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Nano-fertilizers

A Future for Sustainable Agriculture

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Introduction

Widespread existence of nutrient deficiency in agricultural soils has resulted in significant decreases in crop productivity and great economic losses in agriculture. Although application of chemical fertilizers can enhance the crop productivity, their large-scale use is not a suitable option for long run. Moreover, the available nutrients present in the bulk chemical forms as delivered by conventional fertilizers are not fully accessible to plants. In addition, the utilization of most of the macronutrient is

very low due to their inversion to insoluble form in soil. Delivery of agrochemical substance such as fertilizer supplying macro and micronutrients to the plants is an important aspect of application of nanotechnology in agriculture. Nanoscale or nanostructured materials as fertilizer carrier or controlled-release vectors for building of the so-called smart fertilizers can enhance the nutrient use efficiency and reduce the cost of environmental pollution. Nano-fertilizers can precisely release their active ingredients in responding to environmental triggers and biological demands.

The word "Nano" means one-billionth, so nanotechnology refers to materials that are measured in a billionth of a meter (nm). A nanometer is so small that the width of a human hair is 80,000 nanometers. The word "Nano" comes from the Greek word for dwarf.

A nano-fertilizer refers to a product in nanometer scale that delivers nutrients to crops. Nano-fertilizer technology is a recent innovation. Nano-fertilizers are the nutrient carrier of nano-dimensions ranging from 30-40 nm and capable of holding bountiful of nutrient ions due to their high surface area and release it slowly and steadily that commensurate with crop demand. There are naturally occurring nano particles that have been previously proposed for agricultural use, such as zeolite minerals. However, engineered nano materials can now be synthesized with a range of desired chemical and physical properties to meet various applications.

Nanofertilizers are being studied as a way to increase nutrient efficiency and improve plant nutrition, compared with traditional fertilizers. Three classes of nano-fertilizers have been proposed:

1. Nano-scale fertilizer (nanoparticles which contain nutrients),

2. Nano-scale additives (traditional fertilizers with nano-scale additives), and

3. Nano-scale coating (traditional fertilizers coated or loaded with nano-particles)

Nanomaterial coatings (such as a nanomembrane) may slow the release of nutrients or a porous nanofertilizer may include a network of channels that retard nutrient solubility. The use of nanotechnology for fertilizers is still in its infancy but is already adopted for medical and engineering applications.

Characteristics of Nano-fertilizers

- Substituting traditional methods of fertilizer application by nano-fertilizers is an approach to release nutrients into the soil both gradually and in a controlled way.
- Nano-fertilizers show controlled release of agrochemicals through site-targeted delivery, reduction in toxicity, and enhanced nutrient utilization of delivered fertilizers.
- They possess unique features that enhance plants' performance in terms of ultrahigh absorption, increase in production, rise in photosynthesis, and significant expansion in the leaves surface area.
- Besides, the controlled release of nutrients contributes to preventing eutrophication and pollution of water resources.

- In nano-fertilizers, nutrients can be encapsulated by nanomaterials and encapsulation of fertilizers within a nano particle is done in three ways
  a) The nutrient can be encapsulated inside nanoporous materials
  b) Coated with thin polymer film
  c) Delivered as particle or emulsions of nanoscale dimensions
- Nanoparticles can be loaded by nutrients most commonly through one of the following ways:
  - absorption on the nanoparticles
  - attachment on the nanoparticles mediated by ligands
  - encapsulation in nanoparticulate polymeric shell
  - entrapment in nanoparticles

Why we want to use nano-fertilizers

- Three-times increase in Nutrient Use Efficiency (NUE) and enable timely application
- 80-100 times less requirement than chemical fertilizers
- Provide 10 times more stress tolerating capacity to the crops
- Complete bio-source, so eco-friendly and also aids in aggregation
- 30% more nutrient mobilization by the plants
- 17-54 % improvement in the crop yield

Potential disadvantages of nano-fertilizers

- Health Problems
- Ecological Problems
- Lack of knowledge
- Toxicity
- Potential weaponry
- Release of toxic waste

Comparison of nanotechnology-based formulations and conventional fertilizers applications :

Sr. No.	Properties	Nano-fertilizers-enabled technologies	Conventional technology
1	Solubility and dispersion of mineral micronutrients	Nano-sized formulation of mineral micronutrients may improve solubility and dispersion of insoluble nutrients in soil, reduce soil absorption and fixation, and increase the bioavailability	Less bioavailability to plants due to large particle size and less solubility
2	Nutrient uptake efficiency	Nanostructured formulation might increase fertilizer efficiency and uptake ratio of the soil nutrients in crop production and save fertilizer resource	Bulk composite is not available for roots and decrease efficiency
3	Controlled release modes	Both release rate and release pattern of nutrients for water soluble fertilizers might be precisely controlled through encapsulation in envelope forms of semipermeable membranes coated by resin-polymer, waxes, and sulfur	Excess release of fertilizers may produce toxicity and destroy ecological balance of soil
4	Effective duration of nutrient release	Nanostructured formulation can extend effective duration of nutrient supply of fertilizers into soil	Used by the plants at the time of delivery, the rest is converted into insoluble salts in the soil
5	Loss rate of fertilizer nutrients	Nanostructured formulation can reduce loss rate of fertilizer nutrients into soil by leaching and/or leaking	High loss rate by leaching, rain off, and drift