NANO-FERTILIZERS A TECHNOLOGY TO INCREASE CROP PRODUCTION

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Received-01.04.2021, Revised-17.04.2021, Accepted-26.04.2021

Abstract: Recently the Nano-fertilizers are getting importance in sustainable agriculture in increasing crop production, enhancing nutrient use efficiency and reduction in wastage of chemical fertilizers and cost of cultivation. The new developments on application of nano-fertilizer in agriculture, plant mineral nutrition, soil health, and interactions with soil microorganism directed to sustainable way by replacing conventional fertilizers with their nano-particle counterparts possessing superior properties to overcome the current challenges of availability and uptake of nutrients, increasing crop yield and protecting the environment. Nano-fertilizers are very effective tool for precise nutrient management in precision agriculture with matching the crop growth stage for nutrient and may provide nutrient throughout the crop growth period. Several studies showed that nano-particles of essential minerals and non-essential elements affected plant growth, physiology and development, depending on their size, composition, concentration, and mode of application. Nano-fertilizers provide more surface area for different metabolic reactions in the plant system which increase rate of photosynthesis and produce more dry matter and yield of the crop. Nano-fertilizers are applied either to soil and / or leaves. Foliar application can be done during unfavorable soil and weather conditions. In addition to this, it promotes the direct entry of nutrients into the plant system, foliar application of nano fertilizer leads to higher nutrient use efficiency (NUE) and has given a rapid response to the growth of crops. Nano fertilizers are more reactive and can penetrate through cuticle, ensuring controlled release and targeted delivery. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries.

Keywords: Crop, Nano-Fertilizers, Production, Technology

INTRODUCTION

Presently agriculture all across the world is facing a wide range of challenges; the important challenges are (a) crop yield stagnation (b) decrease in arable land due to land degradation and urbanization (c) low nutrient use efficiency (d) deficiencies of more than one nutrient in soil (e) declining soil organic matter (f) water availability etc. Under these challenges, it would be difficult to produce enough food to feed the ever increasing populations, which is expected to cross 9 billion by the year 2050 (UNDESA, 2015). Nanoscience and Nanotechnology research in agriculture and have been found to have lower fertilizer efficiency which ranges from 20 to 50 % for nitrogen and 10-25 % for phosphorus and 70-80 % potassium (Shaviv, 2000). Owing to leaching losses (besides volatilization and denitrification losses) which not only contribute to the greenhouse gases emission but also certain health hazards such as blue baby syndrome as a results of eutrophication and leaching losses of urea. Due to shortage of arable land, water and nutrients the development of agriculture sector is only possible by increasing resource use efficiency with the minimum damage to production bed through effective use of modern Nano-technology (Naderi and Shahrak, 2013). To overcome all these drawbacks, nanotechnology holds promise and nano-fertilizers can go a long way in ensuring sustainable soil health and crop production (Lal, 2008). The term “Nanotechnology” was first defined in 1974 by Norio Taniguehi of the Tokyo science university. It deals with very small sized particles which range between 1nm to 100 nm. Nano-fertilizers are extremely soluble provide precise concentration and slow release of nutrients due to greater surface area. These are also safer than the conventional inorganic fertilizer from the angle of soil and environmental degradation. The optimal NPK fertilizers ratio of 4:2:1 is idea for crop productivity while the current ratio is being maintained at 10:2.7:1 in India nitrogen fertilizers, particularly urea are heavily subsidized by the government and thus its application is more obvious than other nutrients. Nano-fertilizers have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration in to the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizers. Nanotechnology is one of the possible ways for sustainably and precisely attaining these objectives. Nanotechnology based fertilizers hold promise as smart delivery systems for plant nutrients, fundamental properties such as size, specific surface area, crystal phase, surface capping of nanomaterial’s, not only control nutrient dissolution and reactivity but also control material behavior during application.
Nano-fertilizers and their roles

Nano fertilizers enhance growth parameters (plant height, leaf area, number of leaves per plant) dry matter production, chlorophyll production, rate of the photosynthesis which result more production and translocation of photosynthesis to different parts of the plant as compare to traditional fertilizers (Ali and Al-Juthery, 2017, Singh et al., 2017). Foliar feeding combination of N, P and K nano-fertilizer showed improvements of growth and yield parameters of wheat at lower concentration (Abdel-Aziz et al., 2016). Nano-fertilizers are easily absorbed by the epidermis of leaves and translocated to stems which facilitated the uptake of active molecules and enhanced growth and productivity of wheat (Abdel-Aziz et al., 2018). Nano-fertilizer have large surface area and particle size less than the pore size of leaves of the plant which can increase penetration into the plant tissues from applied surface and improve nutrient use efficiency and uptake of the nutrients. (Dimkpa et al., 2015, Qureshi et al., 2018). The positive effect of foliar applied nitrogen, phosphorus, and potassium to sustain proper leaf nutrition as well as carbon balance, and improving photosynthetic capacity is well established by Gosavi et al., 2017.

Fertilizers have an axial role in enhancing the food production in developing countries especially after the introduction of high yielding and fertilizer responsive crop varieties. In spite of this, it is known that yields of many crops have begun to decline as a result of imbalanced fertilization and decrease in soil organic matter. Moreover, excessive applications of nitrogen and phosphorus fertilizers affect the groundwater and also lead to eutrophication in aquatic ecosystems. Such cases along with the fact that the fertilizer use efficiency is about 20-50 percent for nitrogen and 10-25 percent for phosphorus fertilizers implies that food production will have to be much more efficient than ever before. Now a days, nanotechnology is progressively moved away from the experimental into the practical areas. The nanotechnology has become critically important for promoting the development of environmental friendly and sustainable agriculture. Indeed, nanotechnology has provided the feasibility of exploiting nanoscale or nanostructured materials as fertilizer carriers or controlled-release vectors for building so-called “smart fertilizer” as new facilities to enhance nutrient use efficiency and reduce costs of environmental protection. Similarly, nano-fertilizers have great effect on the soil as these can reduce the toxicity in the soil and decrease the frequency of fertilizer application (Naderi and Shahraki, 2013). DeRosa et al. (2010), reported that in nano-fertilizer, nutrients can be encapsulated by NMs, coated with a thin protective film or delivered as emulsions or NPs. Nano and sub Nano composites control the release of nutrients from the fertilizer capsule (Liu et al., 2006). Thus from the above mentioned findings we can articulate that the use of nano-fertilizer leads to an increased efficiency of the micro and macro elements, reduces their toxicity in the soil and reduces the frequency of application of conventional fertilizers.

Apparently, use of nano-fertilizers is the most important application of nanotechnology in agriculture (Agrawal and Rathore, 2014). Nano-fertilizers can be applied either through the soil (for uptake by plant roots), or through foliar spray (for uptake through leaves) (O'Neill et al., 2014) or both (Yan et al., 2018). In this connection, carrier delivery systems of nano-fertilizers can synchronize their release with uptake by crops, thus preventing undesirable loss of nutrients to soil (DeRosa et al., 2010). Actual application of delivery system for nano-fertilizers came rather recently in agriculture (Joseph and Morrison, 2006; Scott and Chen, 2013). Nano-fertilizers are designed to make nutrients more available, consequently increasing the nutrient use efficiency (Suppan, 2013). Some characteristics of nano-particles, including the large specific surface area, unique magnetic/optical properties electronic states, and catalytic re-activity confer nanoparticles better reactivity than the equivalent bulk materials (Agrawal and Rathore, 2014). Regarding Nitrogenous fertilizers, the application of Nano-nitrogen can release the N when crops need it, eventually leading to increase in N efficiency through decrease in N leaching and emissions and long-term incorporation by soil microorganisms (Naderi and Shahraki, 2013; Suman et al., 2010). In previous studies, urca-loaded zeolite chips (Millan et al., 2008) and nanocomposites containing N (Jinghua, 2004) have been use to induce a slow N release and increase plant N uptake. Other materials being used for the same purpose include nutrient sources coated with thin polymer films and nutrients encapsulated inside nonporous materials (Rai et al., 2012).

Encapsulation of fertilizers within a nanoparticle is one of these new facilities which are done in three ways:

a) The nutrient can be encapsulated inside nonporous materials,
b) Coated with thin polymer film, or
c) Delivered as particle or emulsions of nanoscales dimensions.

In addition, nano-fertilizers will combine nanodevices in order to synchronize the release of fertilizer-N and -P with their uptake by crops, sopreventing undesirable nutrient losses to soil, water and air via direct internalization by crops, and avoiding the interaction of nutrients with soil, microorganisms, water, and air. Nanostructured formulation might increase fertilizer efficiency and uptake ratio of the soil nutrients in crop production, and save fertilizer resource. Controlled release modes have properties of both release rate and release pattern of nutrients for water-soluble fertilizers might be precisely controlled through encapsulation in
envelope forms of semi-permeable membranes coated by resin-polymer, waxes and Sulphur. Effective duration of nutrient release has desirable property of Nanostructured formulation; it can extend effective duration of nutrient supply of fertilizers into soil. Nanostructured formulation can reduce loss rate of fertilizer nutrients into soil by leaching and/or leaking. (De Rosa et al., 2010)

**Effect of nano-fertilizer on Seeds germination and crop growth**

Several researches reported that nano-fertilizers significantly influenced the seed germination and seedling growth which revealed the effect of nano-fertilizers on seed and seed vigor. Nano-fertilizers can easily penetrate into the seed and increase availability of nutrient to the growing seedling which result healthy and more shoot length and root length but if concentration is more than the optimum it may show inhibitory effects on the germination and seedling growth of the plant. The toxicity of ZnOnanoparticles on the root growth of garlic (*Allium sativum* L.) (Nel et al., 2006). Nanoparticles have both positive and negative effects on the plant(Pijls et al., 2009).Nano ZnO recorded higher peanut seed germination present and root growth compare to bulk zinc sulphate(Prasad et al., 2012). Similarly, positive effect of nano-scale SiO<sub>2</sub> and TiO<sub>2</sub> on germination was reported in soybean (Mahmoodzadah et al., 2013). Nano-fertilizers increase availability of nutrient to the growing plant which increase chlorophyll formation, photosynthesis rate, dry matter production and result improve overall growth of the plant. Reported similar result that nano-TiO<sub>2</sub> treated seed produced plant recorded more dry weight, higher photosynthetic rate, chlorophyll-a formation compared to the control (Silva et al., 2011).Which indicate that nano-fertilizers significantly improve seed germination and overall growth of the plants.

**Nanostructure applications in agriculture**

Nanotechnology seems to be the alternative that could revolutionize this field of agriculture which has the potential to increase food quality, global food production, plant protection, detection of plant and animal diseases, monitoring of plant growth and reduce waste for "sustainable amplification" (Gruere et al. 2011, Ferwer et al., 2011, Perez & de & Luque and Hermosina, 2013, Prasad et al., 2014, Biswal et al., 2012, Ditta, 2012, Sonkaria et al., 2012).

Recently, nanotechnology providing different nano devices and nano material which having a unique role in agriculture such as nano biosensors can be usedto detect moisture percentage content and nutrient status in the soil and also applicable for site specific nutrient and water management. Nano-fertilizers for efficient nutrient management, Nano herbicides can be usedfor selective weed control in crop field, Nano nutrientparticles to increase seed vigor, Nano pesticides for efficient pest management. Alginate/chitosannano-particles can be use as herbicide carrier material especially for herbicide such as paraquat. Nano herbicides are effective in weed management (Gutierrez et al., 2011). Hence, nanotechnology have greater role in crop production with environmental safety, ecological sustainability and economic stability. The nanoparticles produced with the help of nanotechnology can be exploited in the value chain of entire agriculture production system.

**Application and use of Nano-fertilizer**

Nano-fertilizers are synthesized or modified form of traditional fertilizers, fertilizers bulk materials or extracted from different vegetative or reproductive parts of the plant by different chemical, physical, mechanical or biological methods with the help of nanotechnology used to improve soil fertility, productivity and quality of agricultural produces. Nanoparticles can make from fully bulk materials at nano scale physical and chemical properties are differing than bulk material. Similarly, reported by Joseph and Morrison, 2006 that the rock phosphate if use as nano form it may increase availability of phosphorus to the plant because direct application of rock phosphate nanoparticles on the crop may prevent fixation in the soil similarly there is no silicic acid, iron and calcium for fixation of the phosphorus hence it increase phosphorus availability to the crop plants

**Advantages of nano-fertilizers**

Due to very less size of particles the nano-fertilizers have higher surface area which provides more sites to facilitate different metabolic process in the plant system which results production of more photosynthesis. Due to higher surface area and very less size they have high reactivity with other compound. They are highly soluble in water. Particles size of nano-fertilizers in less than 100 nm which facilitates more penetration of nano particles in to the plant from applied surface such as soil or leaves. Nano-fertilizers have large surface area and particle size less than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizers which leads to more penetration and uptake of the nutrient (Lin and Xing, 2007).

Fertilizers encapsulated in nanoparticles will increase availability and uptake of nutrient to the crop plants. Zeolite based nano-fertilizers are capable to release nutrient slowly to the crop plant which increase availability of nutrient to the crop though out the growth period which prevent loss of nutrient from denitrification, volatilization, leaching and fixation in the soil especially NO<sub>3</sub>-N and NH<sub>4</sub>-N. Particle size below 100 nm nanoparticles can use as fertilizer for efficient nutrient management which are more

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JOURNAL OF PLANT DEVELOPMENT SCIENCES VOL. 13(4) 157
eco-friendly and reduce environmental pollution. Main reason for high interest in fertilizers is mainly their penetration capacity, size and very higher surface area which is usually differ from the same material found in bulk form. This is partially due to the fact that nanoparticles show a very high surface: volume ratio. Thus, the reactive surface area is proportionally over-represented in nano particles compared to larger particles. Particle surface area increased with decreasing particle size and the surface free energy of the particle is a function of its size (Lin and Xing, 2007).

**Nutritional value**

Nano-fertilizers provide more surface area and more availability of nutrient to the crop plant which help to increase these quality parameters of the plant (Such as protein, oil content, and sugar content) by enhancing the rate of reaction or synthesis process in the plant system. Application of zinc and iron on the plant increase total carbohydrate, starch, IAA, chlorophyll and protein content in the grain (Mahajan et al., 2013). Nano-Fe$_2$O$_3$ increase photosynthesis and growth of the peanut plant (Mahmoodzadeh, et al., 2013).

**Health**

Some nutrient also responsible for disease resistance to the plant and due to the more availability of nano nutrient to the plant, it prevents from disease, nutrient deficiency and other biotic and abiotic stress which indicate that nano-fertilizers enhance overall health of the plant. ZnONano-particles also helpful to plant under stress conditions (Naderi and Abedi, 2012).

**Important benefits of nano-fertilizers over conventional chemical fertilizers:**

1. Their nutrient delivery system as they regulate the availability of nutrients in crops through slow/control release mechanisms. Such a slow delivery of nutrients is associated with the covering or cementing of nutrients with nanomaterials. By taking advantage of this slow nutrient delivery, growers can increase their crop growth because of consistently long-term delivery of nutrients to plants. For example, nutrients can be released over 40-50 days in a slow release fashion rather than the 4-10 days by the conventional fertilizers.

2. In addition, nano-fertilizers required in small amount which reduce the cost of transportation and field application.

3. An additional major advantage is over accumulation of salt in soil can be minimized as it required in small amount.

4. Another advantage for using nano-fertilizers is that they can be synthesized according to the nutrient requirements of planned crops. In this regard, biosensors can be attached to a new innovative fertilizer that controls the delivery of the nutrients according to soil nutrient status, growth period of a crop or environmental conditions.

5. The miniature size, high specific surface area and high reactivity of nano-fertilizers increase the bioavailability of nutrients.

6. Providing balanced nutrition, nano-fertilizers facilitate the crop plants to fight various biotic and abiotic stresses. It is reported in several crops that use of nano-fertilizers and nanomaterials enhanced the growth and yield in several crops relative to plant treated with conventional fertilizers. However, the extensive use of nano-fertilizers in agriculture may have some important limitations, which must also be considered and it is crucial to determine the toxicity/biocompatibility of nano-fertilizers.

7. Nano-fertilizers are advantageous over conventional fertilizers as they increase soil fertility, yield and quality parameters of the crop, they are nontoxic and less harmful to environment and humans, they minimize cost and maximize the profit. Nano particles increase nutrients use efficiency and minimizing the costs of environment protection (Nair et al., 2010). Improvement in the nutritional content of crops and the quality of the taste.Optimum use of iron and increase protein content in the grain of the wheat (NAAS, 2013). Enhance plants growth by resisting diseases and improving stability of the plants by anti-bending and deeper rooting of crops.

**Environmental and health concern of nano-fertilizers**

The application of nanostructures or nanoparticles as agrochemicals (fertilizers or pesticides) is systematically being explored, before nano-fertilizers could be used in agriculture or farming for a general farm practice. The properties of many nanoparticles are considered to be of potential risk to human health, viz., size, shape, solubility, crystal phase, type of material, exposure dosage concentrations. However, expert opinions indicate that food products containing nanoparticles available in the market are probably safe to eat, but this is an area that needs to be more actively investigated. To address the safety concern detail studies are required to know the impact of nanoparticles within the human body once exposed through nanofood. Researchers have to assess and develop proper assessment strategies to assess the impact of nanoparticles and nano-fertilizers on biotic and abiotic components of ecosystem. Among the various issues, the accumulation of nanomaterials in environment, edible part of plants might be the important issues before use in agriculture.

**CONCLUSION**

Nano-fertilizers applied alone and in conjunction with organic materials have the potential to reduce environmental pollution owing to significant less losses and higher absorption rate. In addition, nanomaterials were recorded to improve germination rate, plant height, root development and number of roots, leaf chlorophyll and fruits antioxidant
contents. Moreover, controlled and slow released fertilizers having coating of nanoparticles, boost nutrient use efficiency and absorption of photosynthetically active radiation along with considerably lower wastage of nutrients. The future of nano-fertilizers for sustainable crop production and time period needed for their general adaptation as a source of plant nutrients depend on varied factors such as effective legislation, production of novel nano-fertilizers products as per requirement and associated risk management. There is a dire need for standardization of nanomaterials formulations and subsequently conducting rigorous field and greenhouse studies for performance evaluation. For sustainable crop production, smart nano-fertilizers having the potential to release nutrients as per plants requirement in temporal and spatial dimensions must be formulated. Lastly, researchers and regulators need to shoulder the responsibility by providing further insights in order to take full advantage of the nano-fertilizers for sustainable crop production under changing climate with the risk of causing environmental pollution.

REFERENCES


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