



Use of Nano-technology 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. 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 direct applications of nanotechnology in agriculture include delivery of agrochemicals and nutrition, pesticides, Nano-scale carriers, smart packing, Nano sensors, veterinary care, fisheries and aquaculture, detection of nutrient deficiencies. The Nanomaterial's prepared through two basic methods and Bottom-up system where materials are synthesis from atomic level (according to Royal Society and Royal Academy of Engineering). 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.

INTRODUCTION

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 nanometre-scale

and use it in various carriers from medicine to agriculture. 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 also, the physical properties of nanoparticles are different from the properties of the bulk material.

Classification of Nanoparticles (NPs)

Based on their composition, NPs are typically classified into three grades: organic, carbon-based, and inorganic.

Table 1. List showing commonly used nanoparticles in agriculture

Types of Nano particle	Uses in Agriculture
Polymeric Nanoparticles	Release of agrochemicals, excellent compatibility by having minimal effect on non-targeted molecules
Silver and Gold Nanoparticles	Having antimicrobial properties and used in Nano biotechnology for crop improvement
Nano aluminosilicates	Used as efficient pesticides for crop protection
Titanium-oxide Nanoparticles	Used as a disinfectant for water bodies
Carbon Nanoparticles	Act as a source of improved crop growth by enhancing seed germination
Liquid Nanoparticles	Used in form of Nano fertilizers for enhanced crop growth.

Some unique features of nanoparticles-

In Nano-world, materials less than 100-nanometer size behave completely different, the rules that manage the behaviour 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 no technologies offer due to the unique functional properties of nanoparticles and material like

Higher charge density and higher reactivity of nanoparticles due to small size.

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.

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.

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.

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

Nano-fertilizers-

As a cornerstone of sustaining the ever-growing global population and driving the thriving economy, agriculture assumes a vital role. In this pursuit, the indispensable use of fertilizers has emerged as an essential practice for augmenting crop yields and preserving soil fertility. Conventional fertilizers, such as urea, nitrogen, phosphorous, potassium, monoammonium phosphate, and diammonium phosphate, are widely utilized to supplement essential nutrients in the soil. However, conventional fertilizers suffer from low nutrient utilization efficiency due to leaching, leading to substantial economic losses and decreased soil fertility. The leaching of these nutrients from the soil has resulted in a significant decrease in soil fertility. This is primarily due to the relatively low nutrient utilization efficiency of conventional fertilizers, which is around 30–35% for nitrogen, 18–20% for phosphorus, and 35–40% for potassium. The scientific community is already

working on developing slow-release chemical fertilizers; for example, combining hydroxyapatite with urea has allowed researchers to develop slow-release fertilizers that gradually release plant nutrients. Moreover, the environmental impact caused by releasing excess nutrients has necessitated the development of more efficient and eco-friendly fertilizer.

Nano fertilizers have emerged as a promising solution to address such challenges, offering higher efficiency and reduced environmental impacts. They can be classified based on their action, nutrient composition, and consistency. These categories include controlled-release Nano fertilizers, Nano fertilizers for targeted delivery, plant growth-stimulating Nano fertilizers, water and nutrient loss-controlling fertilizers, inorganic and organic nanofertilizers, hybrid Nano fertilizers, nutrient-loaded Nano fertilizers, and various consistency-based Nano fertilizers such as surface-coated, synthetic polymer-coated, biological product-coated, and Nano carrier-based Nano fertilizers.

Controlled-release fertilizers (CRFs) are promising Nano fertilizers with granular structures that deliver nutrients to plants over an extended period, ranging from weeks to months. In addition, controlled-release fertilizers can improve the environmental sustainability of agriculture by reducing the release of nutrients into the environment (Figure 2). Nanomaterials, such as carbon nanotubes, graphene, and quantum dots, have unique properties that make them ideal for controlled-release applications. Their small size, large surface area-to-volume ratio, and ability to be coated with various materials to control the release rate enhance the efficiency of nutrient delivery. These materials can also improve the granular mechanical strength of fertilizers and provide leaching resistance.

Nano-pesticide-

A pesticide is a substance that is used to dispatch, chase away, or control certain different forms of pests. Pesticides include herbicides that are used for ruining weeds and other unwanted vegetation, and insecticides are employed for destroying a variety of insects. In addition, and fungicides are applied to avoid the production of bacteria and fungi. According to Federal agency, US, the sustainable progress of Nano agrochemicals could

be an important agent for plant production along with pest management. Typically, pesticides are very useful in agriculture for disease management, and Nano-materials could be used as Nano-agrochemicals for better crop yield with low ecotoxicity. Metal and metal oxide nanoparticles were found to be highly effective in plant disease management against very serious pathogens which are responsible for huge economic loss. At global level Fusarium wilt is found to be a disorder in tomato and lettuce as a result of its wide manufacturing damage, tedious survival of fungus in land, and propagation of resistant races. These disorders can be diminished to some extent with the help of various chemicals. However, this is expensive as the chemicals used are costly and also not always effective. Thus, an alternative solution is found and which is the use of Nano-materials to control plant pathogens. Various Nano-materials have been synthesized by utilizing hydrated extracts of Punica granatum peels, Olea europaea leaves, green peach aphid (GPA), and Chamaemelum Nobile flowers. The synthesis of pesticides by using metal nanoparticles and polymers is a highly demanding area of pesticide manufacturing. Nano-encapsulation of pesticide is helpful in limited and gradual release of their active ingredients with control in outer shell of Nano capsules. This release of limited doses over a long cycle diminishes surplus drainage of undesirable pesticide. Of Nano-pesticides which were already synthesized. The perk of nanomaterials in plant disorder control and excellent crop growth are compiled in Park et al. Reported that silica nanoparticles are 100% active against powdery mildew disease in cucurbits. Silver nanoparticles (Ag) are broad-spectrum active agents against phytopathogen such as Bipolaris sorokiniana, Botrytis cinerea, Colletotrichum gloeosporioides, Fusarium culmorum, Phythium ultimum, Phoma, Megnaporthe grisea, Trichoderma sp., Sclerotinia sclerotiorum, Sphaerotheca pannosa, and Rhizoctonia solani. Some researchers have reported the synthesis of copper nanoparticles and found them effective against Gram-negative and Gram-positive fungal and bacterial disease pathogens such as Xanthomonas oryzae at very low concentration. Liu et al. also reported the controlled pesticide delivery of porous silica nanomaterial as carrier of validamycin. In order to prevent the

ecosystem from poisonous effects of toxicants, nano-pesticide action must be regulated by federal agencies. Nano-pesticides are categorized into various types based on their target and action. The classification of Nano-pesticides as follows,

Nano herbicide-

Nano-enabled herbicides (also called Nano herbicides) can be designed from organic, inorganic, or hybrid materials. These materials have unique properties such as small size, specific surface area, and the ability to control the release of metal ions and organic molecules in the agricultural field.

Types of Herbicide-

Selective herbicides will kill target weeds and not desired plants (the crop or pasture) when applied at a specified application rate. **Non-selective herbicides** (also called knockdown herbicides) such as glyphosate or paraquat will damage most plants.

Herbicides are widely used as a weed management tool in agriculture that generally requires light, water, as well as nutrients for their proper functioning and thus can often compete with crops. However, overexploitation and indiscriminate application of herbicides in order to increase crop yield have caused hazardous impact on environment some of which include water body's contamination, toxicity in non-target organisms as well as detrimental effects on human health. Therefore, this chapter describes in detail application of Nano herbicides in agricultural fields to enhance the activity of conventional herbicides used for weed control. Encapsulation of herbicides in nanomaterials minimizes the loss of herbicide along with its sustained release and increased specificity toward target weed. Several polymeric nanoparticles, Nano capsules, and Nano spheres are used as carriers for herbicides. Polymers such as alginate, chitosan, pectin, poly(epsilon-caprolactone), poly(methyl methacrylate), and poly(lactic-co-glycolic acid) are considered as ideal Nano carriers for several herbicides such as paraquat, 2,4-dichlorophenoxyacetic acid, diuron, ametryn, atrazine, and simazine, whereas other nanocarriers such as rice husk nanosorbents, mesoporous silica nanoparticles, and nanoclay can be applied for fabrication of nanoherbicides. Nanoherbicides are effective against a variety of

weed species some of which include *Echinochloa crus-galli*, *Chenopodium album*, *Bidens pilosa*, *Amaranthus viridis*, and *Raphanus raphanistrum*. Hence, nanoherbicides can become an efficient strategy in overcoming drawbacks of excessive use of conventional herbicide formulations for agricultural practices.

Nano fungicides

Fungal diseases cause significant reduction in crop yields and economical gain. So attention is given to prepare fungicides that have specific killing or inhibiting fungal diseases thus control soil borne, seed borne and air borne fungal pathogens. Fungicides can control a fungal disease at its occurrence and developmental stage improving storage life and quality of harvested crops.

Nano fungicides respecting the environment are preferred while avoiding the interactions with the non-target organisms that can reduce soil fertility directly or indirectly.

Nano insecticides

Killing of insects or obstruction in behaviour engaging in destructive means are called insecticides which agents of chemical or biological origin. But many synthetic chemical insecticides exert unwarranted toxicity and lethal effect on both terrestrial and aquatic ecosystem. Nanotechnology represents an alternative for detection and physical destruction of carriers of pathogens (malaria vectors, fleas, ants, locusts, grasshoppers), Nano formulations of man-made insecticides or Nano technological botanical insecticides based on active agents from plant extracts or essential oils are applied which show effectiveness due to enhanced absorption in plants and decreased washings.

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