Chapter

Novel Slow Release Nanocomposite Fertilizers

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Abstract

Nanotechnology deals with atom-by-atom manipulation and the strategies and products developed are quite precise. Despite the fact that the nanotechnology is noticeably exploited in the subject of energy, environment and health, the research is agricultural sciences had just scratched the surface. However, the potentials of nanotechnology in agricultural sciences had been reviewed. Among the applications, nanofertilizers technology is very revolutionary and known to exhibit economic advantage if the products advanced are economically feasible and socially sustainable. These nano fertilizers are pronounced to reduce nutrient loss due to leaching, emissions, and long-term incorporation by soil microorganisms.

Keywords: nanofertilizer, slow release, composite, use efficiency

1. Introduction

Today agriculture in the world is facing major tasks are reduction in yield, shrinking in the cultivable land due to globalization, less efficiency of nutrient, lack of nutrient availability and uptake is poor in soil, decreasing organic matter in soil, deficiency of water accessibility. In this critical situation it is more challenging to produce adequate food to feed the increasing populaces, which is projected to pass 9 billion by 2050. The nanofertilizer is ecologically safe and increase soil fertility, crop productivity and nutrient use efficacy. Nanofertilizer deals with atom-by-atom manipulation and the processes and products evolved are quite precise. Despite the fact that the nanotechnology is greatly exploited in the field of energy, environment and health, the research is agricultural sciences had just scratched the surface. Conversely, the importance and potentials of nanotechnology in agricultural sciences had been reviewed [1]. The nanofertilizers technology is very inventive and known to show economic benefit if the products evolved are economically viable and socially maintainable. These customized nanofertilizers are reported to decrease nutrient loss due to leaching, emissions in soil ecosystem [2].

Nano based encapsulated and slow release fertilizers increase the uptake of nutrients, enhance fertility of soil and decreasing toxic effects associated with over application of fertilizer. In Tamil Nadu Agricultural University, Coimbatore, various nano-zeolite based fertilizer research carried out with Nitrogen [3, 4], phosphorous [5], potassium [6], sulfur [7, 8] have been synthesized, characterized and examined in various crops.

Considering the above referred research, there is a crucial requirement to increase smart nanofertilizer can steadily release chemical substances to exact focused places and effectively control nutrient insufficiency. Nano based smart delivery system of nutrient to crop regulated slow release, target oriented and need based [9]. The important crop based nanofertilizer or nano formulation were produced which effectively increase growth and yield of the crops without create any harmful effect in environment ecosystem [10]. Nano fertilizer are less in size, more surface area, high sorption and desorption ability, slow release of nutrient for prolonged time. Conversely, the nanotechnology is new emerging science while using nanofertilizer to crop we have to conform safety measures to environment.

2. Technology of nano fertilizers

The nano-fertilizer denotes in nano scale range to deliver nutrients to plant and also present invention which substitutes conventional fertilizer the nanofertilizer release and uptake of nutrients in the soil and crop is high [10]. The nano fertilizer will improve absorption of nutrient, potentially enhance photosynthesis, enhances the crop production [11]. The encapsulation technique is used to hold nutrient inside the carrier with polymer and steadily release nutrient to crop. The zeolite based nano porous fertilizer utilization and interest will increasing within young researchers in nano technology field [12, 13] nanofertilizer can enable nutrient carriage to the rhizosphere region and minimize nutrient loss and further improve use efficiency of applied fertilizer.

The nano fertilizers work carried out by [14] reported that using silica nano mesoporous particle to encapsulate urea and produce nano nitrogen slow release fertilizer [15] found that apatite as a source of nano phosphatic fertilizer will reduce the hazard and eutrophication problem in water ecosystem. The nano size in nature of fertilizer will enter into the plant cell is very easy without creating any ill effect [16] research reported that chitosan biodegradable polymeric molecule has been used as a source to produce nitrogen, phosphorous and potassium based nanofertilizer.

2.1 Important benefits of nanofertilizers

Nanofertilizer innovative needed products for fertilizer industry and it's having higher surface area and auspicious picking for improving the quality and quantity of plants and seeds grown for consumption, to minimize production cost as well as ecofriendly to sustainable food production. The nanofertilizer are smaller in size, shape, charge of particle this will synthesized based on crop specific and demand oriented. Abundant particle like silver, titanium, zeolite, copper, silica, aluminum, carbon, zinc, and nitrogen based nanofertilizer is available.

Generally nanofertilizers are slow release: over a period of time the nutrient will available to crop at entire life cycle. Quick release: the outer most shell of the nano particle it breaks easily and quick release of nutrient in to the soil. Specific release: some specific chemicals molecules involve to break shell of the nano particle. Moisture release: in the presence of water molecules in nanofertilizer release nutrient in easy manner. Heat release: at a particular temperature nano particle get released. pH release: specific alkaline or acidic condition favor the slow release of nanofertilizer. The nano composite and fertilizers efficiently reduce nutrient loss from environment and increase use efficiency of nutrient [17, 18] found that nanofertilizer play important in agriculture production up to 35–40% to effectively reduce chronic problem, eutrophication, and nano fertilizer are alternative for conventional fertilizer.

2.2 Possessions of nanofertilizer

- **Surface area:** The nanofertilizers possess small particle size which causes increased surface area. Increased surface area raises the nanofertilizer reactivity with other compounds thereby increases the nutrient use efficiency and nutrient uptake.

- **Solubility:** Nano fertilizer with solvents as water possess increased solubility. Excessive solubility of nanofertilizers increases nutrient bioavailability in soil by solubilization and spreading of insoluble nutrient in soil.

- **Particles size:** Nanofertilizer has particle size of much <100 nm. Due to decreased particle size the nanofertilizers diffuses into the plants and increases the uptake of nutrients

- **Encapsulation of nanofertilizer:** Encapsulated nanofertilizer increases the available and nutrient uptake by plants [19]. Zeolite-based encapsulated nanofertilizers enhance availability of zinc and nitrogen to prevent from denitrification, volatilization, and leaching of nutrient in the soil.

- **Controlled release of fertilizers:** Controlled release of fertilizer decreases the toxicity of fertilizer. In peanut seeds Zinc oxide nano fertilizer produce increased growth of root and percentage of germination than bulk zinc sulphate due to its controlled release nature [20].

- **Nutrient uptake efficiency:** Nanofertilizers as increased uptake efficiency and limited leaching loss of applied fertilizers [21].

2.3 Nanofertilizer prepared based on zeolite

Zeolite mesoporous particle is potentially used for synthesis of nanofertilizer and its having higher surface area (900 m^{-2} g^{-1}) of zeolite, making zeolite an extraordinarily effective ion exchange [22]. The surface area, excessive nutrient absorption ability, water holding capacity and internal micro pore numbers is high in nano sized zeolite mineral due to having desirable physical and chemical properties. Zeolite acts as a carrier of nitrogen, phosphorous, potassium and micronutrient fertilizers enhance the productiveness of crops [23, 24]. Accordingly, nanofertilizers prepared based on zeolite are successful of deliver nutrients up to 50 days in case of traditional fertilizer like urea ended with 10–12 days [25, 26] pronounced that ammonium and potassium encapsulated with clinoptilolite it will increase the solubility of nutrient to the crop reported that nano clay like zeolite and montmorillonite carrying nitrogen are ability to deliver prolonged period of time (>1000 h) than conventional fertilizers (<500 h).

The increase nitrogen use efficiency by utilizing adsorbent of nano zeolites. The nitrogen use efficiency of conventional urea rarely exceeds 30–35% and nano zeolites has massive viable to normalize the discharge of nitrogen and nano zeolite encapsulated urea supports adsorption of nitrogen in higher zeolite mesoporous structure. The nitrogen content of zeourea and nano-zeourea confined 18.5 and 28% respectively release nitrogen 34–48 days in case of urea the nitrogen release arrest within 4 days [27, 28] proven that mixing urea with zeolite and sago waste water has extremely good advantage over urea alone as the combination increase the ammonium and available nitrate ions. The zeoponic is a plant grown with zeolite as a substrate and release demand driven nutrient delivery system [29]. The release of phosphorous from unmodified fertilizer loaded with zeolite and surface modified zeolite from strong potassium dihydrogen phosphate was once performed the use of the constant flow percolation reactor. The phosphorous supply from surface modified zeolite used to be available even after 1080 h of continuous percolation, while phosphorous from potassium dihydrogen phosphate was once exhausted within 264 h [30].

The nanoparticles, nano-zeolite as higher surface area due to this property it release fertilizers and anionic sulphate in slow and constant manner [31]. The pure ammonium sulphate and surface modified sulfur nano-zeolite were exposed to test nutrient release pattern by utilizing percolation reactors. The research data obviously designate that all of the available sulphate in pure ammonium sulphate is exhausted after 384 h while the launch of SO_4^{2-} from sulphate loaded surface modified nano-zeolite is sustained even after 912 h, with concentrations ranging from 47.56 to 8.27 $\mu g\ g^{-1}$. The surface modified nano sulfur is confirmed effective sulphure nanofertilizer as compared to conventional sulfur [32].

3. Formulation and preparation of nanofertilizer

3.1 Nitrogen

The urea treated with hydroxyapatite nanoparticles is attained by controlled adding of phosphoric acid into a suspension of $Ca\ (OH)_2$ and urea, monitored by fast drying using spray dryer. The research found that release of urea from the nanohybrids with a 1:6 hydroxyapatite to urea ratio released urea 12 times more gradually associated to pure urea. Additionally, the nanohybrid confined very nearly the same quantity of available nitrogen as pure urea [33].

3.2 Phosphorus

The encapsulated unmodified zeolite potassium dihydrogen phosphate release phosphorus from fertilizer and the percolation reactor used to test release pattern of surface modified zeolite from soil. The research found that the phosphorus source from fertilizer-loaded surface modified zeolite was accessible 1080 h of constant percolation, however phosphorus from potassium dihydrogen phosphate was arrest 264 h. This study confirmed that surface modified zeolite act as a potential nano fertilizer for phosphorus.

3.3 Potash

Li and Zhang [20] described that potassium encapsulated with zeolite as a controlled release fertilizer and observed the hot pepper growth parameter and potassium dynamics in soil. The high cation exchange capacity of the nano clays is produced when silica (Si^{4+}) is replaced by aluminum (Al^{3+}) increase negative charge in the clay lattice. This negative charge is composed by cations such as ammonium, sodium, calcium, and potassium, which are interchangeable with other cations. Potash fertilizer is directly involved in photosynthesis process, it assist stomata opening in leaves and water storage. Potash fertilizer are released slowly by using Polyacrylamide-based coated pellets.

The fertilizer contribute 35–40% of crop productivity along with seed and proper irrigation. The imbalance use of fertilization especially urea it may create surface water nitrate pollution and deficiency of nitrogen in soil. In the earlier few decades, use efficiencies of nitrogen, phosphorous and potassium fertilizers have continued stable as 30–35%, 18–20%, 35–40% respectively. To overcome multi-nutrient deficiencies, imbalanced fertilization, low fertilizer use efficiency and decreasing soil organic matter it is crucial to develop a nano-based fertilizer for smart delivery of nutrient to targeted site. The application of nanofertilizer in foliar spray of 640 mg/ha foliar application (40 ppm concentration) of nano phosphorous gave 18 kg/ha phosphorous equal yield of cluster bean and pearl millet in arid environment condition. The research data propose that stable fertilization can also be deliver through nanotechnological approach to meet out crop demand and fertilizers encapsulated in nanoparticles will enhance the uptake of nutrients [34].

4. Nutrient use efficiency and nanofertilizer

Enhancing nutrient use efficiency is a commendable goal and ultimate trial handled by agriculture fertilizer industry in worldwide. Presently nanofertilizer have involved with the experimental fields to increasing use efficiency of applied fertilizer. The nanofertilizer consist of higher surface area because lesser in size of the nanoparticle and have high reactivity, solubility in water. The nano encapsulation techniques considered as three ways: (a) nutrient can be encapsulation inside nanoporous particle, (b) A thin polymer can be used for outer coating (c) Can be released nanosize level fertilizer. Zeolite based nano encapsulated fertilizer is ability to release nutrient in slowly in to the crops and increase nutrient use efficiency [35].

In the conventional fertilizer the 50–70% of low in nitrogen use efficiency. New smart delivery systems of nano technological approach is enhance nitrogen availability and use efficiency. The fertilizer use effectivity in 10–25% for phosphorus. With nano-fertilizers rising as substitutes to traditional fertilizers, buildup of nutrient in soils and thereby eutrophication and drinking water impurity may additionally be eliminated. In fact, nanotechnology has opened up new opportunities to enhance nutrient use efficiency and limit charges of environmental protection. The encapsulation techniques such as manganese core shell will help to uptake and slow release of nutrient need based (5). Maximum number of agricultural soils in India have low native fertility and effective and continuous crop production on these soils needs regular nutrient efforts. The considerable available of nutrients for recycling through animal manures and crop residues is significantly insufficient to reimburse for the quantities uptake in crop production.

However, the use of conventional fertilizers in worldwide improved progressively over a period of time the use efficiency of nutrients applied as fertilizers continues to remain terribly low in phosphorous (15–20%) and micronutrients (2–5%) like zinc, iron, copper. When nutrient inputs are used incompetently then both cost of farming and threat of biosphere pollution rise. Thus, the economy and ecology highlights the obsessive need for more effective use of nutrients in crop production. Since, fertilizer nutrients are exclusive and used in huge quantities at national level, any rise in use efficiency will lead to a considerable cut in nutrient necessity and huge economic advantage at national level [36]. The slow-release properties of Zn to plants may be closely associated with higher yields. Nanotechnology has great potential in agriculture as it can enhance the quality of life through its application in fields like sustainable and quality agriculture, and improved and rich food for the community [37, 38].

5. Environmental and health situation of nanofertilizers

The utility of nanostructures or nanoparticles as agrochemicals (fertilizers or pesticides) is systematically being explored, before nanofertilizers may want to be used in agriculture or farming for a general farm practice. The homes of many nanoparticles are viewed to be of attainable hazard to human health, viz., size, shape, solubility, crystal phase, type of material, and exposure and dosage concentrations. However, specialist opinions indicate that food products containing nanoparticles available in the market are probably protected to eat, but this is an area that needs to be more actively investigated. To address the protection challenge element research are required to know the effect of nanoparticles within the human body once exposed through nanofood. Researchers have to assess and improve suited evaluation techniques to investigate the impact of nanoparticles and nanofertilizers on biotic and abiotic factors of ecosystem. Among the various issues, the accumulation of nanomaterials in environment, edible part of plants would possibly be the necessary issues earlier than use in agriculture.

6. Conclusion

World population is increasing geometrically its great agricultural challenge for feed the developing population with nutritious food. The biotic and abiotic constraints which limits the agricultural productivity furthermore has an effect on human health and use of exclusive nanofertilizers to improving crop production in agriculture. Consequently, it is required to attentively study the association of nanoparticle and crop microbiome. Supplementary, in order to recognize the interface of nanoparticle with soil and environment ecosystem. Investigational confirmation of the allowable use of nanofertilizer quantity within safety limits need to be described. The interface of nanomaterials with soil and plants varies with the type of nanofertilizer the applied attention of nanoparticle the time of treatment, plant genotype and the stage of growth. Regardless of these possible benefits, the recommendation of nanofertilizer in crop enhancement could come with hazards for the environment non-target plants, useful soil organism affected if nano-materials are misrepresented.

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