International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(3): 2839-2842

Received: 19-03-2019
Accepted: 21-04-2019

Nitumoni Mahanta
PhD Scholar, Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Ashok Dambale
PhD Scholar, Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Montrishna Rajkhowa
MSc Scholar, Department of Soil Science Assam, Agricultural University, Jorhat, Assam, India

Correspondence
Nitumoni Mahanta
PhD Scholar, Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Nutrient use efficiency through Nano fertilizers

Nitumoni Mahanta, Ashok Dambale and Montrishna Rajkhowa

Abstract
Nutrient use efficiency is one of the most important concepts for evaluating crop production systems, which can be highly influenced by various factors such as fertilizer management and soil and plant-water relationships. Improving the nutrient use efficiency has been listed among todays most critical and formidable research issues. The nutrients are used with an objective of increasing the overall performance of crops and cropping systems by providing optimum nourishment and supporting sustainable agricultural production systems through contributions to soil fertility and other important soil quality components. The higher mobility of the Nano-particles lead to transport of the Nano formulated nutrients to all parts of the plants. Due to a high surface area to volume ratio, the effectiveness of Nano-fertilizers becomes superior to the most innovative modern conventional fertilizers. The plant nutrients encapsulated in Nano-particles also increases availability of the nutrient elements and thus uptake to the crop plants.

Keywords: Nutrient use, Nano-fertilizers, nourishment, sustainability, Nano particles, zeolite

Introduction
The emerging field of nanotechnology has a greater role in crop production with a strong promise to affect the current status of fertilizers with environmental safety, ecological sustainability, and economic stability. Due to the growing challenges in Agriculture, interest in nanotechnology has been increased with the goals to increase crop production and to increase resource use efficiency. The products of nanotechnology, the Nano-particles can be utilized in the entire agriculture production system value chain (Tarafdar *et al*., 2012a) [15]. These nanoparticles have a high surface area, high activity, better catalytic surface, rapid chemical reaction, they are rapidly dispersible and they can adsorb abundant water. The Nano formulated nutrient elements hold great promise for application in plant nourishment because of the size-dependent qualities, high surface-volume ratio, and unique optical properties. The physicochemical properties of nanomaterials differ significantly from those of bulk materials having the similar composition. Owing to a high surface area to volume ratio, the effectiveness of Nano-fertilizers may surpass the most innovative polymer-coated conventional fertilizers, which have seen little improvement in the past ten years (Naderi and Danesh-Shahraki, 2013) [11].

Nano fertilizer
The science of nanotechnology has provided the feasibility for the utilization of nanoscale or nanostructured materials as fertilizer carriers or controlled-release carriers for building the "smart fertilizer" to reduce costs of environmental protection (Chinnamuthu and Boopathi, 2009). We can say that the Nano-fertilizers are the Nano formulated particles that can directly supply essential plant nutrients and can be delivered at time and dose required by crops to the rhizosphere (Subramanian and Tarafdar, 2011) [14]. In other words, a nano-fertilizer refers to those products that supply the plant nutrients either by encapsulating the nutrients inside nano-materials or nano-porous materials, or coated with a thin protective polymer film. A nano-fertilizer possesses such unique physico-chemical properties that they can fulfill plant root requirements more efficiently as compared to the conventional fertilizers. Encapsulation of fertilizer nutrients within a nanoparticle can be done in the following ways-
a) The nutrient can be encapsulated inside the nano porous materials
b) The nutrient can be coated with a thin polymer film
c) The nutrient can be delivered as tiny particles or emulsions of nanoscale dimensions

Moreover, for synchronizing the release of fertilizer-N and P with uptake by crops, nano-fertilizers can be combined with nano devices, thus preventing undesirable nutrient losses to the environment and avoiding the undesirable interactions of nutrients with soil, water and air (De Rosa *et al*., 2010) [3].

In a broader sense, the nano-fertilizers are synthesized or modified form of conventional or traditional fertilizers, fertilizer bulk materials or are extracted from different parts of plants through chemical, physical, mechanical or biological methods with the help of the science of nanotechnology, and used for improving soil fertility, productivity and quality of agricultural produces. Coating and binding of nano and sub-nano-composites are capable of regulating the release of nutrients from the fertilizer capsules (Liu *et al*, 2006) [9]. The nano-fertilizers slow up the release of nutrients and thus they reduce the effect on the environment and the contamination of the subsurface water. With very smaller sizes (below 100 nm), nano-particles can be used as fertilizer material for efficient and ecofriendly nutrient management.

Nano fertilizers in crop nutrition

Supplying the required plant nutrients in the form of nano-fertilizers can contribute to plant nutrition in the following two ways:

1. Nanostructured elements are incorporated in such a carrier complex that may or may not be a nanomaterial. It is incorporated by absorption or adsorption in a matrix such as a chitosan, poly acrylic acid, clay or zeolite.
2. Using the required nutrient elements in nanostructured formulations (either in suspension or encapsulated)

In many cases, the problem associated with crop mineral nutrition is not related to the amount of one or more elements present in the soil. But the problem is associated with their availability to the crop plants. Due to this factor, the encapsulation of fertilizer elements and other compounds in inorganic nanomaterials have been explored. Some of the examples are nanotubes of Carbon, nano compounds of clay montmorillonite-urea, nanoparticles of SiO_2, nano porous or mesoporous silica and natural or synthetic zeolites (Ditta and Arshad, 2016) [4].

Higher nutrient use efficiency through nano-fertilizers

The nano-fertilizers possess certain specific properties, which facilitate higher nutrient use efficiency. The important properties are:

1. The nano-fertilizers have a higher surface area, which is mainly due to the very smaller size of the nanoparticles that provide more sites to facilitate the different metabolic process in the plant system. This results in the production of more photosynthesis with less consumption of nutrient elements.
2. They have high solubility in different solvents such as water.
3. The particle size of nano-fertilizers is very small (less than 100 nm), which facilitates more penetration of nano-particles into the plant system.
4. Nano fertilizer elements have the large surface area and particle size smaller than the pores of root and leaves of the plants. This increases penetration into the plant system from applied surfaces and thus improves uptake and nutrient use efficiency of the nano-fertilizers.
5. The reduced particle size of nano fertilizer results in increased specific surface area and a number of particles per unit area of fertilizer, which provide more opportunity for contact of nano-fertilizers and it leads to more penetration and uptake.
6. The fertilizer elements encapsulated in nano-particles increases the availability and hence uptake of the plant nutrients to the crops.

Zeolite-based nano-fertilizers are capable of releasing the nutrients slowly to the crop plant which increase the availability of nutrient elements to the crops though out the growth period. This prevents loss of nutrients through denitrification, volatilization, leaching and fixation in the soil especially NO_3 and NH_4 forms of Nitrogen.

Nanoparticles based delivery systems

It is already mentioned that the nanomaterials used as fertilizers have potential contributions in slow release of plant nutrients. The higher surface tension provided by the surface coatings of nanomaterials on fertilizer particles helps to hold the materials more strongly than the conventional material surfaces. Following are the nanoparticle based delivery system -

1. **Chemical system:** Fertilizer materials with sulfur nano coating are very useful slow release fertilizers as these materials supply sulfur elements in addition to the primary nutrient elements. The fertilizer dissolution rate is reduced by the stability of the coating and thus it allows slow sustained release of sulfur coated fertilizer. In addition to sulfur coatings, encapsulation of urea and phosphatic fertilizers with nano-materials are also beneficial to meet the soil and crop demands. Some other useful nanomaterials with potential application include kaolin and polymeric biocompatible nanoparticle (Wilson *et al*., 2008).
2. **Biological system:** The formulations of bio fertilizer inocula, their storage and method of application are critical to their success in the crop field. The polymeric nanoparticles are potentially suitable for their application for coating of bio fertilizer preparations to yield desiccation resistant formulations.
3. **Field application of fertilizers:** The mode of application of fertilizer influences their efficiency and environmental impact (Matthews and Thomas, 2000). The constraints associated with the droplet size of foliar sprays may be overcome by using nanoparticles encapsulated or nano formulated fertilizer elements that will contribute to efficient spraying and thus will reduce spray drift and splash losses.

Control release of Nano fertilizers

There are a number of ways, by which the control release is achieved in Nano fertilizers. These are discussed below:

1. The nano-fertilizers are mixed with different materials such as hydrogels, special films or other biopolymers such as chitosan to reduce the uncontrolled release in the soil environment (Kashyap, 2015) [6]. These materials aggregate the fertilizers in complexes with mineral nanoparticles obtained from the clay in soil or other types of ceramic materials (Choy *et al*., 2007) [2], that are used for manufacturing controlled- release blocks, pots, or film. These respond to different environmental stimuli such as temperature or irradiance and modify the release of the nano fertilizers according to the plants' need.
2. Another alternative for regulating the release of nano fertilizers to the environment is by applying as foliar spray, especially for the elements having limited

bioavailability in soil such as Fe, Cu and Ni. For this purpose, the emulsions or encapsulated organic nanoparticles can be useful.

Finally, another way to enable slow release of nutrient elements from the nano fertilizers in the environment is by matching their quantities with the stage of crop growth.

Movement of nano fertilizer elements inside the plant

The nanoparticles used as Nano fertilizers are absorbed by the plant roots efficiently due to their very small size. These are then transported through apoplastic and symplastic pathways to the xylem, cross the endodermis and then they move through the vascular bundles to the different parts of the plant. This mode transport inside plant has been observed for mesoporous silica nanoparticles and SiO_2 nanoparticles (Le *et al.*, 2014) [7]. It has been reported that different classes of nanoparticles are transported in the plant to the inside of the cells through endocytosis or through pores or channels (Gao *et al*. 2008) [5].

Presence of an essential plant nutrient element in the substrate or soil in the form of nano fertilizer allows better dissolution, faster absorption and assimilation by the plants as compared to traditional fertilizers and this has been demonstrated for nutrient elements such as N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and Mo (Ditta and Arshad, 2016) [4]. It is very much important that the Nano fertilizers be released in a correct form and at a rate suitable for plants, which minimizes losses by leaching, gasification or by competition with other organisms.

Achievements of nano-fertilizers

Recently several research studies revealed that nano-fertilizers enhanced crop growth, yield and quality parameters of the crop, which resulted better food products for human and animals. The fields of success of nano fertilizer application are discussed below:

1. **Yield**: Several research studies revealed that application of nano-fertilizers significantly increased crop yield as compared to traditional fertilizers. This is mainly because of increased growth of plant parts and enhanced metabolic processes such as photosynthesis, which leads to higher accumulation and translocation of photosynthesis to the economic parts of the plant. It is also reported that foliar application of nano-fertilizers significantly increased yield of crops (Tarafdar, *et al.*, 2012b) [16].
2. **Nutritional Value:** Nano-fertilizers provide more surface area and hence more availability of nutrients to the crop plants. This helps to improve the quality parameters such as protein, oil content and sugar content by enhancing the rate of reaction or synthesis process in the plant system. Application of nano formulations of zinc and iron was found to increase total carbohydrate, starch, IAA, chlorophyll and protein content in the grains of crops.
3. **Health:** We know that some plant nutrient elements are responsible for disease resistance in the plants. Increased availability of nano-nutrient elements to the plant protects the crop plants from disease, nutrient deficiency and other biotic and abiotic stresses, which indicates that overall health of the plants is enhanced by the nano-fertilizers.
4. **Effects of nano-fertilizers on seeds germination and growth parameters of the plant:** It has been reported by several researchers reported that nano fertilizers significantly influenced the seed germination and seedling growth in many crops. This is due to the fact that nano-fertilizers can easily penetrate into the seed and increase availability of nutrients to the growing seedling and result healthy shoot and root growth. Nano formulation of ZnO recorded higher germination percent and root growth of peanut seeds as compared to bulk zinc sulphate (Prasad, *et al.*, 2012) [12]. Similarly positive effect of nano-scale SiO_2 and TiO_2 was found on germination of soya bean seeds (Liu, *et al.*, 2005) [8].

Nano-fertilizers increase the availability of nutrient to the growing plant parts, which increase chlorophyll formation, rate of photosynthesis, dry matter production and thus improve overall growth of the plants. It was reported that the nano-TiO_2 treated seeds produced such plants that showed more dry weight, higher photosynthetic rate and chlorophyll-a formation as compared to the plants produced from untreated seed (Zheng *et al*., 2005) [18].

Conclusion

The nano-particles are found to be an attractive alternative for utilizing in the nano fertilizers production with greater effectiveness and agronomic efficiency as compared to traditional sources of fertilizers. Application of different nano-fertilizers have greater role in enhancing crop yield, minimizing the pollution hazard to environment and reducing the fertilization cost for crop production. Hence with effective use of nano-fertilizers in the crop fields, nutrient use efficiency can be enhanced. The nano-fertilizers improve crop growth and yield when these are applied at optimum doses and concentrations. But exceeding certain optimum limit can have inhibitory effect on crop plants, which may lead to reduced growth and yield of the crops. Therefore optimization of doses of different nano fertilizers for different crops is of prime importance. With the optimization of doses for different nano fertilizers and for different crops, it can lead to a highly efficient production system in an ecofriendly way in near future

References

1. Chinnamuthu CR, Boopathi PM. Nanotechnology and Agroecosystem. Madras. Agric. J. 2009; 96:17-31.
2. Choy J, Choi S, Oh J, Park T. Clay minerals and layered double hydroxides for novel biological applications. Appl. Clay Sci. 2007; 36:122.
3. De Rosa MR, Monreal C, Schnitzer M, Walsh R. Sultan Y. Nanotechnology in fertilizers. Nat. Nanotechnol. J. 2010; 5:91.
4. Ditta A, Arshad M. Applications and perspectives of using nanomaterials for sustainable plant nutrition. Nano technol. Rev. 2016; 5:209.
5. Gao F, Liu C, Qu C, Zheng L, Yang F, Su M *et al*. Was improvement of spinach growth by nano-TiO_2 treatment related to the changes of Rubisco activase. Bio metals. 2008; 21:211.
6. Kashyap PL, Xiang X, Heiden P. Chitosan nanoparticle based delivery systems for sustainable agriculture. Int. J. Biol. Macromol. 2015; 77:36.
7. Le V, Rui Y, Gui X, Li X, Liu S, Han Y. Uptake, transport, distribution and Bio-effects of SiO_2 nanoparticles in Bt-transgenic cotton. J. Nano biotechnology. 2014; 12:50.
8. Liu XM, Zhang FD, Zhang SQ, He XS, Fang R, Feng Z, *et al*. Effects of Nano-ferric oxide on the growth and

nutrients absorption of peanut. Plant Nutr. Fert. Sci. 2005; 11:14-18.

9. Liu X, Feng Z, Zhang S, Zhang J, Xiao Q. Preparation and testing of cementing nano sub nano composites of slow or controlled release of fertilizers. Science Agriculture Journal. 2006; 39(8):1598-1604.
10. Matthews GA, Thomas N. Working towards more efficient application of Pesticides. Pest. Manag. Sci. 2000; 56:974-976.
11. Naderi MR, Danesh-Shahraki A. Nano fertilizers and their roles in sustainable agriculture. International Journal of Agriculture and Crop Sciences. 2013; 5(19):2229.
12. Prasad TN, Sudhakar P, Sreenivasulu Y, Latha P, Munaswamy V, Raja Reddy K *et al*. Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. J of plant nutrition. 2012; 35:905-927.
13. Rajaie M, Ziaeyan AH. Combined effect of zinc and boron on yield and nutrients accumulation in corn. Int. J. Plant Prod. 2009; 3:35-440.
14. Subramanian KS, Tarafdar JC. Prospects of nanotechnology in Indian farming. The Indian Journal of Agricultural Sciences. 2011; 81:887-893.
15. Tarafdar JC, Raliya R, Tathore I. Microbial Synthesis of Phosphorous Nanoparticle from Tri-Calcium Phosphate Using *Aspergillus tubingensis* TFR-5. Journal of Bio nanoscience. 2012a; 6:84-89.
16. Tarafdar JC, Agarwal A, Raliya R, Kumar P, Burman U, Kaul RK. ZnO Nanoparticles Induced Synthesis of Polysaccharides and Phosphatases by Aspergillus Fungi. Advanced Science, Engineering and Medicine. 2012b; 4:1-5.
17. Wilson MA, Tran NH, Milev AS, Kannangara GSK, Volk H, Lu GHM. Nanomaterials in soils. Geoderma. 2008; 146:291-302.
18. Zheng L, Hong F, Lu S, Liu C. Effect of nano-TiO_2 on strength of naturally aged seeds and growth of spinach. Biol. Trace Elem. Res. 2005; 104:83-91.