International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 10; Issue 03 (B); March 2021; Page No.24062-24066
DOI: http://dx.doi.org/10.24327/ijcar.2021.24066.4770

Research Article

NANOFERTILIZERS: A SUSTAINABLE SOLUTION TO AGRICULTURE AND CROP PRODUCTION

Abhinav Dutta[1]., Bharat Gupta[2] and Shahina Tabassum[3]*

[1,2]Ahlcon International School, Delhi, India
[3]National Center of Organic Farming, Ghaziabad

A R T I C L E I N F O

Article History:
Received 6th December, 2020
Received in revised form 15th January, 2021
Accepted 12th February, 2021
Published online 28th March, 2021

Key words:
Fertilizers, Nanofertilizers, Nanoparticles, Nutrient, Agriculture

A B S T R A C T

Increase in world population in the past decade increased the crop productivity to satisfy the needs of people in different countries. Fertilizers have been used for the past many years in agriculture for the benefit of farmers. Green revolution had led to the increased consumption of traditional fertilizers which resulted in severe environmental hazards. Nutrient use efficiency of traditional fertilizers is very low. To overcome all these drawbacks in a better way, nanotechnology can be a ray of hope. Nanofertilizers are the important tools in agriculture to improve crop growth, yield and quality parameters with increase nutrient use efficiency, reduce wastage of fertilizers and cost of cultivation. A nanofertilizer comprises nanoformulations of nutrients deliverable to plants, enabling sustained and homogeneous absorption. Nanofertilizers are very effective for precise nutrient management in precision agriculture with matching the crop growth stage for nutrient and may provide nutrient throughout the crop growth period. Nanoparticles have high surface area, sorption capacity, and controlled-release kinetics to targeted sites making them smart delivery system. Nanofertilizers provide higher surface area for different metabolic reactions in the plant which increase rate of photosynthesis and produce more dry matter and yield of the crop. It also prevents plant from different biotic and abiotic stress.Nanofertilizers can improve overall crop productivity by enhancing the rate of seed germination, seedling growth, photosynthetic activity, nitrogen metabolism, and carbohydrate and protein synthesis. As a result, use of nanofertilizers in agriculture can prove to be the best sustainable solution for increasing crop production and yield.

INTRODUCTION

Increase in world population in the past decade increased the crop productivity to satisfy the needs of people in different countries. Fertilizers have been used for the past many years in agriculture for the benefit of farmers. In conventional agriculture, an excess of fertilizer is applied directly into the soil or sprayed on the leaves, which surpass the nutritional need of the plant. This is because a very low percentage of fertilizer reaches its target site, due to leaching of chemicals, evaporation, drift, hydrolysis, run-off, and photolytic or microbial degradation. This excess of chemical fertilizer negatively affects the nutrient equilibrium of the soil, and causes contamination of local water supplies, due to the leaching of toxic materials into water bodies. Traditional fertilizers are expensive as well as harmful to human beings and the environment. Therefore, there is a need for developing environment-friendly fertilizers having high nutrient value as well as compatibility with soil and environment.

Corresponding author:* **Shahina Tabassum
National Center of Organic Farming, Ghaziabad

Sustainable agriculture demands minimal use of agrochemicals. Advanced nanoengineering techniques are being used to overcome an agricultural crisis by developing an improved crop production system that assures sustainability. Nanotechnology is an emerging technology, which has revolutionary breakthrough in various fields such as electronics, energy, remediation, automobile, space technology, and life sciences. It has great potential in biological and medical applications such as gene and drug delivery, biosensing, diagnostic and tissue engineering (Borm *et al*. 2006; Oberdorster *et al*. 2005).

The term nanomaterials are generally used to describe the materials having a size between 1 and 100 nm. The small size and enormous surface area of such characteristics give unique properties for nanomaterials like optical, physical, and biological (Ratwani *et al*.,). Nanoparticles have potential applications in agriculture system, viz., detection of pollutants, plant diseases, pests, and pathogens; controlled delivery of pesticide, fertilizers, nutrients, and genetic material; and can act as nanoarchitects information and binding of soil structure (Ghormade *et al*. 2011). Nanoparticles can result in modification of plant gene expression and associated

biological pathways which ultimately affect plant growth and development (Nair *et al*. 2010).

Nanofertilizer

Nanofertilizers are synthesized or modified form of traditional fertilizers, bulk materials for fertilizers, or extracted from different plant or plant parts by encapsulating/coating them with nanomaterials for controlled and slow release of nutrients for the development of soil fertility, productivity, and quality of agricultural products (Zulfiqar *et al*.,2019).Nanomaterials improve the productivity of crops and efficiently regulate the delivery of nutrients to plants and targeted sites, guaranteeing the minimal usage of agrochemicals. Nanofertilizers have high surface area, sorption capacity, and controlled-release kinetics to targeted sites attributing them as smart delivery system (Naderi and Danesh-Shahraki 2013). Nanofertilizers along with useful microbes are also known as Nanobiofertilizers which reduce the usage of conventional fertilizers by 50%. The effectiveness of nanofertilizers depends on three factors: intrinsic factors, extrinsic factors, and route of administration. Intrinsic factors include method of preparation of nanoformulations, particle size of nanoformulations, and surface coating. While extrinsic factors include soil depth, soil pH, soil texture, temperature, organic matter, and microbial activity, which may also affect the potential use of nanofertilizers (El Remedy *et al*., 2018). The route of administration through plant roots or leaves (foliar) also plays a significant role in the absorption, behavior, and bioavailability of nanofertilizers.

Conventional Fertilizers are generally applied on the crops by either spraying or broadcasting. However, one of the major factors that decide the mode of application is the final concentration of the fertilizers reaching to the plant. Very less concentration (much below to minimum desired concentration) reaches to the targeted site due to leaching of chemicals, drift, runoff, evaporation, hydrolysis by soil moisture, and photolytic and microbial degradation. It has been estimated that around 40–70 % of nitrogen, 80–90 % of phosphorus, and 50–90 % of potassium content of applied fertilizers are lost in the environment and could not reach the plant which causes sustainable and economic losses (Trenkel 1997; Ombodi and Saigusa 2000). 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 profit. Nano particles increase nutrients use efficiency and minimizing the costs of environment protection (Talgar *et al*., 2011). For example, encapsulation inside nanomaterials coated with a thin protective polymer film or in the form of particles or emulsions of nanoscale dimensions (DeRosa *et al*. 2010). Surface coatings of nanomaterials on fertilizer particles hold the material more strongly due to higher surface tension than the conventional surfaces and thus help in controlled release (Brady and Weil 1999). Delivery of agrochemical substance such as fertilizer supplying macro- and micronutrients to the plants is an important aspect of application of nanotechnology in agriculture. 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 (Tarafdar *et al*.,2012). Enhance plants growth by resisting diseases and improving stability of the plants by anti-bending and deeper rooting of crops. (Farajzadeh *et al*., 2009) also suggested that balanced fertilization to the crop plant may be achieved through nanotechnology.

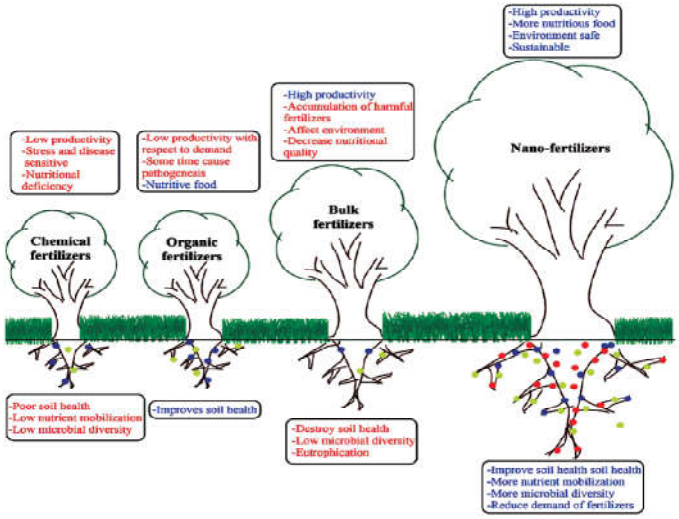

Figure 1 A comparison of chemical fertilizers, organic fertilizers, bulk fertilizers and nanofertilizers on plant growth

Nanofertilizer Formulations and Their Smart Delivery Systems

The formulation of any nano-fertilizer should be in such a way that they possess all desired properties such as high solubility, stability, effectiveness, time-controlled release, enhanced targeted activity with effective concentration, and less eco-toxicity with safe, easy mode of delivery and disposal (Tsuji 2001; Boehm *et al*. 2003; Green and Beestman 2007). Nanoparticles have great potential to deliver nutrients to specific target sites in living systems.

Nanofertilizers are formulated according to their intended purpose as formulations improving solubility, slow release of active ingredients.

Polymer based nano-particles

Polymer-basednanocarriers are majorlydeployed in the slow and controlled release of active ingredients to the target site.

Nano-encapsulation

Nano-capsules or nano-encapsulation are heterogeneous reservoir type structure containing an inner central cavity which confines the hydrophobic or hydrophilic active ingredient, surrounded by a polymer coating ormembrane.

Nanospheres

These are homogeneous vesicular structures, in which the bioactiveingredient is uniformly dispersed throughout the polymer matrix.

Nanogels

These are also known also hydrogel nanoparticles. These are formulated by cross linking of polymeric particles having hydrophilic groups, thus absorb higher quantities of water.

The loading of nutrients on the nanoparticles is usually done by (a) absorption on nanoparticles, (b) attachment on nanoparticles mediated by ligands, (c) encapsulation in nanoparticulate polymeric shell, (d) entrapment of polymeric nanoparticles, and (e) synthesis of nanoparticles composed of the nutrient itself. The following methods can be used for nano-fertilizer delivery to plants:

In Vitro Methods

Aeroponics

Weathers and Zobel (1992) reported this technique. In this technique, roots of the plant are suspended in air and the nutrient solution is sprayed continuously. Gaseous environment around the roots can be controlled. However, it requires a high level of nutrients to sustain rapid plant growth, so the use of aeroponics is not highly useful.

Hydroponics

This method was first reported by Gericke (1937) for dissolved inorganic salts. Volumes of nutrient solution, maintenance of oxygen demands, and pH are factors that need attention while using this method of nutrient delivery. In this case, nutrient solution is flushed from one end and old solution is removed from the other end. The disadvantages with this method are frequent pathogen attack and high moisture rates which may cause over wilting of soil-based plants.

In Vivo Methods

Foliar Application

In this method, liquid fertilizers are directly sprayed onto leaves. Foliar application can reduce the time lag between application and uptake by plant during the rapid growth phase. It can also overcome the problem of restricted uptake of a nutrient from soil. Uptake of iron, manganese, and copper may be more efficient with this method as compared to soil application where they get adsorbed on soil particles and hence are less available to root system (Taiz and Zeiger 2010). As stomata and leaf epidermal cells are majorly involved in nutrient uptake, foliar application method can have agronomic advantage if used for nano-fertilizers. However, damage to the leaves must be minimized in such cases by standardization of application protocol. The shortcomings of this method include specific time (morning and evening) of spraying because the stomata open during these time periods only. Another disadvantage is the possibility of plant damage if correct concentration of chemical (fertilizer) is not applied.

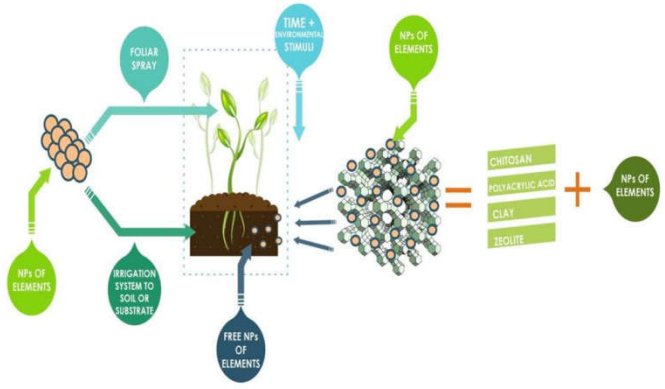

Figure 2 Smart Delivery System of Nano-fertilizer using Foliar Application

Properties of Nanofertilizers

Nanofertilizers facilitate high nutrient use efficiency

Nanofertilizers exhibit a higher surface area due to its minute particle size. The higher surface area is mainly due to very less size of particles which provide more site to facilitate different metabolic process in the plant system result production of more photosynthesis. Due to higher surface area and very less size they have high reactivity with other compound. They have high solubility in different solvent such as water. Particles size of nano-fertilizers is less than 100 nm which facilitates more penetration of nano particles in to the plant from applied surface such as soil or leaves. Nano fertilizer 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 nanofertilizer. 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 (Liscano *et al*., 2000).

Effects of nano-fertilizers on seeds germination & growth parameters of the plant

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 ZnO nano-aprticles on the root growth of garlic (*Allium sativumL.*) (Talgar *et al*., 2011). Nano particles have both positive and negative effects on the plant (Nadi *et al*., 2013). Nano ZnO recorded higher peanut seeds germination percent and root growth compare to bulk zinc sulphate (Liu *et al*., 2005). Reported similar result that nano-TiO2 treated seed produced plant recorded more dry weight, higher photosynthetic rate, chlorophyll-a formation compared to the control (Hamid R. (2012) which indicate that nano fertilizers significantly improve seed germination and overall growth of the plant.

Yield & Yield Parameters

Nano fertilizers enhance the seed germination, vigor, growth parameters (plant height, leaf area, leaf area index 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. Braun and his co-workers in 1983 reported similar result that nano-TiO2 treated seed produced plant recorded more dry weight, higher photosynthetic rate, chlorophyll-a formation compared to the control. This improve translocation of photosynthets from source (leaves) to sink (economic part of the plant it may be grain, tuber, bulb, stem, fibre and leaves.) which result in more yield and quality parameters from nano-fertilizers treated plants compare to without nano fertilizers treated plants or traditional fertilizers treated plants. Sirisena and his co-workers in 2013 reported similar result and nano hydroxyl appetite (nHA) application produced 5.9 g soybean seeds per plant, compared to 4.9 g per plant under regular P treatment, and merely 1.1 and 0.6 g soybean per plant respectively for the controls without P application.

Advantages and Limitations of Nanofertilizers

Though nanofertilizers are a boon to agriculture, yet some researchers have shown their concern regarding the ill effects that may occur with their improper use. Table 1 presents various advantages and disadvantages (Qureshi et.,2018) associated with the use of nanofertilizers.

Table 1 Advantages and limitation of nanofertilizers

S.NO	Properties	Effects
Advantages		
1.	Facilitate higher nutrient use efficiency	Small particle size than pore size of root and leaves leads to more penetration into the plant. Improve uptake and nutrient use efficacy of crop plants. Prevent the loss of nutrients
2.	Nutritional value and health	Nanofertilizers enhance growth of plant parts and metabolic process such as photosynthesis; improve the yield. More availability of nutrients helps to increase the quality parameters of crops, such as protein, oil content, sugar content, etc. More availability of nanonutrient to the plant, prevent from disease, nutrient deficiency and other biotic and abiotic stress, which result in better yield and quality food products for human and animal consumption
3.	Controlled release	Nanofertilizers control the speed and dose of encapsulated nutrient/fertilizers to make more uptake by crop plant. Increase availability due to slow release of nutrients. Increase actual duration of nutrient supply
4.	Reduce lose and demand of fertilizers	Nanofertilizers can take up by the plants due to slower rate of release. Nutrients can be taken up by plants without wastage by leaching and/or leaking. Reduce the demand for fertilizers
5.	Improve soil quality	Improve water-holding capacity and soil quality. Increase microbial activity.
Limitations		
1.	Accumulation of NPs	Nanofertilizers can accumulate in plant parts, leading to growth inhibition, generation of reactive oxygen species, and cell death. Can accumulate in food parts and, when consumed, may cause human health problems
2.	Transformation of NPs	Owing to the property of reactivity, nanomaterials can interact with different components of environment, which leads to transformation and changes in physicochemical properties. Nanomaterials can interact with soil components and may cause toxicity

CONCLUSIONS

Today, worldwide fertilizer application is increasing, along with increasing global population. 30-40% of crop productivity in the agriculture depends on the fertilizers. The use of conventional fertilizers has led to reduction in soil fertility, low productivity and pollution to environment. The advanced nano-biotechnology tools and techniques can improve the way of sustainable agriculture management and have a promising future in the upcoming age of agricultural mechanization. Nanofertilizers offers a promising future in providing sustainable agriculture. Fertilizer nutrient use efficiency in crop production can be enhanced with effective use of nano-fertilizers. Nano fertilizers improve crop growth and yield up to optimum applied doses and concentration. Nanofertilizers have the capability to minimize soil toxicity, reduce the potential negative effects associated with over dosage and frequency of the application as well as the cost of production. As nanofertilizer exhibits a large surface area with minute size, it can easily translocate and uptake by plants and producing more photosynthate, dry matter ultimately increases the yield of a crop.

References

Boehm A., Martinon I., Zerrouk R., Rump E.,and Fessi H (2003) Nanoprecipitation technique for the encapsulation of agrochemical active ingredients. *J Microencapsul* 20:433–441

Borm P., Robbins D., Haubold S., Kuhlbusch T., Fissan H., Donaldson K., Schins R., Stone V., Kreyling W., Lademann J., Krutmann J., Warheit D., Oberdo¨rster E (2006) The potential risks of nanomaterials: a review carried out for ECETOC. Part Fibre Toxicol 3:11

Brady N., Weil R., (1999) In: Brady NR, Weil RR (eds) The nature and properties of soils. Prentice Hall, New Jersey, pp 415–473

DeRosa M., Monreal C., Schnitzer M., Walsh R., Sultan Y (2010) Nanotechnology in fertilizers.

El-Ramady, H., Abdalla, N., Alshaal, T., El-Henawy, A., Elmahrouk, M., Bayoumi, Y., Shalaby, T., Amer, M., Shehata, S., Fári, M., and Domokos- Szabolcsy, E. (2018). Plant nano-nutrition: Perspectives and challenges. In *Nanotechnology, Food Security and Water Treatment*, pp. 129–161. Springer, Cham.

Farajzadeh Memari Tabrizi E., Yarnia M., Khorshidi M. B. and Ahmadzadeh V. (2009) *J. Food Agr. Env*., 7(2), 611-615

Gericke WF (1937) Hydroponics – crop production in liquid culture media. Science 85:177–178

Ghormade V., Deshpande M., Paknikar K., (2011) Perspectives for nano-biotechnology enabled protection and nutrition of plants. Biotechnol Adv 29:792

Green J., Beestman G., (2007) Recently patented and commercialized formulation and adjuvant technology. Crop Prot 26:320–327

Liscano F., Wilson E., Norman J. and Slaton N. A. (2000) AAES Res Bulletin, 963, 1–31.

Naderi M., Danesh-Shahraki A., (2013) Nanofertilizers and their role in sustainable agriculture. Int J Agric Crop Sci 5:2229–2232

Nair R., Varghese H., Nair G., Maekawa T., Yoshida Y., Kumar DS (2010) Nanoparticulate material delivery to plants. Plant Sci 179:154–163

Nat Nanotechnol 5:91

Oberdo¨rster G., Oberdo¨rster E., Oberdo¨rster J (2005) Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. Environ Health Perspect 113:823–839

Rawtani D., Khatri N., Tyagi S. and Pandey G., (2018) "Nanotechnology-based recent approaches for sensing and remediation of pesticides," *Journal of Environmental Management*, vol. 206, pp. 749–762.

Taiz L., Zeiger E (2010) Plant physiology, 5th edn. Sinauer Associates Inc., Massachusetts, 781 pp

Talgar S., Jianxiu G. U., Changshan X. U., Zhikun Y., Qing Z., Yuxue L. and Yichun L. (2011) Nanotoxicology, 1–8.

Tarafdar C., Raliya R. and Tathore I. (2012a) Journal of Bionanoscience, 6, 84-89

Torney F., Trewyn G., Lin VS-Y, Wang K (2007) Mesoporous silica nanoparticles deliver DNA and chemicals into plants. Nat Nanotechnol 2:295–300

Trenkel ME (1997) Controlled-release and stabilized fertilizers in agriculture. International Fertilizer Industry Association, Paris

Weathers P., Zobel W (1992) Aeroponics for the culture of organisms, tissues and cells. Biotechnol Adv 10:93–115

Zulfiqar, F., Navarro, M., Ashraf, M., Akram, N. A., and Munné-Bosch, S. (2019). Nanofertilizer use for sustainable agriculture: Advantages and limitations. *Plant Sci.*, 110270.

Talgar S., Jianxiu G. U., Changshan X. U., Zhikun Y., Qing Z., Yuxue L. and Yichun L. (2011)Nanotoxicology, 1–8

Nadi E., Aynehband A. and Mojaddam M., (2013) *Int. J. Biosci*., 3, 267-272

Liu X.M., Zhang F.D., Zhang S.Q., He X.S., Fang R., Feng Z. and Wang Y. (2005) Plant Nutr. Fert. Sci., 11, 14-18.

Hamid R.B. (2012) *Arpn J. of Agri. and Biological Sci*., 7 (4), 233-237

Braun H. and Roy R. N. (1983) Proc. Symp. Efficient use of fertilizers in agriculture development in Plant and Soil Science, 10, 251-270.

Sirisena D. N., Dissanayake D. M. N., SomaweeraK. A. T. N., Karunaratne V. and Kottegoda N., (2013) Annals of SriLanka Department of Agric., 15, 257-262

Qureshi, A., Singh, D. K., and Dwivedi, S. (2018). Nano-fertilizers: A novel way for enhancing nutrient use efficiency and crop productivity. *Int. J. Curr. Microbiol. App. Sci.*, **7**, pp. 3325–3335.

How to cite this article:

Abhinav Dutta *et al* (2021) 'Nanofertilizers: A Sustainable Solution to Agriculture and Crop Production', *International Journal of Current Advanced Research,* 10(03), pp. 24062-24066. DOI: http://dx.doi.org/10.24327/ijcar.2021.24066.4770

****