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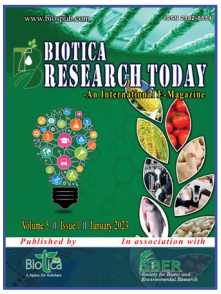

Biotica Research Today Vol 5:1 2023

13/16

How to cite this article?

Ram *et al.*, 2023. Overview of the Mechanism of Nanofertilizers and the Effects of Their Use on Crop Yield. Biotica Research Today 5(1):13-16.

Overview of the Mechanism of Nanofertilizers and the Effects of Their Use on Crop Yield

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Keywords

Nanofertilizers, Nanotechnology, Nano Urea, Synthetic fertilizers

Abstract

The oldest and largest agricultural sector is currently facing with a number of issues. Due to the expanding global population and resource depletion, there are expectations for the ever-increasing food and grain requirements. This led to the widespread use of synthetic fertilizers, which increased the expense of farming. Low-quality, ineffective synthetic fertilizers have simply made things more challenging and had detrimental effects. By adjusting fertilizer output, nanotechnology has proven its ability to support sustainable agriculture and act as a boon. Nano-fertilizers are used to boost soil fertility, increase nutrient efficiency, and enhance plant nutrition. The manufacture, characteristics, and applications of bio-nano-fertilizers are reviewed critically in this paper, along with potential future directions for their promotion. The utilization of active chemicals at the nanoscale, as well as promising aspects including controlled release and targeted delivery of nano-fertilizers, are discussed along with improvements in crop and quality implications.

Introduction

In recent decades, the use of foliar spraying of nano-fertilizers has emerged as a successful strategy to combat the issue of soil and water salinity. The newest form of precision agriculture, known as nanotechnology, is projected to increase agricultural output in order to fulfill rising food demand (Elemike *et al.,* 2019). One of the emerging technologies for prosperity, nanotechnology is said to have potential properties that are anticipated to significantly contribute towards solving societal and environmental problems as well as promote sustainable competitiveness. More pressure will be exerted on resources like land and water in order to feed the enormous global population. In comparison to the usage of organic fertilizers, which has been known to humans for more than 1000 years, and phosphate and nitrogen fertilizers, which have been used for 100 years, the nano fertilizer (NFs) industry is more recent. Due to the growing population, fertilizer was utilized extensively to produce the necessary nutritious food. The environment of people could experience a variety of negative side effects from the extensive usage of chemical fertilizers. As a result of the growing population, a wide range of fertilizer products were created and made that were very beneficial to agricultural fields and therefore essential for the production of animal and plant goods (Mikkelsen, 2018). The NFs were discovered and explored as a technique to increase nutritional dosage and plant nutrition along with healthy diet, as opposed to typical fertilizers, after all various fertilizers focused on plant nutrition. Agricultural engineers, environmentalists, and soil scientists have become interested in NFs because of their capacity to boost crop yields, improve soil fertility, decrease

Article History

Received on: 27th December 2022

Revised on: 03rd January 2023

Accepted on: 04th January 2023

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down pollution, and mark a developing eco to flourish microorganisms (Rahman *et al.,* 2020) examined the effect of platinum nanoparticles on seed germination and growth performance of *Pisum sativum* plants as a function of soaking time. The study related the variation in yield and biomass content to the growth-regulating hormones rapid alteration by nanoparticles.

Mechanism of Nano-Fertilizer

There are various delivery mechanisms proposed involving nanofertilizers such as nanoscale fertilizers applied *via* foliar and soil routes with controlled release method (CRM), nanoscale additives, and nanoscale coatings.

i) Controlled Release Mechanism

• One of the crucial factors being taken into account is the designing and development of new nanoparticles for controlled release, which will lead to increased nutritional absorption rates.

• Research into nanotechnology for sustainable and precise agriculture paves the path for the creation of controlled-release fertilizers that release nutrients slowly.

• By minimizing nutrient losses to the environment, this will eventually result in the efficient use of fertilizer, making it eco-friendly.

• The encapsulation or coating of inorganic or organic components is a characteristic of controlled release fertilizers. This characteristic regulates the timing, pattern, and rate of nutrient release in plants.

• Nanocomposites of urea and hydroxyapatite show mature administration lower volatilization and sustained availability of NPK over the course of one month of incubation, compared to conventional fertilizers such as nitrogenous fertilizers, which have an efficiency in the 30-60% range, and phosphate fertilizers, which are lost by chemical bonding in soil and were unavailable to plants to the extent of 80-90%.

ii) Stimuli-based Release

• In comparison to current diffusion and/or ion exchange channels, the mechanism including stimuli-based release holds the higher potential to produce more active and intelligent delivery systems, and could represent a significant advancement towards controlled release nano-fertilizers.

• There have been reports of stimuli being a signal molecule emitted by plants when they are lacking in a particular nutrient.

• It is reasonable to infer from the literature that engineered nano-fertilizers can significantly reduce the amount of fertilizer applied, improving their efficiency and decreasing release into the environment as compared to conventional formulations. This is because they release measured amounts of necessary and sufficient quantities of required ingredients over a period of time.

iii) Nanoscale Additive Fertilizers

• Fertilizers with nanoscale additions fall within the category of conventional fertilizers.

• According to El-Ramady *et al.* (2017) adding selenium nanoparticles to a bulk fertilizer for the cultivation of *Ziziphus jujuba* fruit resulted in increased fruit yields and higher selenium content in the harvested fruit.

iv) Nanoscale Coating Fertilizers

• Fertilizers with nanoscale coatings are created by loading or coating conventional fertilizers with nanoparticles.

• The modifications could take the form of coatings with thin polymer film particles, (1) nanoscale emulsions, (2) nano-phase encapsulation containing nutrients of interest, or (3) nanoscale coatings.

• Encapsulating bacterial or fungal microorganisms is a good idea since it increases NPK availability in the root zone, which promotes plant growth.

• Different dimensionalities at the nanoscale, such as coatings, nano-thin films, or nano-porous materials used to encapsulate fertilizers, may be employed to achieve the ejection of nutrients in crops.

Comparison of Organic Fertilizers, Bio-Fertilizers, Chemical Fertilizers and Nano-Fertilizers

i) Organic Fertilizers

• The primary purpose of organic fertilizers is to supply essential nutrients and minerals. As a result, the organic matter and microorganisms in the soil increase, which is crucial for the development of agricultural crops.

• These organic fertilizers are produced from a variety of plant-derived materials and animal manures and litter, and they are often applied to crops by showering or spreading. The biodegradable materials function better as organic fertilizer or as nutrient sources.

• Organic fertilizers are not always advantageous because not all of the products are produced equally, and because the organic materials obtained from different plants and animals are not all the same and so cannot supply the same nutrients and organic matter as fertilizer.

ii) Bio-fertilizers

• The bio-fertilizer is injected into the soil where fungus and bacteria grow and support the availability or supply of nutrients as part of the mechanism.

• The bio-fertilizers in NKP include rhizobacteria, endo/ecto mycorrhizal fungi, and cyanobacteria that promote plant growth as well as N-fixers, P and K solubilizers, and beneficial

microscopic creatures.

• As bio-fertilizers work to protect and enhance the natural environment, as well as the social and economic situations of farmers, they play a critical role in ensuring the health and wellbeing of all farmed species.

• Newer approaches to the efficient use of bio-fertilizer are being researched, including liquid bio-fertilizer, modified strains that can withstand heat and drought, and optimization of bio-fertilizer composition.

iii) Chemical Fertilizer

• Chemical fertilizers based on nitrogen, phosphate, and potassium reach groundwater and become more harmful. Chemical fertilizers are a class of synthetic compound substances produced specifically to maximize crop yield.

• These chemical fertilizers are "nitrogenous" - containing nitrogen, phosphate, and potassium-based. The nitrate-based fertilizer causes methaeglobinaemia, which damages the vascular and respiratory system. A combination of ammonium phosphate, nitro phosphate, potassium, and other nutrients can be found in the complex chemical fertilizers.

• Although chemical fertilizers are well-known for being predictable, dependable, and certain to instantly transform deficient soil into fruitful by supplying an adequate amount of the three essential nutrients (NPK) required by the plant, they can also have negative effects.

iv) Nanofertilizers

• The benefit of nanometer-sized nano-fertilizers is their ease of access to soils, water, air, and plants.

• Nano-fertilizers are improvised agricultural inputs that are intended to release nutrients into soils in a controlled manner.

• According to numerous studies, nanoparticles may cause phytotoxicity through production of reactive oxygen leads to an oxidative stress, oxidative DNA and protein damage, and liquid peroxidation in plants.

• When making nano fertilizer, the active components must more correctly respond to environmental stimuli and biological demands through mechanisms like slow/ controlled or targeted delivery mechanisms and conditional release.

• In order to more efficiently promote plant growth, nano-fertilizers function as slow release nano-fertilizers to counter changes in soil acidity, moisture, and temperature.

• Nanofertilizer has greater opportunities to improve inputs use efficiency, minimize costs and also reduce environmental deterioration.

• In order to more efficiently promote plant growth, nano-fertilizers function as slow release nano-fertilizers to counter changes in soil acidity, moisture, and temperature.

The harms of chemical fertilizers compared to the benefits offered by their use are quite evident and use of bio- and nano-fertilizers in isolation also does not appear effective. Therefore, environmentally friendly biotechnological methods that balance the use of nano- and bio-fertilizers may provide an alternative to chemical fertilizers. The synthesis of inorganic nanoparticles as eco-friendly fertilizers will have new research prospects made possible by the biosynthesis of nanomaterial using bacteria, algae, yeast, fungi, and plants. With its effectiveness in utilizing various water and land resources, as well as their ability to lessen environmental contamination, bio- and nano-fertilizers have the potential to become one of the most crucial instruments in the new age of agriculture.

Effect of Nanofertilizers Application on Crops Growth, Yield and Nutritional Value

Effect of application of nanofertilizers on crops growth, yield and nutritional value are discussed below and mentioned in Figure 1.

• The major purpose of synthesizing and utilizing nano-fertilizers is to raise the nutritional value and yield of crops.

• The proper usage to certain optimum concentrations may promote crop growth and produce the desired outcomes.

• In comparison to other classes of fertilizers, nanoparticles used as nano-fertilizers are referred to be smart delivery systems because they generate different nutrients directly to crops in a shorter amount of time.

• Due to their "Nano" nature, the nano-fertilizers have high surface areas, higher sorption capacities, and controlled-release kinetics to targeted sites, increasing nutrient uptake in plant cells and reducing nutrient loss.

• Nano-fertilizers also affect seed germination, the degradation of chlorophyll content, fresh and dry weight, and the relative

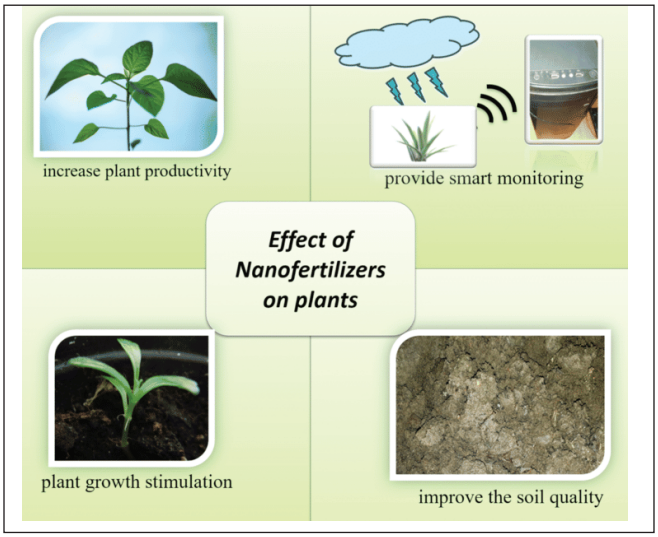

Figure 1: Effect of Nano-fertilizers on plants (Fatima *et al*., 2021)

growth rate of plants.

Demerits of Nano-Fertilizers Application

• There are allegations about the usage of nano-fertilizers in excess amount. When nutrients are used in excess, it can have major negative effects on health and crop growth.

• Foliar spray at improper concentration causes an increase in chlorophyll content and other enzymes that are hazardous or toxic if over controlled, as well as improper concentration affects seedling growth, oxidative stress, and exhibited toxicity.

• Also, improper concentration affects seedling growth, oxidative stress, and exhibited toxicity. Root length will either increase or decrease, and there will be more accumulation in the roots and shoots.

Conclusion

The addition of nano-fertilizers enhances crop growth and yield by acting as a source and on-site carrier for precise nutrient amounts. It is clear that different plant characteristics are affected differently by NFs. Sensitive factors include application techniques, size/ shape/ morphologies, and concentrations. The main cause of resource losses and serious environmental concerns is the high amounts of NPK from applied fertilizers wasted components that are released into the environment. The biggest application rate and most availability issues are associated with the efficient treatment of N, P, and K NFs. In order to develop appropriate nano-fertilizers that are alternatives to currently available carriers, there is a significant opportunity to conduct spatial and temporal study outside of controlled contexts. The number of inputs and waste produced could be decreased by developing nano-carriers in a way that they can anchor plant roots, soil characteristics, and organic matter. The mechanisms underlying the increased growth and productivity of crop plants brought on by the use of various nano-fertilizers must be further clarified and supported by further data. Another area of research to investigate is the determination of the trait-based optimal dose for removing harmful effects. Given the toxicological effects of NMs/ NPs on crops, soil, and the environment, as well as on human food consumption, it is urgent to investigate nano-fertilizers for the nutrition of crop plants.

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