

Strategic Applications of Nano-Fertilizers for Sustainable Agriculture: Benefits and Bottlenecks

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ABSTRACT

The promising potential of nanotechnology to improve the agricultural sector by increasing the efficiency of agricultural inputs and offering solutions to agricultural and environmental problems for improving food productivity and security while maintaining the quality of the environment that is sustainable agriculture is one of the major global concerns which is the fundamental concept of nanotechnology in agriculture. A Nano-meter is a unit of length in the metric system, equal to one billionth of a meter (10^{-9}). Hence, nanotechnology is manipulating matter on atomic levels.

INTRODUCTION

The global population is rapidly expanding and is expected to reach 9.7 billion by 2050. Such a huge population coupled with increasing food demand is causing unprecedented pressure on global agriculture to provide food and environmental security. Excessive use of chemical fertilizers has led to the loss of nutrients from agricultural fields through leaching, runoff and gaseous emissions that create environmental pollution. Therefore,

there is a need for developing environment-friendly fertilizers having high nutrient value as well as compatibility with soil and the environment (Davarpanah et al., 2017). Research has shown that nano-fertilizers can enhance plant productivity, increase nutrient usage, reduces soil toxicity as well as fertilizer application frequency and mitigate possible adverse effects of excessive use of chemical fertilizers. Synthesis of nano-fertilizers is a cumbersome process and includes physical,

chemical and biological methods (Raliya and Tarafdar, 2013). Nano-fertilizers positively affect the agricultural sector by reducing the volume of conventional fertilizers currently applied in addition to achieving higher crop yield. Nano-fertilizers may lead to self-reliance and help in meeting sustainable development goals with reduced environmental footprints (Kanjana, 2020).

Nano-fertilizers for sustainable agriculture

The rapid development of nanotechnology has been promoting the transformation of traditional agriculture, more precisely the invention of nano-pesticides and nano-fertilizers. Nanomaterials are the collection of atoms. The range varies from 1–100 nm. Compared with mass materials, it can fundamentally adjust its physical and chemical properties. Through numerous research and developments, various nanomaterials have been developed for the agricultural sector application for the promotion of precision farming by reducing wastage and energy benefits. Recently during 2021-22, the world’s first commercial nano fertilizer i.e., nano- urea was released by IFFCO. Similarly, other nano-fertilizers i.e., nano-DAP and nano-zinc are under research and development for their commercial use in agriculture.

Nano-fertilizers versus conventional fertilizers

Table 1: Difference between nano-fertilizers and conventional fertilizers (Thavaseelan and Priyadarshana (2021))		
Properties	Nano-fertilizer	Conventional fertilizer
Rate of nutrient loss	Low loss of fertilizer nutrients	High loss rate through drifting, leaching, run-off
Controlled release	The rate of release and release pattern are precisely controlled	The rate of release and release pattern are not controlled
Solubility	High	Low
Bioavailability	High	Low

Dispersion of mineral micronutrients	Improved dispersion of insoluble nutrients	Lower solubility due to large size particle
Effective duration of release	Effective and extended duration	Uses at the plant site while the rest is converted into an insoluble form
The efficiency of nutrients uptake	Enhanced uptake ratio and saves fertilizer resource	Low efficiency of nutrient uptake
Soil adsorption and fixation	Reduced	High

Benefits of nano-fertilizers

- Nutrients are released with respect to some specific signals.
- Required in low amounts and improved soil fertility.
- Enhanced absorption and efficient utilization.
- Controlled release of nutrients.
- Lowering the risk of environmental pollution.
- Higher diffusion rate and solubility of nano-fertilizers, etc.

Bottlenecks of nano-fertilizers

- Produce waste toxic materials.
- Has ill effects on plant system if used in excess amounts.
- Potential to cause respiratory disorder and carcinogenic effect.
- Safety concerns for farm workers and consumers, etc.

Classification of nano-fertilizer

1. Nano-formulation of macronutrients.
2. Nano-formulation of micronutrients.
3. Nutrient-loaded nanomaterials.

Method of application of nano-fertilizers

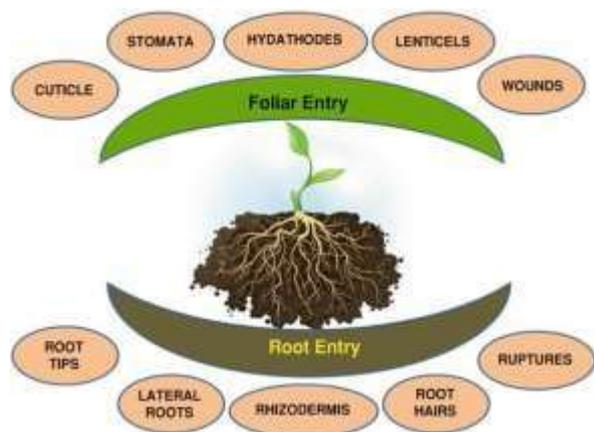


Figure1: Potential entry points of nanoparticles of nano-fertilizers into the plant

(Raliya and Tarafdar. 2013)

Mechanism of action

When nano-fertilizers are sprayed on the leaves they easily get absorbed into the plant system directly and through stomata. Nano-fertilizers on entering into the leaves are distributed to other plant parts through phloem translocation and metabolically assimilated as proteins, amino acids, etc. as per the plant's need. Nano-fertilizers are stored in plant cell vacuoles and are released slowly in a controlled manner as per the plant's need during its entire growth cycle.

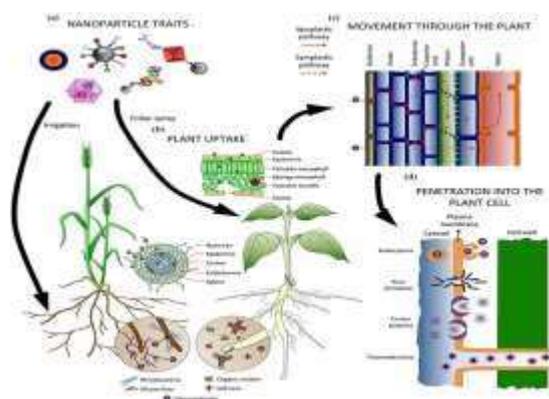


Figure 2: Effect of different factors on absorption, uptake, transport and penetration of nanoparticles in plants.

(Raliya and Tarafdar. 2013)

Criticism of nano-urea

Chemically packaged urea is 46 % nitrogen, which means 45 kg bag contains 20 kg of N. contrastingly, nano urea sold in 500 ml bottles has only 4 % N or 20 gm.

~Dr N.K. Tomar

1. Different parts of the plant contain nitrogen in varying proportions and because nanoparticles are so small and numerous having lot more surface area relative to their volume.
2. The interaction and metabolism is vastly improved.
3. More surface area of nanoparticles in nano-urea delivers more nitrogen.
4. A subject of research is still going on about the mechanism of nano-urea.
5. Farmers are getting benefit from nano-urea and ultimately, they are the best judge.

~ Dr. Ramesh Raliya (Inventor of nano-urea)

CONCLUSIONS

Nano-fertilizers positively affect the agricultural sector by reducing the volume of conventional fertilizers currently applied in addition to achieving higher crop yield. Nano-fertilizers are utilized alone or in conjunction with organic materials to efficiently boosting nutrients to crops plants while reducing environmental pollution through minimizing nutrient loss and enhance the higher absorption rate.

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