unique functional properties of nanoparticles and materials like:

1. Higher charge density and higher reactivity of nanoparticles due to small size [10].

2. As the surface area increases in comparison to volume, the activity of the atoms on the surface of the particles becomes more than the inside the particles.

3. As a result of large surface to volume ratio, the nanoparticles had more strength, increased heat resistance, decreased melting point and different magnetic properties of Nano-clusters

4. Differences in the exposed surfaces of different nanoparticles lead to variances in atomic distribution across the nanoparticles, this, in turn, affect the electron transfer rate kinetics between metal nanoparticles and corresponding adsorbed species.

5. Nanoparticles have higher catalytic activity when they are present in tetrahedral structure followed by cubic and spherical structure, recognized for the improvement of chemical reactivity at the sharp edges and corner of the former [11].

Nanomaterials and Agriculture

Nanomaterials often have chemical, physical, or biological properties that are different from those of their larger counterparts and due to their different properties, nanomaterial may pose different safety issues than their larger counterparts. There has been main attention in using nanotechnology in agriculture and the food system due to great potential as it can improve the quality of different products, also, with the rapid advancement of nanotechnology since the last decade of last century, controlled preparation of Nanomaterials with desired morphology and size, and newly established concepts and methodology have underpinned the solid bases to solve the unsolved questions in nutrient uptake.

Direct applications of nanotechnology in agricultural production and products generally embrace delivery of various agrochemicals, the study of plant disease mechanisms and genomes improvement [12].

There are various positive effects of Nanomaterials in Agriculture like:

In nano-world, materials less than 100-nanometer size behave completely different, the rules that manage the behavior of the elements of our known world start to give way to the rules of quantum mechanics, and everything changes. There are various advantages that nanotechnologies offer due to the unique functional properties of nanoparticles and materials like:

(1) The higher solubility of nanoparticles in suspension.

(2) The higher surface area and particle size of the nanoparticles, which facilitates penetration of seed coats and subsequently emerging roots.

(3) Better bioavailability of molecules to the seed radicals [13].

The properties of nanomaterial for agricultural applications

The model Nanomaterials for agricultural applications are supposed to have the following properties:

1. Providing actual concentration and controlled release of fertilizers or pesticides in response to certain conditions (TiO_2 Nano particles used as plant fertilizer for Mung bean to enhance crop production) [14]
2. Improved targeted activity [15].
3. Lower Eco harmful with safe and relaxed transport.

Nanomaterials usage in agriculture

Nanomaterials have many usages in all stages of agricultural production, in different forms and various procedures such as:

1. Nano-fertilizer for balance crop nutrition [16,17]
2. Crop improvement (Zinc Nano fertilizer used to enhance crop production of *Pennisetum americanum)* [18]
3. Plant protection ingredients (pesticides, fungicides, weedicides) [19]
4. Weed management.
5. Nano pesticides [20]
6. Nano sensors [21]
7. Post-Harvest Technology [22]
8. Bioprocessing (bio synthesized) nanoparticles for agricultural use [18]
9. Bio sensors for Aqua culture [23]
10. Nano biotechnology (Analysis of gene expression and Regulation) [24]
11. Monitoring the identity and quality of agricultural produce [25]
12. Precision agriculture: Precision agricultural techniques might be used to promote increase crop yields but not damage soil and water, decrease nutrients loss due to leaching and emissions, in addition to enhance nutrients long-term incorporation by soil microorganisms as shown in (Figure 3).
13. Seed technology.
14. Water management [27]
15. Plant growth regulators [28]
16. Soil management [29]
17. Agricultural engineering aspects [30]
18. Food technology [31].

Some applications of Nanotechnology in Agriculture

a. Crop improvement
b. Increase efficient fertilizers and pesticides
c. Soil management.
d. Plant disease detection.
e. Water management
f. Analysis of gene expression and Regulation
g. Post-Harvest Technology.

Figure 3: Roles of nanotechnology in precision agriculture {26}.

Potential Risks of Nanotechnology

There are some negative effects of Nanomaterials on biological systems and the environment caused by nanoparticles, like chemical hazards on edible plants after treatment with high concentration of Nano Silver, also, in some cases, nanomaterial generated free radicals in living tissue leading in DNA damage, therefore nanotechnology should be carefully evaluated before increasing the use of the nano agro_materials [32].

Conclusion

Nanotechnology consider a novel key to growing agricultural production through implementing nutrient efficiency, improve plant protection practices, also, nanotechnology may have real solutions for various agriculture problems like improved crop varieties, plant protection, detect diseases and monitor plant growth. Nanotechnology offers generous visions for the development agricultural sector through advanced applications and the probability of products and increases global crops production volume to feed the world population in next decades. Promising results and applications are already being developed in the areas of nano nutrients, implement crop productivity, protect plants (herbicides and pesticide), nano-packing and Nano sensors.

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