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Nanofertilizer: A Promising Future for Global Agriculture

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Abstract

With an increment of population day by day the agriculture sector is facing a big issue with the production and the economics of production as well. Nanofertilizers are essential substance in crop production because decreasing land, size increase population, conventional fertilizers having low use nutrient efficiency, environment pollution and shortage of labour for frequent application of fertilizers. Nanofertilizers permit the nutrients intelligently by controlling release rate to match uptake pattern of crop. Nano-structured formulations improve the efficiency of fertilizer, uptake ratio their by enhancing crop yield and also saves fertilizer resources. Nanofertilizers maximize the profit, minimize the cost of production, and also help in reduction of environment pollution. Nano fertilizers are more advantageous as compared to conventional fertilizers as increasing crop quality and soil fertility. They are less harmful and non-toxic to environment and humans as compared to conventional fertilizers.

Introduction

Nanotechnology is the understanding and control of matter of sizes roughly in the range of 1 to 100 nanometres. If one of the dimensions is in this range, it is considered a nanoparticle. Bulk materials when reduced to the nano-scale show some properties (melting point, physical strength, surface area, penetration power, electric conductance, optical effect, magnetism *etc*.) which are different from what they exhibit on a macro-scale enabling unique applications. These materials can be either natural or engineered. At nano-scale, gravity would become less important, whereas surface tension and van der Waal forces would become more important (Tarafdar and Adhikari, 2015). Molecular modified or synthesized material with the help of nanotechnology used to nanoparticles for improve the fertility of soil for a better yield and increased crop quality are called as Nano-fertilizers. Non-fertilizers are the nutrient carries in the dimension of 1-100 nm (De Rosa *et al.,* 2006). Nano-fertilizer particles can be coated with nano-membranes that provide slow release of plant nutrients *e.g.,* patented nano-composite containing N, P, K, micronutrients, mannose and amino acids that improve the nutrient uptake and utilization of nutrients by grain crops. Non-fertilizer in soil lead to reduce toxicity, increased efficiency of the nutrients of nutrients in the soil, reduce negative effects caused by excessive consumption of fertilizers and reduce the frequency of application of fertilizers. Nano-fertilizers have emerged as a promising alternative that ensures high crop production and soil restoration. After successful scientific testing, preparations are being made to make nano-manure on a large scale for agriculture by the Indian Farmer Fertilizer Cooperative (IFFCO).

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Nanoparticles

Nanoparticles are molecular aggregates with at least dimension between 1 and 100 nm, that can drastically modified their physico-chemical properties compared to the bulk material (Bhattacharya *et al*., 2010). The properties like surface area, cation exchange capacity, larger surface to volume ratio, ion adsorption, higher charge density, high reactivity, can be pass through cell wall.

Syntheses of Nanoparticles

Two approaches are generally involved in the generation of nanoparticles. Top-Down approach - It is an approach given by Richard Feynman; it is based on miniaturizing techniques like lithographic techniques, machining, and templating. It's involved division of a larger solid particle into smaller particle (Nanoparticles). In nature, these methods quick and aren't cheap, are slow and not suitable for larger scale production. *E.g*., milling/ attrition, photo-lithography, electron beam lithography, chemical methods, X-ray lithography *etc*. Bottom-Up approach was discovered by Jean-Marie Lehn; it's based on gradual addition of atoms and molecules. It involved condensation of atoms/ molecules in gas phase or in solution phase allowing them to grow in size until they reach the nanoscale size. In this approach, fabrication costof the nanoparticles is much less. *E.g.,* chemical vapor deposition, Sol-gel processing, plasma spraying synthesis and molecular condensation, *etc*.

Methods Involving Nanoparticle Synthesis

Nanoparticles can be synthesized by physical, physico-chemical (Aerosol) and biological methods.

Physical Method

• Grinding: By ball mill or pot mill. *E.g.,* Phosphorus nanoparticles can be prepared physically from rock phosphate after remove the impurities and then grinding by ball mill and pot mill to obtain respectively, 28 nm and 70 nm sizes.

• Thermal evaporation: The base materials are heated at its vapor points or above.

• Sputtering: It is the remove of atom materials from a solid due to energetic bombardment of its surface layer by ions or neutral particles.

Physio-Chemical (Aerosol) Method

Aerosol methods are preferred over chemical and physical methods. There are five different aerosols techniques used for nanoparticles production.

• Furnace method: (> 100 nm)

• Flame method: (suitable precaution) TiO_2.

• Electro spray: It's the most accurate method for nanoparticles production but slowest among all the methods, *e.g*., 1 g $year^{-1}$.

• Chemical Vapour Deposition (CVD) method.

• Physical Vapour Deposition (PVD) method.

Biological Methods

There are various means of biological synthesis of nanoparticle where selected microbial protein is used to breakdown salts into their respective nano forms.

• Bacteria: *E.g*., *Bacillus megaterium* bacteria produce P NPs from Ca_3PO_4.

• Fungi: *E.g*., *Aspergillus oryzae* fungi produces Zn, P, Ag, Fe and Ti NPs.

• Plants: *E.g., Azadirachta indica* plant produces Ag NPs.

• Biomolecules (Proteins): *E.g.,* Protein is used to synthesis Mg, Zn and Fe NPs from their respective oxide salts.

• Herbs: *E.g., Desmodium triflorum* herb is used to synthesize Ag NPs.

• Microwave-assisted biosynthesis: *E.g.,* Microwave-assisted anti-malignant plant leaf of guava is used for synthesize of stable poly-shaped Au (gold) NPs.

Behavior of Nanoparticles in Soil

The characteristics behavior of nanoparticle in soils still obscure. The NPs that are present in soils may undergo transformations, such as growth, aggregation, dissolution and aging, changing the micro- or nano-environment surrounding the individual soil NPs. NPs may interact in different ways with an array of minerals of the soil solid phase and a variety of soil solution aqueous species. Because of these transformations and interactions, the extent and time scale of processes and reactions that control the fate of nutrients and contaminants may also change. Numbers of key processes are to affect the bioavailability and fate of nanoparticles in the soil environment. Nano-formulation or nano-sized fertilizers are made from ammonium humate, ammonia, urea, peat, plant waste and other synthetic fertilizers. An example of nano-formulation is the nano-sized nitrogen (N) fertilizer prepared as a result of the deposition of urea on calcium cyanamide (Chandana *et al.,* 2021). Nano nitrogen fertilizers are helpful in increasing the productivity of rice (Figure 1). It is considered an excellent alternative to chemical fertilizers as it promotes growth and reduces environmental pollution.

Nanofertilizers are Delivers Nutrients in Three Ways

Encapsulated by nanomaterial's. Encapsulated - it is packaging the fertilizers with in a kind of tiny 'envelope' or 'shell'. Reduce the contact of active ingredients with agricultural workers, environment reducing run-off rates and decrease solubility. SRF - related to their water

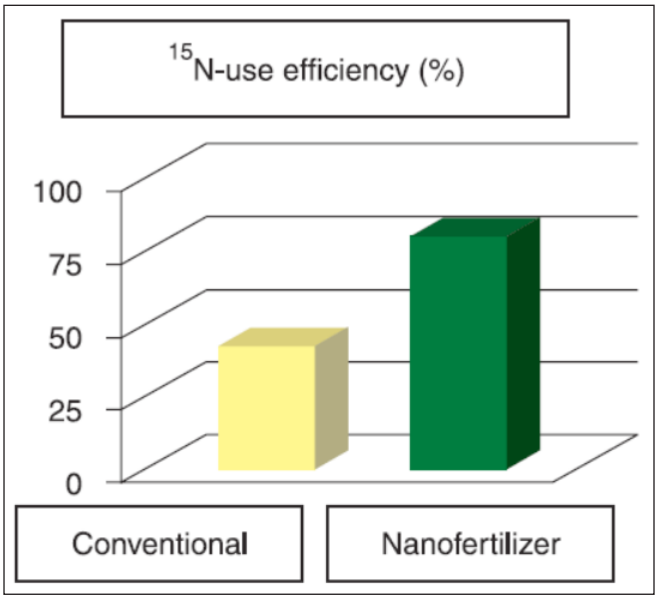

Figure 1: Nitrogen-use efficiency (%) of conventional and Nanofertilizer (Source: Chandana *et al*., 2021)

solubility, microbial degradation and chemical hydrolysis. CRF-soluble fertilizer coated with materials that limit of exposure of materials to water or slowly release of nutrient from nanofertilizer. Delivered as emulsions - Smart delivery system. A smart delivery system for agriculture should consider the factors or combination of factors such as time controlled, specifically targeted, highly controlled, remotely pre-programme and multifunction characteristic to avoid biological barriers for successful target releases of required quantity nutrients for plants. Nanomaterials and their functions are presented in table 1.

Commercial Nanofertilizers

Many commercial nanofertilizer are use in crop production such as Zeolite based nanofertilizer, Nanomang, Nanobor, Nanofert, Nanozinc, Nano-Gro fertilize, Nano-5, Nano-iron, organic nanofertilizer, Bioumik, Nano NPK, Nano gypsum, Nano-lime Florican and Nano urea.

1. Nano Urea

Nano urea its World's 1st Nano Urea launch at 31st may 2021. The production of IFFCO Nano Urea Liquid will commence by June of 2021, are developed by IFFCO's NBRC in Kalol, Gujarat in the tune of 'Atmanirbhar Bharat' and 'Atmanirbhar Krishi'. In the recent countrywide trials conduct on 90 crops, an average 8% increase in yield. This increases the production with improved nutritional quality. It contains 40,000 ppm of Nitrogen in one 500 ml bottle of Nano Urea Liquid would replace at least one bag of conventional Urea. IFFCO has price Nano-Urea at Rs. 240.00 per 500 ml bottle for the farmers which is 10% cheaper compared to cost of a bag conventional Urea.

Table 1: Nanomaterials and their functions

Sl. No.	Nanomaterial	Functions
1	Carbon nanotubes	Seed germination
2	Nanonutrients	Plant/ animal/ human nutrition
3	Nanopesticides	Plant protection
4	Nanaoscale carrier	Efficient delivery of fertilizer, pesticides, herbicides
5	Nanosensors	To detect nutrients and contaminants
6	Nanochips/smart machines	For machinery and tracing
7	Nanocellulose	Light weight material
8	Identity Preservation and Tracking	To promote quality
9	DNA nanovaccines and Gene delivery	For treatment
10	Nano barcode technology	As ID tags for multiplex analysis
11	Photocatalysis	TiO_2, ZnO, SnO_2, ZnS etc. (oxidizing agent)

(Source: Tarafdar and Adhikari, 2015)

2. Nano Organic Fertilizer

Iranian Nanotechnology Initiative Council (2009) produced the first nano-organic iron-chelated fertilizer in the world. Nano-fertilizers have unique features like ultra higher absorption, increase of 20 to 200% in production, rise in photosynthesis by 3.5 times and a 70% expansion in the leaf surface area.

3. Bio Nano-Fertilizer

Dr. Tarafdar of the Central Arid Zone Research Institute under the ICAR innovated nanofertilizers using biosynthesis, for the first time in the world. Since it is complete bio-source, nanofertilizer is eco-friendly fertilizer and improves carbon build-up, soil aggregation, and moisture retention. There is no health hazard and is suitable for all crop varieties including food grains, vegetables and horticulture (Tarafdar *et al.*, 2014).

4. Nano Gypsum

Gypsum is recommended for the reclamation of sodic soils but ability to reclaimination depends on the fineness and solubility. The possibilities of nanotechnology in soil reclamation and to improve the efficiency of gypsum requirement, a maiden attempt was made to design nano gypsum for soil reclamation.

5. Nano Lime

Nano amendment for effective remediation of soil acidity - in order to optimize the rate of lime nanotechnological approach was used. Naturally available micro-size conventional $CaCO_3$ particles were used for synthesis of nano crystals through top down approach and encapsulated with nano-ionic surfactant (1% chitosan). It produced uniform nano-sized particles (Nano-lime).

Conclusion

In a very critical situation globally we will be facing food scarcity to feed out upcoming emerging populations. The development of agriculture sector is only possible by accelerating the resources use efficiency with the minimum reduction to the yield through effective utilization of modern technologies, for this Nano-fertilizers become more potential for achieving sustainable agriculture, especially in developing countries. Nanofertilizer minimizes the cost of production, maximizes the profit and also helps in reduction of pollution.

It's just the beginning of a new advanced era and there is a great need of agricultural technique modification to fulfil the requirement of this and upcoming generation.

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