Nano Fertilizers: An Overview

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After the introduction of fertilizer responsive and high yielding crop varieties, fertilizers are found to have a prominent role in improving the food production in developing countries especially. Synthetic fertilizers greatly impact the world's food security and without which, there would be only half of the amount of food production that we are producing now. "About 35-40% of the crop productivity depends upon fertilizer". The applied fertilizers are also subjected to various types of losses such as leaching, volatilization, denitrification, fixation etc. which reduces their efficiency. Based on recent fertilizer use efficiency studies it is identified that the efficiency of fertilizer nitrogen is only 30-40% in rice and 50-60% in other cereals, while the efficiencies of fertilizer phosphorus, Potassium and sulfur are 15-20%, 60-80% and 8-12% respectively in most of the crops. With regards to micronutrients, the efficiency of most of them is observed to be below 5%. Therefore, there is an emergent necessity to adapt sustainable alternative strategies to enhance crop production.

Raising the rate of fertilizer utilization and reducing the contamination caused by illogical fertilization were the key steps for the sustainable development of agriculture. However, the progression aims of the fertilizer were slow/controlled release, precision, and eco-environmental health in the world. There has been an interest in the use of nanotechnology in agriculture for nearly 15 years identified various promising opportunities for applying nanotechnology to improve sustainable agri-food systems. Latest technologies such as controlled release technique and targeted delivery of agrochemicals (fertilizers and pesticides) for plant nutrition and pest control and thus, increase food safety and security and sensors for assessing specific conditions or analytes of interest in plant systems. Considering the resource use efficiency and safety, nanotechnology can precisely detect and deliver accurate quantity of nutrients to crop thereby reducing the residual effect in soil.

Table. Causes for low efficiency

Nutrient	Efficiency	Cause for low efficiency
Nitrogen	30-35%	Immobilization, volatilization, denitrification, leaching
Phosphorous	15-20 %	Fixation in soils Al
Potassium	60-80 %	Fixation in clay lattices
Sulphur	8-10 %	Immobilization, leaching with water
Micronutrients (Zn, Fe, Cu, Mn, B)	2-5 %	Fixation in soils

Nano fertilizers

Nano materials which can supply one or more nutrients to the plants when are fortified with nutrients. The synthesis of nano fertilizers is done by fortification of nutrients with nano-dimension singly or in combination on to various adsorbent materials. Nano-fertilizer can be defined as nano particles encapsulated materials which slowly delivers nutrients to crops. Different kinds of encapsulation methods include:

(a) encapsulation of nutrients with nanomaterials like nanotubes or nanoporous materials,

(b) coating of nutrients with a thin protective layer of polymer and

(c) formulations which can deliver nutrients as particles or emulsions of nanoscale dimensions

IFFCO Nano Urea

It is a nanotechnology based revolutionary Agri-input which provides nitrogen to plants. When compared to conventional urea prill, it has a desirable particle size of about 20-50 nm and more surface area

(10,000 times over 1 mm urea prill) and number of particles (55,000 nitrogen particles over 1 mm urea prill).

Table. Conventional fertilizers vs. nano-fertilizers

Index	Nano-fertilizer	Conventional fertilizer
Solubility	High	Low
Dispersion of mineral micronutrients	Improved dispersion of insoluble nutrients	Lower solubility due to large particle size
Soil adsorption and fixation	Reduced	High
Bioavailability	High	Low
Efficiency of nutrients uptake	Increased uptake ratio; saves fertilizer resource	Conventional fertilizer is not available to roots and the nutrients uptake efficiency is low
Controlled release	Release rate and pattern precisely controlled	Excess release leading to toxicity and soil imbalance
Effective duration of release	Extended effective duration	Used by the plant at the site and time of application; the rest is converted into insoluble form
Loss rate	Reduced loss of fertilizer nutrients	High loss rate due to leaching, drifting, run-off

Benefits: Nano Urea is produced by an energy efficient environment friendly production process with less carbon footprints.Increased availability to crop by more than 80% resulting in higher Nutrient Use efficiency. Its application to crops as foliar fertilization enhances crop productivity to the tune of 8% with commensurate benefits in terms of better soil, air and water, and farmers profitability.

IFFCO Nano DAP is an efficient source of available nitrogen (N) and phosphorus (P2O5) for all the crops and helps in correcting the Nitrogen & Phosphorus deficiencies in standing crops. Nano DAP formulation contains Nitrogen (8.0% N w/v) and Phosphorus (16.0 % P2O5 w/v).Nano DAP (Liquid) has advantage in terms of surface area to volume as its particle size is less than 100 Nanometre (nm). This unique property enables it to enter easily inside the seed surface or through stomata and other plant openings. Nano clusters of Nitrogen and Phosphorus in Nano DAP are functionalised with bio-polymers and other excipients. Better spread ability and assimilation of Nano DAP inside the plant system leads to higher seed vigour, more chlorophyll, photosynthetic efficiency, better quality and increase in crop yields. Apart from this, Nano DAP through precision and targeted application fulfils the nutritional requirement of crops without harming the environment.

Nano Zinc Fertilizer: Nano Zinc Fertilizer is a customized liquid zinc nutrient mix containing particulates of ionized zinc embedded in a colloidal amino acid matrix; for use in agricultural fertilization programs and animal feed supplements. It is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops.

Ethical and safety issues of nano-fertilizers application

Undoubtedly nanotechnology has incredible potential to revolutionize many aspects of human life. However, the advancement of this multidisciplinary branch of science, especially the benefits from the practical application of nanoparticles have to be considered with some precautions.

The major concern at world scale is whether the unknown risks of nanoparticles involving their environmental and health impact prevail over their potential benefits. Thus, the risks associated with the application of nanoparticles are yet to be evaluated before the application of nanoparticles is fully accepted and implemented. Hence, "nanotoxicology" has been developed, which is responsible for assessment of the toxicological potential and promoting safe design and use of nanoparticles. Due

to the thorough quantitative analysis of the potential health impacts, environmental clearance, and safe disposal of nanoparticles, improvements in the design of further applications of nanotechnology can be anticipated.

No direct human disease has been linked to nanoparticles so far. Nanoparticles, which constitute a part of ultrafine particulate matter, can enter in the body of humans/animal through the oral, respiratory or intradermal route. Currently, there is a common assumption that the small size of nanoparticles allows them to easily enter tissues, cells, and organelles and interact with functional biomolecular structures (i.e. DNA, ribosomes), since the actual physical size of an engineered nanostructure is similar to many biological molecules (e.g. antibodies and proteins) and structures (e.g. viruses).

Merits of nanofertilizers

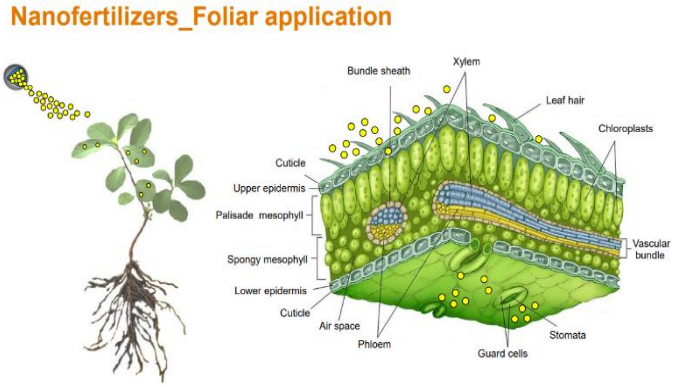
- Increased nutrient use efficiency
- Extended fertilizer release period
- Reduce the usage of chemical fertilizers by 50%
- Nutrient mobilization increased by 30%
- Increase in crop yield by 15-30%
- Reduced soil toxicity
- Reduces frequency of application
- Minimize the effect of over dosage.

Demerits of nanofertilizers

- Reactivity and variability are different under different conditions.
- This raises safety concerns for farm workers who may become exposed to xenobiotics during their application.
- It is reported that inhalation of nanoparticles during application caused chronic lung effects and exposure to metal based nanoparticles caused skin irritation, rashes, headaches. These include not only those exposed to nanofertilizer manufacturing but also nano fertilizer application in the field.
- The accumulation of nanoparticles in plants and potential health concerns.
- Some studies have reported phytotoxic effect of nanoparticles due to bioaccumulation.

Future Prospects

- Evaluation of the effect of nano fertilizers in the soils with different physio-chemical properties is necessary in order to recommend a specific nanofertilizer for a specific crop and soil type.
- Biosynthesized nanoparticle-based fertilizers and nano biofertilizers should be explored further as a promising technology in order to improve yields while achieving sustainability
- Accumulation of NPs in edible parts of crops and bioavailability of the accumulated NPs to the next trophic level. In this regard, specific studies of NPs bioavailability in edible parts are urgently needed to use nanofertilizers safely.
- Understanding nanoparticles in agro-ecological ramification (plant specificity, dose dependency and bio toxicity)
- Physiological explanation of mechanism of



uptake and translocation by plants • Influence of nanoparticles in rhizosphere and on root surface

- Accounting possible interactions of nanoparticles with the biotic or abiotic environment and their possible amplified bioaccumulation effects
- Effect on environment and human health

- Minimising the residual effect
- Lab to land.

Conclusion

Nanofertilizers mainly delays the release of the nutrients and extends the fertilizer effect period. Obviously, there is an opportunity for nanotechnology to have a significant influence on energy, the economy and the environment, by improving fertilizers. Hence, nanotechnology has a high potential for achieving sustainable agriculture. Nano-fertilizers have opened up new opportunities to improve inputs use efficiency, minimize costs and environmental deterioration in some aspects. Therefore, the scope for application of nanofertilizers in agricultural system needs to be prioritized in 21st century to accelerate the productivity of crops and sustain soil health and environmental quality through promoting use of nanoparticles in fertilizers and nano-sensors in soil microbial activity.

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