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# Impact of Nanofertilizers in Sustainable Agriculture

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## Introduction

Nanotechnology, which uses nanoparticles with a diameter of less than 100 nm, could provide a once-in-a-lifetime opportunity to generate concentrated sources of plant nutrients with greater absorption rates, higher usage efficacy, and lower losses. Nano-fertilizers (NFs) are made by encapsulating plant nutrients in nanomaterials, covering them thinly with nanomaterials, and delivering them as nano-sized emulsions. Plant leaves with nanopores and stomatal apertures enhance nanomaterial uptake and penetration deep inside the leaves, resulting in increased nutrient use efficiency (NUE). Nanofertilizers provide better nutrition transport and delivery thanks to plasmodesmata, which are nanoscale (50–60 nm) channels that connect cells. Nanofertilizers have a greater NUE and much lower nutrient losses, resulting in increased field crop productivity (6–17%) and nutritional quality. However, the primary limiting constraints in their widespread acceptance as plant nutrient sources are their manufacturing and availability, as well as their effective law and risk management.

The use of NFs improves nitrogen utilisation efficiency while also reducing fertiliser application frequency and, as a result, soil toxicity and other potential negative consequences associated with excessive chemical use. A comparison of nano-agrochemicals to conventional equivalents revealed a 20–30% increase in efficacy over conventional products. Nano-fertilizers encourage early seed germination, as well as improved plant development and yield. The type of plant and the type and size of particles in the designed NF have a big impact on NF uptake. Nano particles (NPs) have the ability to interact inside the plant system, assisting in the improvement of plant metabolic activity and stress tolerance to biotic and abiotic challenges. Furthermore, they have the potential to boost crop yield by boosting germination, growth, photosynthesis, nitrogen metabolism, and protein and carbohydrate synthesis in plants. Seed treatment, soil application, and foliar spray are examples of application methods.

## Fertilizers importance

Aside with improved nutrient uptake efficiency, novel and creative fertilizers can help reduce environmental footprints. The fertilizer business was the first to develop and offer enhanced efficiency fertilizers (EEF), which are aimed solely at the Asian market. Revolutionary high-tech fertilizer that is also economically feasible could be a true solution for the heavily subsidised Indian fertiliser sector. Agriculture intensification solutions, which enhance food output per unit of inputs and resources, can be developed using nanotechnology. Nano fertilizers based on nanotechnology have emerged as a feasible solution to fill this gap in the conventional and novel fertilizer industry due to their size advantage and regulated manufacturing process through chemical, physical, and biological means. "Synthesized or modified form of traditional fertilizers, fertilizer bulk materials or extracts of various botanical, microbial, or animal origin manufactured by chemical, physical, mechanical, or biological methods with the help of nanotechnology but not limited to it,"

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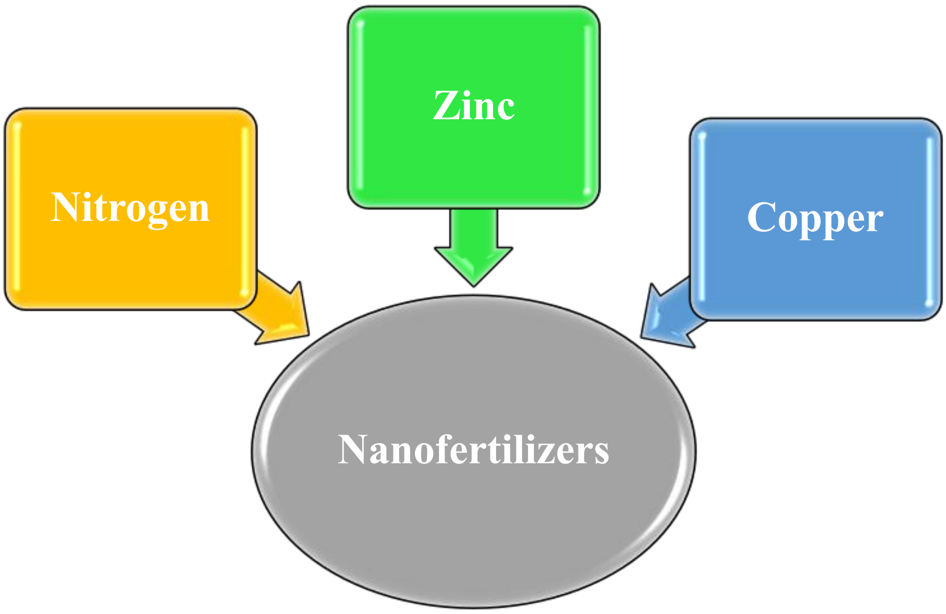
according to the definition of nano fertilizers.

Bulk conventional fertilizers can also be used to make these nanoparticles. Nano-fertilizers' physical and chemical properties are dynamic and distinct from their counterparts at the nanoscale. They have a high availability and absorption due to their increased surface area to volume size ratio and nano size. Nano-fertilizers have particle sizes that are smaller than 1-100 nm in at least one dimension, allowing for improved uptake from soil or leaves and the creation of more photosynthates and biomass needed for healthy crops. In comparison to conventional fertilisers, nano-fertilizers have advantages in terms of application and small requirements, slow release mechanism, reduced transportation and application costs, and generate comparably little salt accumulation in soil. These effectively meet crop nutrient requirements while increasing nutrient bioavailability. Through bio-fortification, foliar-applied nano-fertilizers boost NUE and nutritional quality of crops.

## Nanofertilizers

Nano fertilisers are playing an increasingly important role in boosting food production in developing nations, particularly since the development of high-yielding, fertilizer-responsive crop types. Nano-sized mineral micronutrient formulations may improve insoluble nutrient solubility and dispersion in soil, reduce soil absorption and fixation, and boost bioavailability, resulting in increased nutrient uptake efficiency. Nanostructured formulations may improve fertiliser efficiency and soil nutrient absorption ratios in crop production while conserving fertiliser resources. Encapsulation in envelope forms of semi-permeable membranes coated with resin-polymer, waxes, and sulphur has qualities of both release rate and release pattern of nutrients for water-soluble fertilisers that can be carefully controlled. Effective length of nutrient release is a desirable attribute of Nanostructured formulation because it can extend the effective duration of fertiliser nutrient supply into soil. Leaching and/or leaking of fertiliser nutrients into soil can be reduced by using nanostructured formulations.



## Nitrogen-nanofertilizers

Nano-based slow-release or controlled-release fertilisers have enormous potential for improving nutrient utilisation efficiency. Nanofertilizers can control nutrient release and give the exact amount of nutrients to crops in the right proportions, boosting productivity while assuring environmental safety. Alternative strategies to improve nitrogen use efficiency in crop production systems include nitrogen fertilizer enriched with nanoporous zeolite.

## Zinc- nanofertilizers

Zinc (Zn) and zinc oxide (ZnO) are two metal- and metal oxide-engineered nanomaterials that are extensively used on plants. Zinc deficiency is one of the most common micronutrient deficiencies in soil, and it is the fourth most significant yield-limiting nutrient after nitrogen, phosphorus, and potassium. Because of its widespread use in consumer products, it's possible that Zn or ZnO will end up in the atmosphere, either through unintentional release or deliberate application. This might have a big impact on a lot of organisms, especially plants, which are the foundation of every ecosystem. For the species of Buck wheat (*Fagopyrum esculentum*), ZnO had an influence on root germination. In a cluster bean rhizosphere, ZnO NPs helped to improve chlorophyll content and protein synthesis, as well as the rhizospheric microbial population, acid phosphatase, alkaline phosphatase, and phytase activity. Supplementing MS media with ZnO NPs boosted proline synthesis and improved the activity of superoxide dismutase (SOD), catalase (CAT), and peroxidase, resulting in increased biotic stress tolerance.

## Copper- nano fertilizers

Copper is also one of the eight essential plant micronutrients, necessary for plant metabolism and seed development. Increased susceptibility to harmful fungal and bacterial infections can result in considerable output losses due to copper deficiency. Copper is needed for a variety of physiological functions in plants, including mitochondrial respiration, cellular transportation, antioxidative action, protein trafficking, and hormone signalling. Cu nanofertilizers were used to improve the stress tolerance of wheat.

## Conclusion and Future perspectives

In the agricultural industry, nanofertilizers have a substantial impact on increasing productivity and tolerance to abiotic stressors. As a result, promising nanofertilizer applications in the agrifood biotechnology and horticulture sectors must not be disregarded. Furthermore, in the current climate change scenario, the potential benefits of nanofertilizers have sparked a lot of interest in increasing the production capacity of agricultural crops. Reduced leaching and volatilization associated with the use of conventional fertilisers are the primary economic benefits of using nanofertilizers. Simultaneously, the well-known positive influence on output and product quality has the potential to significantly boost growers' profit margins when this technology is used.

Foods, personal care items, and other consumer products now contain designed nanoparticles. Silica nanoparticles in baby formula, titanium dioxide nanoparticles in powdered cake donuts, and other nanomaterials in paints, plastics, paper fibres, pharmaceuticals, and toothpaste are only a few examples. Many features of nanoparticles, such as size, shape, crystal phase, solubility, material type, and exposure and dosage concentrations, are thought to pose a risk to human health. Experts agree that food products containing nanoparticles on the market are probably safe to consume, but this is an issue that needs to be explored more. To address these difficulties, more research is needed to understand how nanoparticles interact with the human body after being exposed through nanofood. Researchers must undertake life cycle analyses of nanoparticle impact on human health and the environment, create strategies to assess and manage any concerns, and find sustainable ways to manufacture nanoscale materials for agricultural application. For next-generation fertilizers and their usage in agricultural systems, there is a pressing need to improve nanosynthesis and delivery capacities.