

SMALL SIZE, BIG IMPACT: THE RISE OF NANOFERTILIZERS

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INTRODUCTION

Agriculture is the backbone of the world's economy, and feeding the growing population is a significant challenge for farmers. Soil fertility plays a vital role in achieving sustainable agriculture. Fertilizers have been used for years to enhance soil fertility and crop productivity. However, traditional fertilizers have several limitations, including nutrient losses due to leaching, volatilization, and runoff, which lead to environmental pollution. Researchers have developed new types of nanofertilizers to overcome these limitations. Nanofertilizers are nanoscale materials used to improve plant growth and crop yields. These materials are typically composed of nanoparticles, particles ranging in size from 1 to 100 nanometers. They can be applied to plants through several methods, including foliar spraying, seed coating, and soil incorporation.



THE SYNTHESIS AND MECHANISM OF ACTION OF NANOFERTILIZERS

Nanofertilizers are a type of fertilizer that contains nanoparticles, which can help improve the efficiency and effectiveness of fertilization in plants. The synthesis of nanofertilizers typically involves the following steps:

Selection of nanoparticle material:

The first step in synthesizing nanofertilizers is to select the appropriate nanoparticle material that will be used as the carrier for the fertilizer. Common nanoparticle materials include titanium dioxide, iron oxide, and silica.

Preparation of nanoparticle suspension:

The selected nanoparticle material is then prepared as a suspension in water or another suitable solvent. This can be done by adding the nanoparticles to the solvent and then sonication or stirring the mixture to ensure that the nanoparticles are evenly dispersed.

Addition of fertilizer:

Once the nanoparticle suspension has been prepared, the desired fertilizer is added to the mixture. The amount of fertilizer added will depend on the desired concentration and the type of fertilizer being used.

Mixing and drying:

The nanoparticle-fertilizer mixture is thoroughly mixed to ensure the fertilizer is evenly distributed throughout the nanoparticle suspension. The mixture is then dried using a suitable drying method, such as freeze or spray drying.

Characterization:

Finally, the synthesized nanofertilizer is characterized using various analytical techniques, such as scanning electron microscopy, X-ray diffraction, and Fourier transforms infrared spectroscopy, to ensure that it has the desired properties and that the nanoparticles are well dispersed and stable. Different types of nanofertilizers available in the market are listed in table 1. Notably, synthesizing nanofertilizers requires expertise and specialized equipment to ensure the nanoparticles are synthesized and dispersed correctly. Following appropriate safety procedures when handling nanoparticles is essential, as they can pose a health risk if not handled properly.



MECHANISM OF ACTION OF NANOFERTILIZERS:

1. Enhanced Nutrient Uptake:

The small size of nanoparticles allows them to penetrate the cell wall of plants more efficiently, increasing nutrient uptake. For example, nano-sized particles of zinc oxide have been shown to increase the uptake of zinc by plants.

2. Improved Growth:

Nanofertilizers can also improve plant growth by increasing chlorophyll content, photosynthetic rate, and water use efficiency. For example, nano-sized particles of silicon have been shown to improve the growth and yield of tomato plants.

3. Increased Yield:

Nanofertilizers can also increase yield by improving the nutrient content of plants and reducing nutrient loss through leaching. For example, nano-sized particles of calcium carbonate have been shown to increase the yield of rice crops.

Table 1:- Different types of nanofertilizers available

S.no.	Type of Nanofertilizer	Composition	Particle Size	Potential Benefits
1	Nano-iron fertilizers	Iron nanoparticles	10-100 nm	Increases photosynthesis and chlorophyll content improves plant growth, enhances nutrient uptake, and increases crop yield.
2	Nano-silicon fertilizers	Silicon nanoparticles	10-100 nm	It enhances plant growth, improves stress tolerance, increases nutrient uptake, and reduces disease incidence.
3	Nano-potassium fertilizers	Potassium nanoparticles	20-200 nm	It improves water use efficiency, enhances photosynthesis, increases nutrient uptake, and boosts crop yield.
4	Nano-nitrogen fertilizers	Nitrogen nanoparticles	10-100 nm	It enhances plant growth, improves nitrogen use efficiency, reduces leaching losses, and reduces environmental pollution.
5	Nano-phosphorus fertilizers	Phosphorus nanoparticles	10-100nm	Increases phosphorus availability, improves plant growth, enhances root development, and boosts crop yield.

BENEFITS OF NANOFERTILIZERS

Nanofertilizers have been studied extensively for their potential applications in agriculture. Here are some of the most promising applications of nanofertilizers:

1. Improved nutrient delivery:

Nanofertilizers can improve the efficiency of nutrient delivery to plants by increasing the solubility and uptake of essential nutrients. For example, a study showed that zinc oxide nanoparticles could improve the uptake of phosphorus by plants.

2. Controlled release of nutrients:

Nanofertilizers can release nutrients slowly, reducing the need for frequent fertilizer applications. For example, a study showed that slow-release urea nanoparticles could improve nitrogen uptake by plants and reduce fertilizer waste.

3. Enhanced crop yields:

Nanofertilizers can increase crop yields by improving nutrient uptake, reducing nutrient loss, and enhancing plant growth. For example, a study showed that copper oxide nanoparticles could increase the growth and yield of tomato plants.

4. Reduction in environmental pollution:

Nanofertilizers can reduce environmental pollution by reducing the amount of fertilizer needed and preventing nutrient runoff. For example, a study showed that zinc oxide nanoparticles could reduce nitrogen and phosphorus leaching from the soil.

5. Improved resistance to abiotic stress:

Nanofertilizers can improve the resistance of plants to abiotic stress, such as drought and high salinity. For example, a study showed that titanium dioxide nanoparticles could improve the drought tolerance of wheat plants.



NANOFERTILIZERS AND CRISPR/CAS9 TECHNOLOGY

Nanofertilizers and CRISPR/Cas9 technology are both cutting-edge technologies that hold great promise for revolutionizing the field of agriculture. Nanofertilizers are a type of fertilizer that utilizes nanotechnology to improve plant nutrient uptake, reduce fertilizer waste, and increase crop yields. These fertilizers are designed to deliver nutrients precisely to the areas most are needed, allowing plants to grow more efficiently. CRISPR/Cas9, on the other hand, is a powerful gene-editing tool that allows researchers to make precise changes to cell DNA sequences. This technology has tremendous potential for improving crop yields and making plants more resistant to pests and diseases. The two technologies can create plants with enhanced nutrient uptake and improved disease resistance. For example, researchers at the University of Nebraska-Lincoln have used CRISPR/Cas9 to modify genes in plants to improve their ability to take up iron from the soil and then used nanofertilizers to deliver iron precisely to the areas where it is needed most in the plant. Another example comes from a study published in Nature Communications, where researchers used CRISPR/Cas9 to create wheat plants resistant to a devastating fungal disease called powdery mildew. They then used nanofertilizers to deliver nutrients to the plants, resulting in a 20% increase in wheat yield compared to untreated plants.

CHALLENGES AND POTENTIAL CONCERNS

While nanofertilizers offer many potential benefits for agriculture, there are also several challenges and potential concerns associated with their use. Here are some of the main ones:

Environmental impact: There are concerns about the potential environmental impact of nanofertilizers, particularly their potential to accumulate in soil and water and impact ecosystems. A study showed that silver nanoparticles in wastewater irrigation could accumulate in the soil, affecting soil microorganisms, plant growth, and soil enzymes.

1. Health risks:

There are concerns about the potential health risks associated with nanofertilizers, particularly for workers exposed to these particles during manufacturing or

application. A study showed that exposure to silver nanoparticles could cause lung inflammation and oxidative stress in rats.

2. Lack of regulatory guidance:

Currently, there is a lack of regulatory guidance for using nanofertilizers in agriculture, which could lead to potential risks and uncertainties. It is crucial to develop regulatory frameworks that address the potential risks associated with these particles and ensure their safe and responsible use.

3. Cost:

The production of nanofertilizers can be expensive, which may limit their use in some regions or for some crops. The cost of production needs to be reduced to make nanofertilizers more accessible to farmers.

4. Toxicity:

The toxicity of nanofertilizers is an important area of research, as there is concern that their use may have negative effects on human health, animal health, and the environment. Several studies have investigated the toxicity behavior of different types of nanofertilizers, with varying results. One study published in the journal *Environmental Science and Technology* found that the use of copper oxide nanoparticles as a fertilizing agent in soil resulted in negative effects on earthworms and soil microorganisms. The study suggested that these negative effects were due to the release of copper ions from the nanoparticles, which are toxic to living organisms.

5. Limited research:

There is still limited research on the long-term effects of nanofertilizers on plant growth, soil health, and ecosystem functioning. More research is needed to understand these particles' potential benefits and risks fully.

CONCLUSION

Nanofertilizers have the potential to revolutionize the agricultural sector, providing a sustainable solution to the challenges facing modern agriculture. Their use can improve crop yields, reduce fertilizer wastage, and increase nutrient absorption by plants while reducing the environmental impact of agriculture. However, their safety and regulatory concerns need to be addressed, and their cost needs to be reduced to make them more accessible to farmers in developing countries. Further research and development are needed to unlock the full potential of nanofertilizers.

