Advances in Bioresearch
Adv. Biores., Vol 14 (6) November 2023: 586-595
©2023 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.14.6.586595

REVIEW ARTICLE

Vital Role of Nanoparticles as Nanofertilizer in Crop Yield Improvement

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ABSTRACT

Nanofertilizers are nutrient transporters with nanoscale dimensions ranging from 30 to 40 nm that can retain a large number of nutrient ions extremely large surface area and dispense them slowly and surely in response to crop demand. Controlling the release of nutrients from fertilizer granules with nanofertilizers and composite materials can improve uptake of nutrients while limiting nutrient ions from being fixed or lost to the environment. Nanofertilizers have a high application efficiency, therefore nutrients may be transported to a rhizospheric target quickly.

Keywords: Nanofertiliser, nanoparticles, rhizosperic target.

Received 24.05.2023 Revised 01.06.2023 Accepted 11.11.2023

How to cite this article:
Gunmala G, Anjali S. Vital Role of Nanoparticles as Nanofertilizer In Crop Yield Improvement. Adv. Biores., Vol 14 (6) November 2023: 586-595.

INTRODUCTION

Crop yield plateau, poor nutrient use efficiency, declining organic matter, lack of nutrients, arable farming, water resources and availability of labor due to agricultural migration are among the challenges affecting today's agricultural zones [1,2]. According to the Food and Agriculture Organization of the United Nations, depletion of land and water poses serious challenges to producing enough food and other agricultural commodities to sustain life and meet the needs of the world's ever-growing population [3]. Nanoscience, which generates ultra-small molecules with a remarkably high surface area to volume ratio and improved semiconductor-based and physico-chemical properties compared to bulk derivatives [4], is now considered as a potential mechanism for enhancing plant growth and development [5-8]. This notion is critical to mainstream agricultural science, in which farmers use technology to ensure efficient irrigation, fertilization, and other resources. Species-appropriate management increases agricultural sustainability by reducing waste and energy consumption. Nanoparticles and their compounds are being studied for a range of uses in agriculture, including increasing crop yields and reducing pesticide use. Agricultural strategies are used that are effective in increasing crop yield while polluting the soil or water. It can also help prevent nitrogen losses due to erosion and runoff along with soil microorganisms. Nanoscale sensors are used to monitor nutrient presence, pesticide use and contamination in agricultural products. Through the post-harvest process, extend the lifespan of agricultural products, nanopesticides eliminate pathogens, increase biomolecules and minerals in food, water treatment, use smart fertilizer, nano-fertilizer [9-12]. In this article, we discuss nano-fertilizers and their important role in improving crops.

ROLE OF FERTILIZER IN PLANT GROWTH

Fertilizers provide the nutrients that plants need to grow to thrive. Fertilizers are frequently widely used in agricultural via surface applications, beneath application, or in combination with irrigation water. However, a large portion of the fertiliser delivered by these methods is discharged into the environment or surface freshwater resources, causing harm to the biosphere [13,14]. Excess nitrogen, for example, is lost as NH3 by vaporization, released as N_2O or NO, or leached or drained into bodies of water. Excess phosphate, is from the other hand, becomes "trapped" in soil, where it creates synthesized connections with other elements including Ca-P, Mg-P, Al-P, Fe-P, and Zn-P, making it unavailable to plant absorption. Finally, rain bleaches the N and P elements into natural freshwater bodies, rivers and streams, and the sea, where they can cause pollution problems. Fertilizer use is increasing in lockstep with global population growth. Due to the fact that plants can only absorb about 42% of the phosphorus given to them, farmers use over 85% of the world's total mining phosphorus as nutrients [15]. If this scenario is correct, the world's phosphorus supply may run out in the next eighty years, limiting agricultural output. trends in urbanised states in the USA suggest a 77% reduction in cropland between 1978 and 1987 Farmland [16, 17]. Nowadays, farmers use more chemical fertilizers to meet food demand, which pollutes the soil and environmental health as well as depletes natural resources. It is possible to grow some crops with hydroponics, but it costs (in terms of energy and money) more than conventional farming, but these methods are not cost-effective nor sustainable in the long run. [16]. Therefore, it is essential to develop long-term strategies to yield higher agricultural and nutrient yields while consuming fewer resources and fertilizers. about the use of small quantities. The term "nano-fertilizers" is used in the literature on applications of nanotechnology in agriculture to describe both materials with a physical size of 1-100 nm in at least one dimension, and materials that exist. at the volumetric scale but modified with nanomaterials (eg, fertilizers coated with nanoparticles). Therefore, the term "nano-fertilizer" is used in this article to refer to both the actual nanoparticles and the nano-activated raw materials used as fertilizers. Nanoparticles have the potential to improve the mobility of minerals and nutrients such as phosphorus in the biosphere and may have an effect on the metabolic activities of plants compared with other products [18],19]. Nanotechnology-based agricultural inputs are shown in Figure 1. In the following sections, we will discuss recent papers on nanoparticles/nanomaterials used as nanofertilizers for growth of plants. The discussion is therefore structured so that farmers and researchers can better understand the fundamental aspects and applications of nano-fertilizers for precision and sustainable agriculture

NANOFERTILISERS

Nanofertilizers include all or part of nanostructured formulations that can be applied to plants and allow for efficient absorption or gradual release of the active ingredients. Because traditional bulk fertilizers are applied in large quantities, their absorption is very slow. Two main problems are related to chemical fertilizers that absorb less phosphorus and nitrogen. They changed their chemical form so that plants could not easily absorb and wash away rainwater and degrade soil fertility. As a result, hazardous carbon emissions (such as some nitrogen oxides) and eutrophication, have serious consequences for agricultural safety and the environment. Therefore, it is important to develop smart fertilizers that are easily absorbed by plants. Scientists are actively exploring the various uses of metal nanoparticles in plant science and agriculture as possible ways to achieve this goal in a sustainable and concise way. Therefore, nanotechnology is a possible approach to achieving this goal in a sustainable and appropriate way. In addition, the environmental, health and safety aspects of nanotechnology need to be considered to determine the effectiveness of nanofertilizers [20-22]. The plant receives the nanocomposite, which gives different results and benefits over traditional or ionic salts [23-26]. A kind of inorganic, organic, and hybrid nanomaterials were examined on lots of vegetation to peer how they have an effect on crop development, productivity, and yield. The desk blanketed data approximately nanoparticle characteristics, nanoscale properties, mechanism of nanoparticle delivery, examined seedlings, and studied responses due to the fact the consequences of nanomaterials and the corresponding plant responses are stimulated through a selection of things associated with nanoscale assets, soil, and eco system. The following subsections cross over particular examples of nanoparticles which have been used as nanofertilizers or nanonutrients.

ANALYTICAL METHODOLOGY

The intrinsic properties and external relations of nanoparticles have a significant impact on their effect on plants. This is likely among the many purposes why the research has discovered conflicting results from the same particle category. For example, TiO2 nanoparticles retarded corn seed germination [85-86], but had no effect on paddy seed germination and enhanced wheat seed germination.In the following section, we'll go over some of the factors to consider when assessing a nanoparticle type and its affect on plants.

Nanoparticle/nanofertilizer synthesis

Nanomaterials are commonly synthesized by both "wet" methods such as solgel, hydrothermy, homogenous precipitation, biosynthesis using enzyme and protein models and reverse micelle methods

[87-88], and a "dry" synthesis strategy " as an aerosol-based process [8990], varying from single-element nanoparticles, semiconductor oxides, other metal oxides, metal alloys, polymers, doped nanoparticles, and composites. Nanoparticles for use as fertilizers require a synthesis method capable of producing large-scale particles with controlled physicochemical properties at low cost [91].

Nanoparticles delivery, uptake, translocation, and biodistribution

Agrochemicals can be applied to plants by three methods: seed treatment, soil application or foliar spray. When the nanoparticles were mixed into the soil, the exposure and localization concentrations were significantly greater than those of repeated exposure during foliar spray or transfer to fruit roots, resulting in very little ingestion and contribution. In addition, high risk concentrations may affect soil microorganisms or the biosphere [92-95], as well as cause caking or clumps due to the physico-chemical characteristics of the soil which may constrain plant particles. [96-97]. A study comparing the delivery of nanoparticles to plants through foliar spray versus soil treatment showed that foliar spraying offers significant benefits for nutrient delivery at scale. nano [98]. Experiments showed that an effective aerosol spray supports the generation of monodisperse particles and avoidance of soft aggregates during foliar application. Nutrients and insecticides have been applied to the leaves for many years. Theoretically, soil treatment or fertilizer treatment is based on soil nutrient deficiencies, while foliar treatment (aerosol treatment) is based on plant nutrient efficiency characteristics. [99]. To reduce nutrient loss, foliar treatments must have a higher leaf area index, a low exposure dose, the potential for multiple applications, and an application duration that varies with the season. Poisoning could occur if people or other animals inhale an aerosol of manufactured nanoparticles. However, this conclusion is influenced by particle concentrations in the environment, daily/time weather patterns, exposure concentration and physico-chemical properties of the particles [100-102]. To ensure safe foliar application of nano-fertilizer, it is essential to use appropriate protective equipment such as masks, gloves and eye protection [103-104]. Particles in aerosols are monodisperse, dispersed and significantly more stable than particles in typical solution spray or soil applications that stack as a result of particle or particle-soil interactions [105-106].

The features of nanofertilizers are especially significant for foliar distribution because they allow shape to be limited upward along the abdominal channel [107]. It has been demonstrated that controlling nanofertilizer particle size in conjunction with the aerosol delivery strategy, as reported in the preceding [108], improves stomatal uptake. Furthermore, foliar dispersion of iron and magnesium nanofertilizer for Urd *(Vigna unguiculata*) was demonstrated to have a considerable favourable influence on plant growth and development [109]. The results demonstrated that nanoparticles with diameters less than 100 nm created by an aerosol technique enter the foliar part of watermelon plants through the stomach , transit through the phloem, and reach the root. It is important to note that in many situations, plant parts are studied to explore the transit of nanomaterials using the ICP-MS technique, which detects ions rather than particles. Several other research, however, have confirmed their ICP-MS observations with microscopic or X-ray spectroscopy investigations of plant components to explain the presence of actual particles. However, non-representative results when it comes to imaging of a relatively small fraction of the entire plant are a main emphasis of electron microscopy of plant tissue [110-113]. Aerosol-mediated foil coating, cuticle, permeates the nanoparticles, overcoming the primary blockage of the plant cell [114-115]. Convective systems - the phloem transport channel, a bidirectional channel along the photosynthate gradients - transfer nanoparticles from shoot to root. Both the apoplast and symplast routes transport nanoparticles within cells. The apoplast pathway prefers larger molecules (200 nm), whereas the simple pathway prefers smaller particles (50 nm).

FUTURE EXPECTATIONS

Due to the specific physico-chemical properties of nanostructures, their use as agrochemicals (fertilizers or pesticides) for plant development and crop protection is under constant investigation. Currently, investments and future study requests appear to be more focused on the development of eco-friendly nanoscale materials for successful reactions. Research on nanotechnology in agriculture is still in its infancy but is progressing rapidly. However, before nano-fertilizers can be used in the field for typical agricultural practices, a better understanding of their mechanisms of action is required in accordance with the regulatory structure that provides for the appropriate use of such agrochemicals. The United States Food and Drug Administration has previously published guidance on the use of nanometry in animal nutrition [116]. Manufacturers are also incorporating engineered nanoparticles into foods, skin care products, and other consumer products. Silica is an example. Nanoparticles in baby food, titanium dioxide nanoparticles in powdered sugar donuts and other nanomaterials in paints, plastics, paper fibres, medicines and tubes of toothpaste [117-118]. Many characteristics of nanoparticles, such as size, shape, crystalline phase, solubility, type of substance, exposure and dose concentration are considered hazardous to the health of the market and are safe to consume, but this was an area that needed more thorough investigation. These challenges require additional research on the mode of action of nanoparticles [121]. Once the human body has been exposed to nanoparticles through nano foods, researchers need to develop a life cycle assessment of the health and environmental impacts of nanomaterials, as well as methods to assess and manage any risks, and also the sustainability of the nanostructured materials used in agriculture. To come up with solutions. Some of the key issues with nanoscale innovation and its use in agrochemicals need to be addressed.

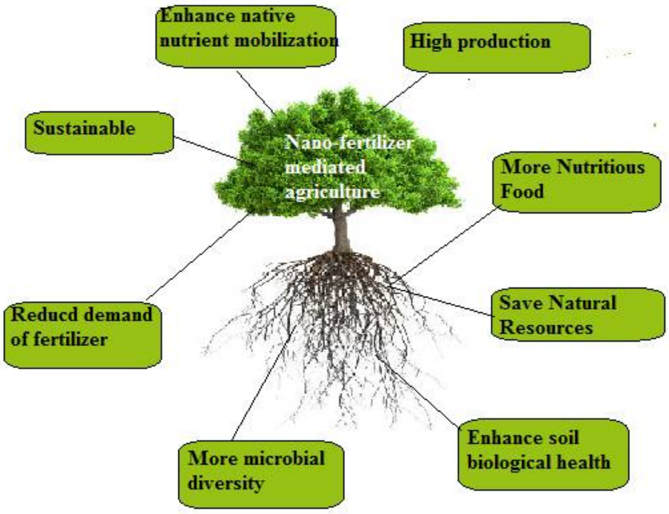

Figure1: Nanotechnology based Agriculture

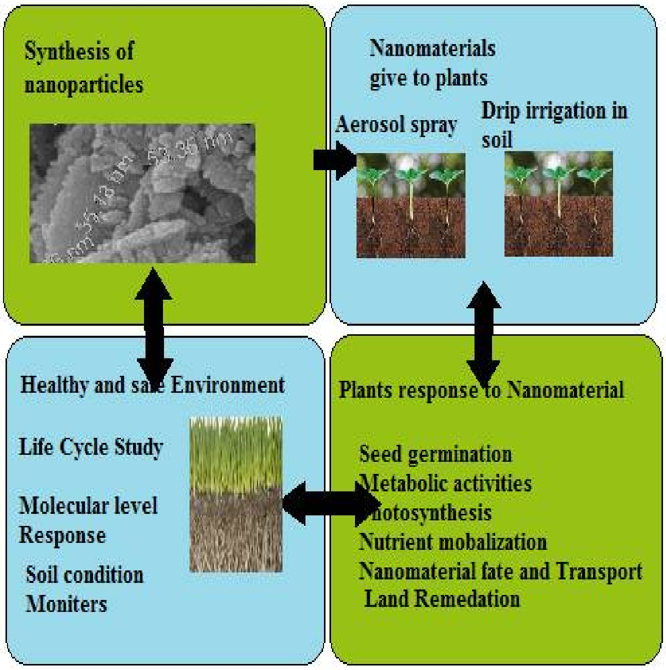

Figure 2: Methodical analysis of nanoparticles in agriculture

Table 1 Type of nanoparticle used as in crop and effect on plant growth

Type of NP	Concentration (ppm)	planning method in plants	Plant	Observation
ESSENTIAL PLANT NUTRIENT				
Carbon based NPs	5-500	Nutrient media and uptake; Seed treatment	Tomato [27,28,29]; Tobacco [30,31,32] Wheat [33]; Gram [34,35] melon [36] *Saltmarsh cordgrass* [37] Soybean [38,39,40] Corn, Barley, rice, [41,42]	1. Progressing upregulation of stress-related genes. 2. Risen root elongation. 3. Enhancing crop yield and seed property. 4. Reduce heavy metal toxicity.
Nitrogen Urea HA	50 Kg/ha	Soil exposure	Rice [43-44]	1. A gradual release of nitrogen 2. Enriched rice yield
phorous $CaPO_4$, CMC –HA, Phosphorite Zn induced P	10-100	Soil and foliar applications	Cotton[45]; Pearlmillets [46] Beans [47-49] Wheat, Rye, Pea, Barley, Corn, Buckwheat, Radish, Cucumber [50]	1. Protect toward oxidative pressure 2. Mobilize native P and improve uptake 3.Improves plant growth and yield
Magnesium MgO	15	Foliar	Clusterbean [51]	1.Advancing biomass, chlorophyll content & phenological growth
Manganese	100 -1200	Foliar & seed treatment	Corn [52], Tomato [27,28,29]	1.Improved seedling germination, plant biomass, and biochemical activities
Zinc ZnO	10 - 2000	Foliar application Seed application	Peanut [53] Beans [54-57] Tomato [27,28,29] Cotton [58] Maize [59]	1. Accretion of yield potential and plant growth. 2. Enhance plant hormone level and plant growth 3.Help to decrease drought intensity and improve agronomic support Enhance shoot length, root length, root and shoot dry mass, leaf area and number of roots, plant biomass, root and shoot growth
Iron Iron Oxide	1.5-4000	Foliar Spray	Wheat [60]; Watermelon [61,62] Clover [63]; Soybean [64] Rice [44]; Tomato [27,28,29] Peanut [53]; Corn [52] Zea mays [65] Pumpkin [66]	1. Enhance photosynthesis rate, chlorophyll content, biomass, grain yield & nutritional quality 2. Improving plant growth 3. Enhance nutrient absorption by increase microbial enzyme activity in the rhizosphere chlorophyll content, root length, leaf length, and stem length
NON-ESSENTIAL PLANT NUTRIENT				

Type of NP	Concentration (ppm)	planning method in plants	Plant	Observation
Titanium TiO2	200-600	Seed, soil and foliar exposure	Spinach [67-69] Lemna minor [70] Tomato [27,28,29] ; Wheat [71] Watermelon [61-62]; Mung Bean [72] Moth bean [73] Pearl millet [74] Clusterbean [75,76]	1.Raised plant biomass and photosynthetic movement. 2. Increased biochemical enzyme activity and light absorption by chloroplast, carbon fixation 3. Enhanced germination rate. Increased nitrogen metabolism
Cerium CeO	0.1-250	Irrigation; Seed/root	Tomato [77-78] *Arabidopsis thaliana* [79-80] Cilantro [81]; Wheat [60]	1.Cultivated plant growth and yield 2. Enhanced physiological and Molecular response 3. Increase stress threshold enzyme activity
Silver Ag	1 -10	Hydroponics, Soil	Poplars [82] *Arabidopsis thaliana* [79-80] Clover	1.Influence Phyto-stimulatory effect 2. Increase nutrient consumption by improving microbial activity in the rhizosphere.
Silica Si SiO SiO_2	5-800	Soil irrigation, Seed & Root exposure	Tomato [27,28,29] Wheat, Lupin [83] *Larix olgensis* [84]	1. Help overcome from salinity stress and Improve plant growth. 2.Enhance germination and growth. 3. Enrichment in total protein and chlorophyll content. 4.Raised seedling growth and quality.
Cobalt Ferrite	1– 1000	Root exposure	Tomato [27-29]	1. **Encourage root growth**
Indium In_2O_3	250	Seed/Root	*Arabidopsis thaliana* [79-80]	Improved physiological and molecular response

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