Nano fertilizer: A review on applications and impact of their use on growth ,yield on crops.

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Abstract

There are various problems in the agriculture sector, such as climate change and expanding food consumption, It makes it necessary to encourage agricultural development in order to ensure agricultural and economic stability from many years ago, farmers have benefited from the use of fertilizers in agriculture. Traditional fertilizers are costly and damaging to both people and the environment, thus, there is a need to provide environmentally friendly fertilizers that are high in nutrients and compatible with the soil and environment .To improve the quality attributes therein, nanotechnology is emerging as a possible solution in the form of nanofertilizers. Nanotechnology has an enormous record of solving agricultural issues and expanding the agricultural sector, which has the most impact on environmental and social development. By introducing value-added food items, agriculture, and improving the safety of the food supply, nanotechnology has the potential to raise the efficiency of food production and protect both consumers and producers.

Key words: Nanotechnology, Nanofertilizers, Traditional fertilizers, nano macronutrients

Introduction

The addition of traditional chemical fertilizers and their overuse to compensate for the lack of soil nutrients lead to environmental pollution as well as the high costs of these fertilizers (Walpola and Yoon, 2012), and as a result of the negative effects of the ill-advised use of chemical fertilizers in the southern region, including the problem of soil pollution as well as increasing it. The salinity of the soil of the region, it was necessary to think about using modern fertilizers as an alternative to traditional fertilizers and using them to provide the nutrients necessary for plant growth and increase productivity, while maintaining the soil in a good condition and a clean environment (Miransari, 2011). Among these fertilizers are the environmentally friendly and very effective fertilizers called "Nanofertilizer", and on this basis we have used the integrated nanofertilizers. Nanotechnology means studying the basic principles of molecules and compounds whose size does not exceed 100 nanometers (Solomon et al., 2007) .This technique depends on reducing the part to a size equal to one billionth of a meter and then using the new material. In a wide range of sciences such as medicine, engineering, agriculture and food, positive effects have been shown (Mozafari *et al.,* 2008). The use of nano fertilizer is one of the most widely used and widely used molecules for its positive effect on improving plant growth (Drostkar *et al.,* 2016).The technology of using nanofertilizers is still on the scale of experiments in Iraq. However, a number of countries surrounding Iraq have made great strides in using this technology, including Iran, Saudi Arabia, Jordan and Egypt. Attention to plant nutrition and the search for new sources of nutrition to provide all the nutrients for any crop in the quantities needed by the plant is necessary to obtain the highest yield and quality, and the availability of major and minor nutrients is very important for the growth of plants in terms of their participation or entry into some Plant vital activities (Saeed *et al.,* 2012), and that the lack of one or more of these nutrients for any crop becomes the determining factor for the growth and productivity of that crop.

Nanomaterials and Nanoparticles

One of the 21st century's most important technologies is nanotechnology. The word "nano" is a translation of the Greek word for "dwarf." It means 10^{-9} or billionth of a meter. (Pantidos and Horsfall 2014). "Nanoparticles" are particles with at least one dimension smaller than 100 nm (Naik, 2020). Due to their high surface area to volume ratio, nanoscale regime, and special characteristics, nanoparticles are widely used. Sharma (2008) stated that the importance of nanotechnology lies in the fact that tiny objects with nanoscale dimensions have properties that differ when they are at this size from their properties when they combine to form larger bodies. Peddis *et al.*, (2009) explained that there are some unique properties of nanoparticles such as very high specific surface area and high surface energy, and this leads to a great difference in their behaviors and environmental fate compared to their counterparts with larger particles. Ghorbani *et al.,* (2011) reported that nanoparticles (NPs) at a scale of less than 100 nm exhibit material properties that differ from them when they are of conventional dimensions greater than 100 nm. Musante (2011) indicated that some materials at the nanoscale show a change in the surface area, the degree of freezing or melting, and some other properties compared to the aggregation of particles at a higher level than that. It was later found to have many positive effects in the fields of medicine, pharmacy, biology, agriculture and other diversified industries (Roco, 2003, Nowack and Bucheli, 2007). Hosseini and Eghtedari (2012) indicated that global production from sources of nanoparticles reached 103 tons in 2004 and is in a continuous annual increase and can play an important role in the economic development of developing countries in the agricultural field. Nair *et al.,* (2010) showed that nanomaterials possess all the properties necessary for their use in agriculture, such as effective concentration with high solubility, good stability and efficacy, in addition to controlling their release time, as they are less toxic and safe, and are used in small quantities and avoid repeated application on plants, thus obtaining a good result. From the first application, it also has the ability to enhance the plant's ability to rapidly absorb nutrients and other smart sensors that are used against viruses and treatment of pathogens for other crops (Thul *et al.,*2013).Prasad *et al.,* (2014) showed that the use of nanomaterials nanoparticles is a modern technology that has become used in a wide range of life sciences, including adding them to the soil to improve their properties or vital components or adding them to plants with the intention of increasing their growth and improving their productivity, and that nanoparticles have unique and distinctive behavior and characteristics such as their smallness and possession of a surface area. Highly effective with high solubility and permeability inside the plant and stability and stability within the treated area. Moslemi *et al.*,(2014) noted that nanoparticles are products in the form of envelopes or capsules of micronutrients small in diameter (µm) with many nutritional properties, namely: (1)Improving the contact surface for absorption and thus increasing bio-readiness (2)Lower production costs. (3)Safe biodegradation for food and the environment, and it is worth noting that most of the research and development work in the field of encapsulated micro-nutrients is in the food and drug fields (Choi et al. 2009 Majeed; *et al.*, 2013 and Moslemi *et al.*, 2014).

Nanofertilizers

Nano-fertilizers are emulsions or particles of a nanoscale or smaller that contain one or more the macro- or micronutrients (Chhipa, 2017). They are a substances that provide nutrients to crops inside capsules within nanoparticles, and this packaging is done by putting the nutrient inside the nanomaterials (De Rosa *et al.*,2010). According on the technique of nutrient delivery, the feeder is encapsulated by being inserted within the nanoparticles. Physical and chemical characteristics of nano fertilizers include a good surface area due to the aggregation of atoms and molecules on the surface. This makes it feasible to create nano-fertilizers with properties that enable them to release nutrients gradually and sustainably in response to the needs of the plant, so that they can be used and absorbed by the plant roots, preventing them from being converted into substances or chemical forms and gases, with the help of this technology, it is possible to raise global production, protect plants from disease, enhance food quality, increase agricultural output, reduce resource loss, and maintain a sustainable environment(Prasad et al.,2014).

It is possible to extract nanofertilizers from various plants or plant parts by encasing or coating them in nanomaterials, or they can be produced from bulk fertilizer materials, traditional fertilizers, or other plant components for the enhancement of soil fertility, productivity, and quality of agricultural products; for the regulated and gradual release of nutrients(Zulfiqar *et al.*,2019). Due to nanomaterials' high level of reactivity, they interact with fertilizers to improve and maximize plants' ability to absorb nutrients(Prasad *et al.*,2017). The delivery systems for the nanomaterials have a big impact on how well they are absorbed by leaves. Nanofertilizers are able to increase human health and nutrition by decreasing the need for biocides, improving plants' resistance to abiotic stresses and improving metabolite(Figure 1).Correct use of nanofertilizers can feed plants gradually in a way that raises NUE, prevents leaching, reduces volatilization, and lowers overall environmental concerns(Chen and Wei,2018). Due to their high specific surface area, smaller and more reactive, nanofertilizers increase the availability of nutrients.

Manjunatha et al.,(2016) categorized nanofertilizers as follows:By

1- Slow release: nutrient-releasing nano-fertilizers that are contained in a capsule and released over a specified period of time.
2- Quick release as soon as they contact the surface, the nanoparticles split apart and diffuse.
3- specialized release By introducing a certain chemical or by having a particular enzyme present, the capsule or nano-shell that protects the fertilizer opens.
4- When water is present in the planted soil or when there is moisture, the nutritional element releases.
5- The nutrient element is released when the soil temperature reaches a certain level.
6- Release of the nutrient component based on the pH of the soil, for instance, in alkaline or acidic conditions.
7- When exposed to external ultrasound frequencies, the nanovessels burst, releasing the nutrient through ultrasound.
8- When placed in a magnetic field, the nanoshells release their magnetic charge.
9- Nanocapsules of DNA.

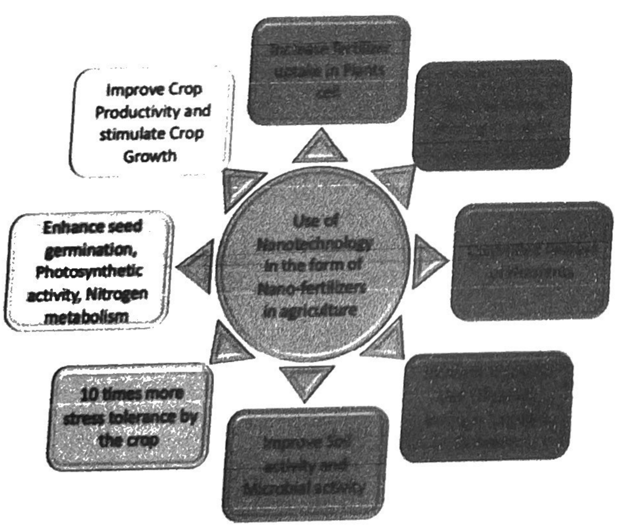

Figure 1.The use of nanobiofertilizers in various agricultural applications.

According to Mikkelsen (2018), nano-fertilizers are nutrient carriers with very large surface areas that range in size from 1 to 100 nanometers and divided them into encapsulated nano-fertilizers (conventional fertilizers supplemented with nanomaterials or encapsulated in them), also to nano-additives (traditional fertilizers including nano-additives) and nano-fertilizers (nutrient-carrying nanoparticles).

Three methods can be used to encapsulate nutrients with nanomaterials (Iqbal, 2019).

- In the nanomaterials' encapsulation.
- Coated with the nanoparticles.
- In the form of nanoemulsions.

The three following factors affect how effective nanofertilizers are internal and external factors, as well as the method of management, Internal factors are ,the preparation process, particle size, and surface coating for a nanoformulation ,While external factors such as soil temperature, organic matter, soil depth, soil pH, soil texture, and microbial activity, which might potentially have an impact on the use of nanofertilizers (Solanki *et al.*,2015, El-Ramady *et al.*,2018). Additionally, the method of application through plant roots or leaves also has a big impact on how well nanofertilizers are absorbed, and bioavailability. The comparative application of various fertilizers, from conventional to nanofertilizers, is shown in Figure 2.

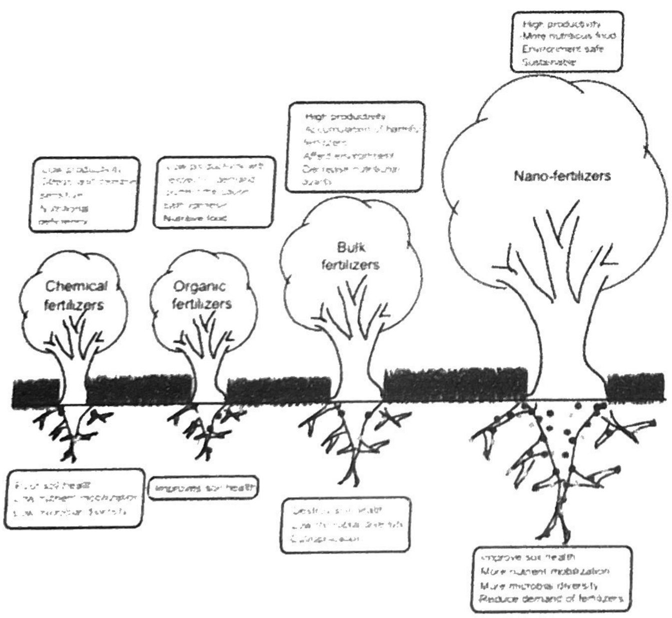

Figure 1. A comparative assessment of the effects of chemical fertilizers, organic fertilizers, bulk fertilizers, and nanofertilizers on plant growth and the soil rhizosphere. [Text in red and blue, respectively, indicates negative and positive impacts]

Comparison of traditional fertilizers with nanofertilizers

Chang et al.,(2013)indicated that crucial characteristics of nano-fertilizers, like high solubility and controlled release of nutrients in accordance with the right period for plant growth, are present, it also shows superior efficacy and activity by supplying the necessary concentration and lowering toxicity with a simple safe transport of nutrients. The nitrogen release from nitrogen fertilizer coated with Nano Zeolite Urea (NZU) lasted from 34–48 days as opposed to standard urea fertilizer, which lasted for only four days, (Subramanian and Manikandan ,2015). In a study by Rameshaiah et al., (2015), they found that combining urea fertilizer with zeolates, which have a large surface area and nanopores, decreased the rate of urea decomposition and decreased nitrogen loss, enhancing the fertilizer's effectiveness. Rajemahadik *et al.,* (2018) demonstrated that nano-fertilizers are more effective than conventional fertilizers because they minimize fertilizer and nutrient loss and efficiently release nutrients in accordance with the needs of crops, which improves the plant's capacity to control the decomposition process and absorb nutrients because it enters cells easily, in addition to its contribution to boosting the activity of photosynthesis by raising the chlorophyll content of plant leaves, and increasing crops' ability to endure different stress conditions and disease resistance, while lowering the environmental dangers associated with the use of conventional fertilizers. According to Pramanik *et al.,* (2020), nano-fertilizers are intelligent fertilizers that give plants nutrients on their own, in combination, or in addition to conventional fertilizers, enhancing and expanding crop yield in agriculture.

Uptake of nanofertilizers in the plant

The process of adding nano-fertilizers spraying on plants provides the best and easiest way to penetrate the plant due to its small size and the speed of its spread, which enables it to increase the speed of absorption, and the interaction of nano-fertilizers affects the solubility of nutrients and their spread, thus becoming ready for absorption by the plant. It has been reported that after spraying nanofertilizers on the plant's shoots, the particles fell to the leaves and accumulated in the horizontal leaves before penetrating the epidermis through the pores or stomata on the epidermis outer surface(Hong *et al.,*2014). Serag *et al.,* (2015) mentioned that a carbon nanotubes interact with the surfaces of plant roots, and this contact varies from one plant to another, and these tubes can enter the cell cytoplasm by creating holes in the cell wall. In general, depending on the type of nanoparticles that can be sprayed on plant leaves, they may spread towards different plant tissues by entering through stomata or the bases of filaments.(Singh *et al.,* 2017). The transformation and accumulation of nanoparticles in plants, as well as their uptake and transport, are very essential factors connected to the kind of plant, growth stage, growth environment, biochemical processes, and nanoparticle use mechanism. Additionally, nano-fertilizers in plants have attracted a lot of scientific attention, but it is still unclear what happens to them once they are within plants and how exactly they are stored(Rico *et al.,*2011)

Types of nanofertilizers (NFs)

Nano-fertilizers play important roles in plant nutrition, whether when sprayed on the vegetative system or added through ground treatments. Nano-fertilizers are more soluble and active than conventional fertilizer particles.(Naderi and Shahraki 2013; Rameshaiah and Jpallavi,2015). Various nutrients that the plant needs, whether they are essential or minor, are already available in nano form .Nanofertilizers can be classified into three groups based on the type of nutrient: focused on macronutrients, micronutrients, and biofertilizers. Categories of macronutrients include primary and secondary. Although essential macronutrients (N, P, and K) are taken in in greater amounts, secondary macronutrients (Ca, Mg, and S), which include calcium, magnesium, and sulfur, are also extremely important for plant growth. Despite the fact that all of the macronutrients are significant, primary macronutrients are taken in greater amounts than secondary ones. These three basic macronutrients (Nitrogen, Phosphorus, and Potassium) are known as fertilizer elements because they are represented by the well-known "N-P-K" on fertilizer labeling. Although micronutrients are only necessary in very small amounts for optimum plant development and production. Micronutrients are very important because they have catalytic and stimulatory effects on the process of metabolism, which improve yield and quality(Hänsch and Mendel, 2009) So, the plant's physiological and metabolic functions may be severely disturbed by their lack(Farooq et al., 2012 .For all higher plants the six micronutrients Fe, Mn, Zn, Cu, Mo, and Ni are necessary for the healthy growth of plants and other crops, only trace amounts of micronutrients are needed in compared to macronutrients. Nanoparticles and biofertilizers are combined to create nanobiofertilizer. It is a method in which biofertilizers are covered in a suitable nanomaterial. They reduce the negative impacts of environmental stresses and manage the movement of nutrients into the soil. They increase the availability and uptake of nutrients, utilize less chemical fertilizer, are cost-efficient, and are environmentally friendly as well as promoting crop yield and productivity (Thirugnanasambandan,2019). A biofertilizer is made entirely of microorganisms that are beneficial to biology, such as rhizobium, blue-green algae, mycorrhizae, the bacterium Azotobacter, Azospirillum, and phosphate-dissolving bacteria like the Pseudomonas and Bacillus spp.

Nano-macronutrient fertilizers

Since many of these **nutrients** are difficult for plants to absorb, farmers prefer to use large dosages of fertilizer to almost overcome their low nutrient values causing well-known environmental, water, and land damage . Using NFs will increase fertilizer nutrients, improve agricultural output and efficiency, and reduce the adverse impacts of synthetic fertilizers (Czymmek, et al.2020). Zhang *et al.*,(2016) investigated how crops would respond to controlled-release fertilizers that were covered with nanomaterials, these nanocomposites were found to be safe for the germination, emergence, and seedling growth of wheat(*Triticum aestivum* L.), and they can give nutrients to plants in a controlled, timely, and reactive method. Additionally, many studies show that external use of specific nanoparticles may greatly improve plant development(Mandeh *et al.*, 2012; Song *et al.*, 2013). As compared to normal P fertilizers as superphosphate, it considerably enhanced soybean biomass by 18.2% (above ground) and 41.2% (below ground) (Liu and Lal, 2014). Chickpea yield and yield components increased after foliar application of nano-fertilizer NPK due to an increase in growth hormone activity and better metabolic action, which also led to an increase in flowering and productivity (Drostkar et al., 2016).Abdel-Aziz *et al.*, (2016) found that the numbers of spikelets per spike, 100 kernel weight, spikelets per spike, and spikelets per plant of wheat were higher in plants treated with nanofertilizers than in plants treated with conventional fertilizer. According to Rathnayaka *et al.*, (2018), who investigated the effects of urea and nano-N fertilizers on rice, nano-N fertilizers increased plant height, the number of tillers per plant, and plant biomass dry weight. Al-Juthery *et al.*, (2018) indicated that wheat responded to the application of Super Micro Plus nano fertilizer(SMP), achieving a height of 87.77 cm as compared with 67.22cm when conventional NPK fertilizer.When compared to normal nitrogen fertilizer treatments, nitrogen nano-fertilizer has been demonstrated to produce the highest seed yield (17.6%) and oil yield (28.7%) when applied at a rate of 60 kg ha^{-1}(Handayati and Sihombing , 2019). The results of Liao *et al.*, (2019) indicated that Dry weight of wheat increase when fertilized with nano NPK fertilizer compared to conventional fertilizer and control treatment. In the experiment of Saleem *et al.*, (2021) showed that wheat plant height reached 80cm as a result of the addition of DAP nanofertilizer with nanopotassium, whereas the plant height reached 50 cm with the addition of traditional NPK fertilizer. Astaneh *et al.*, (2021) noted that increasing the level of nitrogen nanofertilizer at levels 14, 27, and 41 kg N ha^{-1} led to a significant increase in grain yield of wheat amounting to 31, 44, and 98%, respectively, compared to the addition of urea fertilizer at levels 37, 74, and 110 kg N ha^{-1} the grain yield increased by 9,19 and 27%, respectively .The results of Al-Shummary (2021) showed that increasing the level of traditional phosphate fertilization led to an increase in the leaf area of wheat, as the level of 100 kg P ha^{-1} gave the highest number of spikes and the number of grains per spike reached 398.0 spikes m^{-2}, and 103.07 grain $spike^{-1}$compared to the control, which gave the lowest value of 326.0 spikes m^{-2} and 85.40 grain $spike^{-1}$,as for the nano-fertilizer, level of 5 kg ha^{-1} gave the highest number of spikes of 382.8 spikes m^{-2} compared to the control which gave the lowest (263.0 spikes m^{-2}).Sajit (2022) explained that the addition of mineral and nano nitrogen fertilizers together with the treatment of 100 kg N ha^{-1} + 1L ha^{-1} nano led to an increase in the flag leaf area of wheat as it excelled and recorded 42.70 cm^2 with no differences in the treatment of 200 kg N ha-1 and 150 kg N ha +1\ 4 L ha^{-1} nano, which recorded 42.47 and 42.30 cm^2 respectively, while the treatment 2 liters ha^{-1} nano gave the lowest (38.90 cm^2), also indicated that the levels of nitrogen had a significant effect on the number of tillers and the spike length of wheat, that the treatment of 200 kg N ha^{-1} mineral fertilizer had a recorded the highest average of 417.33 tiller m^{-2} and

16.68 cm , while the treatment 100% N nano gave the lowest of 313.67 tiller m^{-2} and 15.11cm respectively.Saedpanah *et al.,* (2016) observed that spraying corn (*Zea mays* L.). with nano fertilizers of NPK, achieved the highest grain yield of 8.16 tons ha^{-1}, while the control treatment recorded the lowest yield of 5.66 tons ha^{-1}. K-nano-fertilizer application improves soil fertility and crop output in sandy and alkaline calcareous soils (Rajaei, 2010).When potassium nanofertilizer was applied to peanut(*Arachis hypogaea* L.) plants at a level of split twice 150+150 ppm compared to other treatments, there was a noticeably higher concentration of nutrients in the shoots and seeds(Afify *et al.*,2019). EL-Ghanam and El-Ghozoli (2003) found that the application of K-nano-fertilizer greatly increased the yield of faba bean(*Vicia faba* L.) dry matter. The effectiveness of magnesium hydroxide nanoparticles in promoting seed germination has also been studied, at a concentration of 500 ppm the particles had 100% seed germination and rapid growth..(Shinde et al.,2018). Sulfur nanofertilizers were found to reduce Mn uptake, improves metabolism, increase seedling water content, and bring an end to physiological drought, these results indicate that sulfur nanofertilizers can reduce the negative impacts of Mn stress.(Ragab and Saad-Allah ,2020).

Nano-micronutrient fertilizers

Researchers found the positive impacts of nano fertilizers for microelements in enhancing growth, yield, photosynthetic efficiency, and other crucial activities for various crops.(Mandeh *et al.*,2012 ; Song *et al.*,2013 ; Ghafariyan *et al.,* 2013 ; Alidoust and Isoda,.(2014).The use of nanoparticles of iron, zinc and aluminum had positive effects on plant growth, as it helped in increasing the rates of germination and seedling growth, stimulating the absorption of water and fertilizers by the roots, and increasing the activities of oxidizing enzymes. As compared to using common zinc fertilizer, Prasad *et al.,* (2012) in India found that spraying peanut plants with nano-zinc fertilizer improved the production of pods in the plant by 29.5% and 26.3% for the two seasons. In the study by Moosapoor *et al,.* (2013), Bohr Nano-Fertilizer was sprayed on a field pistachio crop in five concentrations (0, 1, 2, 3, and 4 gm L-1), and its effectiveness was compared to that of traditional chelated iron fertilizer in four concentrations (0, 2, 4, and 6 gm L^{-1}).), it was found that the application of nano-fertilizer significantly increased the seed yield, the number of grains per pod , pods yield, harvest index, and the weight of 100 seeds. Spraying cotton with chelated zinc nanoparticles and traditional chelated zinc compared to control improved the physiological processes in cotton with a significant superiority of chlorophyll content, plant dry weight and the number of nuts in the plant.(Rezaei and Abbasi,2014). Sharifi *et al.,* (2016) indicated that there was a significant increase in plant height, reached 184.50 and 167.20 cm when spraying with nano-iron and zinc fertilizer, respectively. While reached 180.04 and 154.06 cm when spraying with the traditional fertilizer, respectively. it was found that spraying with nano-fertilizers of iron and zinc led to an increase in grain weight of plant by 75.63 and 69.75% and grain yield by 13.89 and 17.90%, compared to the control of the two types of fertilizers, respectively (Janmohammadi *et al.,* 2016). Cu-chitosan NPs applied topically or in a combined seed coating increased the yield and growth profile of finger millet (*Eleusine coracana* Gaertn)plants and enhanced their defense enzymes, which reduced blast disease(Sathiyabam and Manikandan, 2018). Compared to MnSO4 salt, which is sold commercially, manganese nanoparticles (MnNPs) have been shown to be a superior micronutrient source of Mn. MnNPs have been found to improve mung bean (*Vigna radiata*). photosynthesis in addition to promoting growth(Pradhan et al.,2013). Spraying three different concentrations of boron metal and its Nanoparticles (0, 90, and 180 mg L^{-1}), boron Nanoparticles at a concentration of 90 mg L-1, increased the plant's height, the quantity of pods, and the seed yield with more efficiency(Ibrahim and Al Farttoosi,2019),.Additionally, it has been shown that when boron nanofertilization is applied under calcareous conditions, alfalfa can be produced in high amounts with adequate feed quality(Taherian et al.,2019). Using MoNPs liquid as a basic source of Mo for chickpea and found that its treatment, either alone or in conjunction with microbial treatment, had the potential to increase the yield, performance, and disease resistance of both legume and other crop species(Taran et al.,2014). Zotikova *et al.,*(2018) showed that Nickel nanoparticles (NPs) with a 5 nm size at doses of 0.01 and 0.1 mg/L had no effect or promoted development in 10-day wheat seedlings.

The disadvantages of nanofertilizers

Although nanotechnology has greatly improved the manufacture of fertilizer, there are still certain limitations and drawbacks to be cognizant of. When it comes to large-scale applications, practical issues and production availability are the main limits. Additionally, there are significant disadvantages such as higher production costs and a lack of uniformity. Because nanoparticles are a relatively new technology, there is a higher danger associated with them. Several studies have been carried out on its application in crops (Solanki *et al.*, 2015).

Conclusion

In general, nanofertilizers increase the fertilizer effect period and delay nutrient release. By making fertilizers better, nanotechnology may undoubtedly have a huge impact on the energy, economy, and environment. As a result, nanotechnology offers great promise for attaining sustainable agriculture. Nano-fertilizers have created new potential to increase the effectiveness of input utilization, reduce prices, and, in certain cases, slow down environmental damage. Therefore, in order to increase crop output while maintaining soil health and environmental quality in the twenty-first century, the potential for using nanofertilizers in agricultural systems must be given the greatest importance by encouraging the use of nanoparticle fertilizers and nano-sensors for monitoring soil microbial activity

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