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Role of nano-fertilizer in agriculture: A review

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Abstract
Global agricultural systems face numerous challenges, such as the issue of feeding orchids because many agricultural soils deteriorate due to contamination with chemical fertiliser residues, as well as enhancing fruit tree growth and productivity and producing high-quality fruits, which are primarily dependent on quantity availability. Since nano fertilisers are an efficient alkaline fertiliser, nanotechnology is a useful tool for agricultural development, particularly in fertilisation programs. Researchers have been looking for ways to increase fertiliser use efficiency without exposing themselves to losses or pollution in order to ensure food safety. They have a number of advantages since they are used in less quantities, are quickly absorbed by the plant, and are very stable in a range of conditions, which enables them to be kept for longer periods of time. Nanotechnology may be more important in sustaining crop sustainability, increasing agricultural output, and improving crop quality. According to this study, nanotechnology has the potential to produce innovative methods for enhancing fruit crop quality and productivity, which would guarantee food and nutritional security for the world's growing population.

Keywords: Agriculture, nutrients, nano fertilizers

Introduction
In order to feed the world's population, which is expected to increase by 110 percent by 2050, agricultural productivity must increase by 70%. In order to achieve global food security, improved food output, and increased food productivity, it is critical to validate new and emerging breakthrough technologies in horticulture crop cultivation, yield, and productivity. Nanotechnology can help with the production, processing, packaging, storage, and transportation of horticultural products (Mousavi and Rezai, 2011; Ditta, et al., 2015) [30, 11]. According to Derosa et al. (2010) [12], the use of nanotechnology can significantly enhance the long-term integration of soil microorganisms, fertiliser products, energy, economics, and the environment. In order to feed the world's expanding population, problems including insufficient nutrients, uneven fertilisation, inefficient fertiliser use. Soil needs to be handled. This calls for the creation of a fertiliser composition based on multifunctional nanotechnology To increase soil fertility and boost agricultural yields, enormous amounts of fertiliser are required (Li et al., 2014) [25]. The world's soil fertility has been drastically reduced by 40% as a result of intensive farming practices; chemical fertilier is required to restore it (Dijk and Meijerinck, 2014) [13]. Aside from the effectiveness of other agricultural inputs, fertilisers account for onethird of produ ctivity in horticulture and agriculture. Enhancing nutrient uptake can be achieved by encasing fertiliser in nanoparticles. A fertilizer is any item that is used in the soil or sprayed on plant tissues to supply one or more important nutrient components to improve crop plant nutrition (Bhardwaj et al., 2014) [5]. Fertilizers can be obtained from a variety of sources, both natural and synthetically created. In contemporary agriculture, fertilizer application is essential for increased crop output. One of the major obstacles in crop fertilization is that large amounts of employed fertilizers are wasted in different ways, polluting the environment and raising production costs. The use of nano-fertilizers is a major recent advancement in decreasing the environmental impact of applied fertilizers. Nano-fertilizers are made by combining plant nutrients with nano materials, coating nutrient molecules with a thin layer of nano materials and forming nano-sized emulsions. Nano fertilizers and nano biofertilizers which combine natural and synthetic

elements, boost bioavailability and soil fertility more effectively than standard fertilizers (Sidorowicz, et al., 2019) [39].

The combined application of urea-modified hydroxyapatite and copper, iron, and zinc nanoparticles has been demonstrated to provide a slow and long-lasting release of essential nutrients into the soil and water. The ladies' finger plant's nutrient content was verified, and the fertilizer's physicochemical attributes were found to be better than those of commercial fertilizer. Researchers got significant results on *A. esculentus*. To keep the environment safe, slow-release fertilizers can sustainably release nutrients that are needed. Nano fertilizers have demonstrated positive impacts on enhancing soil fertility, mitigating nutrient depletion, and enhancing agricultural productivity. The utilization of nanoparticles in the field of agriculture plays a fundamental role in fostering robust plant development. Researchers have inferred that nano fertilizers have significant benefits as plant nutrients, such as gradual and enduring nutrient discharge, minimal application rates (50 mg/week), cost-effectiveness, nutrient-dense produce, and negligible environmental pollution (Tarafder et al., 2020) [42].

Difference between Conventional Fertilizer vs Nano Fertilizers

Conventional fertilizers are usually applied to crops by spraying or broadcasting. The final fertilizer concentration that reaches the plant is an important factor of the application method. However, only a small portion of the final concentration—far less than the minimum desired concentration—reaches the targeted site due to chemical leaching, drift runoff, evaporation and hydrolysis by soil moisture, photolytic, and microbial degradation. Around 40-70 percent of applied nitrogen, 80-85 percent of phosphorus and 30-40 percent of potassium is expected to be loss in the environment and unable to reach the plant, resulting in long-term and economic losses (Ombodi and Saigusa, 2000) [32]. These problems have led to the widespread use of fertilizers and pesticides, which has harmed the soil's natural nutritional balance. The increasing use of chemical fertilizers and pesticides, on the other hand, has contaminated the environment, harming flora and fauna. Use of too much fertilizer, according to Tilman et al., (2002) [43], lowers soil micro flora and inhibits nitrogen fixation. In order to meet crop nutrient requirements while lowering the risk of contamination, it is imperative to make the most of chemical fertilization. To provide the necessary nutrients for crop production and plant growth while preserving a clean environment and a healthy soil structure, a variety of strategies must be tried (Miransari, 2011). In order to create so-called smart fertilizers—new facilities that increase nutrient use efficiency and lower pollution costs—nanotechnology has allowed researchers to investigate nanoscale or nanostructured materials as a fertilizer carrier or controlled release vector (Chinnamuthu and Boopati, 2009) [7]. A nano fertilizer is a nutrient delivery product that is measured in nanometer regime. Encapsulation, for example, inside nano materials covered with a thin protective polymer coating or in the form of nano scale particles or emulsions. Because of surface tension, nanomaterial surface coatings on fertilizer particles hold the material in place better than conventional surfaces, helping to control the substance's release (Brady and Weil, 1999) [6]. One important aspect of the use of nanotechnology in agriculture is the delivery of agrochemical materials, like fertilizer, to the plant, which provides macro and micronutrients. The regulated release of agrochemicals, site-targeted distribution, reduced toxicity and improved nutrient use of supplied fertilizers were all features of nano fertilizers (Cui, et al., 2010) [8]. Because of their enormous surface area to volume ratio, high solubility and selective targeting owing to their very small size, high mobility and low toxicity, nano particles have these qualities (Sasson, et al., 2007) [37].

Benefits of Nano-Fertilizers

The agricultural economy is under increasing pressure to meet the ever-rising demands of a growing human population. Chemical fertilizers are widely used in numerous applications and are thought to be essential for increasing agricultural output (Feregrino et al., 2018) [18]. The remaining minerals target for the intended location may seep down and get fixed in the soil or contribute to water pollution, as crop consumption frequently amounts to less than half of the fertilizer applied (Chen, 2018) [9]. For example, it has been observed that essential macronutrient elements added to the soil, such as N, P and K, are lost by 40–70%, 80–85% and 40–50%, respectively, resulting in a significant loss of resources (Solanki, et al., 2015) [41]. Furthermore, growers commonly employ these fertilizers in order to achieve desired higher yields, which can lead to a decrease in soil fertility and increased salt concentrations, resulting in future crop losses. In addition, imbalanced fertilization without nutrient release control has the potential to damage product quality. Therefore, developing slow-release fertilizers is essential to ensure a sustainable future of horticulture production as well as for improving crop yield and quality. There is a lot of demand on the horticulture sector right now to use fertilizers other than chemical ones in order to increase food security (Liu and Lal, 2015) [26]. New ideas and methods are required if worldwide horticulture output and demand are to be satisfied in a way that is both economically and environmentally sustainable. Nano materials are defined as materials with a particle size of less than 100 nanometers in at least one dimension. There are various types of nano materials such as single or multi walled nano tubes, magnetized iron nano particles, copper, aluminum, silver, gold, zinc and zinc oxide, silica, cerium oxide and titanium dioxide (Monreal, et al., 2016) [29]. Because of the unique characteristics of nanomaterials, such as their high surface to volume ratio, controlled release kinetics to designated areas, and sorption capacity, nanotechnology is highly relevant to the design and application of novel fertilizers. In order to meet the essential nutritional needs of plants, nano fertilizers are nutrients coated with nanomaterial that releases one or more nutrients over time and within control. These smart fertilizers are now being viewed as a viable option (Rameshaiah, et al., 2015) [33], to the point that, in certain circumstances, they are regarded to be the preferable kind of fertilizer over traditional ones (Iavicoli, et al., 2017) [20]. Nano fertilizer applications in agriculture may serve as an opportunity to achieve sustainability towards global food production. Nutritional deficiencies in human populations are mostly caused by the use of less nutritious foods and a low dietary intake of fruits and vegetables, putting significant strain on the food production industry. The nutrient delivery technique of nano fertilizers has significant advantages over conventional chemical fertilizers. They use gradual release techniques to control the availability of nutrients in crops. The covering of nutrients with nano materials is linked to such a slow delivery of nutrients. Because nutrients are continuously supplied to plants over time, farmers can benefit from this gradual delivery of nutrients to increase crop development. For instance, nutrients can be delivered gradually over 40–50 days as opposed to the 4–10 days that traditional fertilizers require. nano particles (NPs) and a greater quantity of impurities. In the bottom-up approach, one starts with molecules in the solution and moves via association of these molecules to form NPs using chemical reactions. Examples of bottom-down approach are precipitation method, hydrosol methods, spray freezing into liquid or supercritical fluid technology and self-assembly. Other methods based on different types of nano materials used are ionic gelation, polyelectrolyte complex formation, solvent diffusion, solvent evaporation, complex coacervation, co-precipitation, self-assembly, solid-lipid NPs and nano structured lipid carrier suspension. Because it is a chemically controlled synthetic process, particle size and contaminants may be regulated and decreased. Biologically synthesized NPs are an alternative to top-down and bottom-up approaches. Plants, fungus, yeast and bacteria are some of the natural sources. Two of the most desirable characteristics of NPs are their ability to control particle size and toxicity. To guarantee that the preparation of nano fertilizer is both economical and effective, care should be taken.

Types of Nano-fertilizers

Nano particles carriers basically modify the role of fertilizers and help to improve crop yield. Basically, they modify the role of fertilizers, thereby improving the crop yield. Depending on the type of nutrient, nano fertilizers can be broadly divided into three types: macronutrient based, micronutrient based and biofertilizer based.

Macronutrients are essential nutrient components that must be consumed in much bigger amounts for optimal plant growth and productivity.

In order to give the target crops the right ratio of nutrients while also lowering their extent amount and increasing their use efficiency, one or more of these nutrient components are usually mixed with nanoparticles. One or more nutrient components are encapsulated with particular nanoparticles in macronutrient nano fertilizers. It is anticipated that 265 million tonnes of nitrogen, phosphorus, and potassium are expected to be utilized in crop production by 2020. Nano fertilizers that contain nitrogen, like hydroxyapatite, mesoporous silica nanomaterials, and zeolites, release nitrogen gradually or under control. Nano fertilizers have been discovered to increase the efficiency and productivity of agricultural plants. Phosphorus is a component of a bio safe nano fertilizer. It's a water phosphorite particle suspension that's nano scaled (60-120 nm). More study is needed to understand the specific mechanisms of action of applied nano fertilizers as they interact with plants, soil, plant micro biome and the environment. The destiny of nano fertilizers in the environment necessitates extensive investigation in order to ensure their safety. Nano fertilizers cost-effectiveness and market availability enable a wider deployment of these innovative agrochemicals.

Micronutrients are involved in protein production, glucose metabolism and hormone control (e.g., auxins), all of which help protect plants from infections and pests. Zinc based nano fertilizers' use in a variety of horticulture crops. Iron source nano fertilizers are used to boost yields in horticultural crops including mango, citrus and garden pea. Copper, another crucial element, is required for plant growth and development. Cu nano particles in the right concentration improve the physiological growth of several horticultural crop plants dramatically. Cu in high levels, on the other hand, has deleterious effects on a variety of agricultural plants.

Additionally, manganese plays a crucial role in the physiological and metabolic processes of plant growth. By regulating different enzyme activities, it also acts as a co-factor to help plants adapt to a range of environmental conditions. The development and yield of agricultural plants are enhanced by nano Mn fertilizer if the soil lacks this micronutrient. Any micronutrient's recommended dosages are generally essential for the growth and productivity of horticultural plants. Therefore, before recommending the use of nano fertilizers as a micronutrient analysis, soil research is necessary.

Biofertilizers are formulations or preparations that contain one or more microorganisms that increase soil productivity and fertility by fixing nitrogen from the atmosphere, solubilizing phosphorus and stimulating plant growth by producing growth promoting compounds (Simarmata, et al., 2016) [40]. As a result, nano biofertilizers may be defined as biofertilizers combined with nanostructures or nano particles in order to increase plant development. Controlling the distribution of biofertilizers in the soil and extending the usable life of formulations are critical to achieving this aim. The interaction of nanoparticles with microorganisms, as well as the biofertilizers' dispersion and shelf life, are all crucial considerations in the development of nano biofertilizers. It has been demonstrated that the interaction of gold nanoparticles with rhizobacteria which promote plant growth is beneficial (Malusa et al., 2012) [28]. Silver nanoparticles cannot be used with biofertilizer because they disrupt biological processes in microorganisms, such as affecting the shape and function of cell membranes. The use of nanomaterials may increase the shelf life of biofertilizers, which is a limiting factor in these formulations. In terms of desiccation, heat and UV inactivation, nano formulations can help to increase biofertilizer stability. Desiccation resistant formulations, for example, can be made with polymeric nano particle coatings, increasing the useful life of these objects (Jampilek and Kralova, 2017) [21]. Nano materials can also be employed to increase biofertilizer distribution to soil and plants. Trials have demonstrated that adding hydrophobic silica nano particles to a water in oil emulsion improves product distribution while also extending shelf life by reducing desiccation (Kaushik and Djiwanti, 2017) [23]. However, because nano scale constructions are often smaller than cells, there is a basic issue in the creation of nano biofertilizers. According to Vandegheynst et al. (2007) [44], macroscopic filters made of radically aligned carbon nanotube walls that have the ability to absorb Escherichia coli could be a viable method for gathering and transferring additional microbes from fermentation processes to plants. Therefore, more research and development is needed, but nano biofertilizers have the potential to overcome some of the drawbacks of biofertilizers.

Limitations of nano-fertilizers

Recent advances in sustainable agriculture have undoubtedly witnessed the successful application of nano-fertilizers to increase crop yields. However, there could be a number of unanticipated and irreversible effects if this technology is purposefully used in agricultural activities. In this instance, the use of this technology in the production of horticultural crops may be restricted due to new health and environmental safety risks. Since different plants respond differently to different nanomaterials at different doses, phytotoxicity from nanoparticles is an additional issue in this field (Ashkavand et al., 2018) [2]. Therefore, before releasing nano fertilizers onto the market, it is crucial to consider both their advantages and disadvantages. Nano materials, in particular are highly reactive due to their small size and high surface area. These materials reactivity and unpredictability are also a source of worry. This raise worries about the safety of agricultural workers who may be exposed to xenobiotics when applying them (Nair, 2018) [31].

This includes not just individuals who have been exposed to nano fertilizer manufacture, but also those whohave been exposed to nano fertilizer application in the field. Given the anticipated benefits, further research into the practicality and usability of these innovative smart fertilizers is required. Transportation, toxicity and bioavailability issues,as well as unforeseeable environmental consequences from exposure to biological systems, limit their use in sustainable agriculture and horticulture. Risk assessment and hazard identification for nanomaterials, life cycle assessment of fertilizers or nanomaterials, and toxicological research objectives are all crucial. Given the build-up of nanoparticles in plants and the ensuing health risks, this is especially relevant. In fact, there are now major worries about food security, human health, and food safety due to the use of nano fertilizers made from nanomaterials (Lopez-Moreno et al., 2018) [27].

Agricultural Application of Nano Fertilizer

Nano-fertilizer is used to stimulate vegetative growth, pollination and fertility in flowers, resulting in greater yield and better product quality for fruit crops (Zagzog et al., 2017; Zahedi et al., 2019) [46, 47]. The results of a study conducted to assess the effects of spraying a mixture of nano fertilizer ZFM containing Fe, Zn and Mn on the quantitative and qualitative parameters of almond varieties revealed an increase in the concentration of elements Fe, Zn, Mn and Cu in the leaves, as well as a significant decrease in the disproportion of the percentage of fruit precipitation, indicating that ZFM spraying improved fruit quality and productivity (Sekhon, 2014) [38]. Spraying blue berries with nano calcium under salt stress conditions enhanced their vegetative growth and leaf chlorophyll content (Sabir et al., 2014) [35]. In accordance to the findings of another study that compared the application of nano boron with boron sprayed on mango tree leaves, using nanotechnology to deliver boron enhanced the overall yield and chemical characteristics of fruits, as well as the amount of chlorophyll and elements N, P, K, Mn, Mg, B, Zn, and Fe in the leaves (Ahmed et al., 2019) [1]. When mango trees were sprayed with nano zinc, the fruit weight improved, the yield increased, the amount of carotene and chlorophyll in the leaves increased, and the concentration of elements N, P, K, and Zn increased (Zagzog and Gad, 2017) [46].
Spraying with nano zinc and boron had a positive effect in improving the quality of fruits, increasing the number of fruits in per tree, increasing the ratio of T.S.S., total sugars, total phenols and increasing the fruit product of pomegranate (Davarpanah, et al., 2016) [14]. Spraying palm trees with nano Zn, Fe, Mn and B had a good effect on raising the leaf area, total chlorophyll content, carotenoids, N, P and K in the leaves, as well as lowering precipitation rates and increasing the weight of fruits (El Sayed, 2018) [16]. In addition to reducing weight loss and maintaining the T.S.S ratio, treating loquat fruits with nano silicon increased the fruits' glucose and fructose content and improved their defense against cold, all of which contributed to the fruits' longer shelf life and ability to be kept in refrigerated stores without losing quality (Song et al., 2016). Date palm production and vegetative growth are increased by nutrient use and the injection of nano NPK fertilizers (Jubeir et al., 2019) [22].
In contrast to traditional fertilizer (500 ppm), growth metrics (leaf fresh weight, leaf dry weight, and leaf area) were improved when Sultani Fig cultivars were treated with high concentrations of nano-fertilizers (300 and 400 ppm) applied topically. In terms of nutrient status, nano NPK at (300 and 400 ppm) recorded identical amounts of nutrient as traditional NPK at 500 ppm, suggesting that there may be a way to minimize additional fertilizers without negatively impacting plant growth and nutrient status. In compared to normal NPK, nano-NPK increased the activity of enzymes (peroxidase and polyphenol oxidase). The benefits of using nano-fertilizers in terms of growth performance and environmental conservation by minimizing the amount of minerals applied to the soil were validated in a recent study (Mustafa, et al., 2018). In comparison to other combinations of CNTs (0.2, 0.4 and 0.6 percent) and nitrogen (40, 30 and 20 g N/vine/year), (Abdelhak, 2018) [3] found that adding CNTs at a rate of (0.6 percent) with 80 percent of the recommended dose of nitrogen (50g N/vine/year) improved most vegetative growth parameters, nutrients status and measured fruit quality. Treating Flame Seedless grapes with 0.4 percent (T4) of nano zinc resulted in noticeably higher vegetative growth parameters, nutrient content, and recorded fruit quality characters compared to other treatments (T1 Tap water only (control), T2 zinc sulphate at 565 ppm, T3 zinc EDTA at 140 ppm, T5 nano zinc at 0.8 ppm, and T6 nano zinc at 1.2 ppm). According to Emamifar et al. (2011) [17], using packaging materials with silver and ZnO nanoparticles reduced the rate of microbial growth in orange juice and increased the fresh orange juice's shelf life by up to 28 days without compromising sensory metrics. According to (Zandi, et al., 2013) [48], strawberries, like many other fruits and vegetables, are subject to quality changes after harvesting, with weight losses of up to 40% possible during storage. Additionally, they discovered that nano composite packaging (nano-silver based on polyethylene and polypropylene and nano-silicate based on polyethylene and polypropylene) preserved strawberry fruit quality criteria and increased shelf life in comparison to traditional polymer packaging. Additionally, polyethylene or polypropylene based on nanosilicate reduced weight losses more than polyethylene and polypropylene based on nanosilver. According to Yang et al. (2010) [45], there is a significant difference in the quantity of acids found in nano containers compared to regular polymer containers for strawberry preservation over time. Furthermore, they asserted that because nano containers store more humidity and permit less oxygen to enter and exit, strawberries in nano containers are more marketable than strawberries in regular polymer containers. (Gad, et al., 2016) [19] looked into the effect of nano chitosan on the shelf life and quality of peach fruits (Prunus persica L. Bastch). Peach fruits were covered with one of three concentrations (0.2, 0.4 and 0.8 percent) and kept for 28 days at 0°C and 90-95 percent relative humidity. The obtained data show that utilizing nano chitosan 0.4 percent resulted in the lowest fruit deterioration percentages and TSS/acid ratio throughout two consecutive seasons 2015 and 2016. Furthermore, after 28 days of cold storage, the 0.4 percent nano chitosan treatment resulted in the finest quality peach fruits. Kumar, et al., (2019) [24] stated that a potential packaging material, manufactured agar-ZnO and nano composite film was used to extend the postharvest shelf life of green grapes. At a temperature of 400C, Mazafati date (Phoenix dactylifera L.) packaging containing 2 percent zinc oxide improved the quality and shelf life of the fruits (Sadeghipour, et al., 2019) [36].
Because of their antimicrobial and antibacterial qualities, silver nano particles (AgNps) are commonly utilised for postharvest fruit treatments. Blackberry quality and shelf life are improved by silver nano particles (AgNps) produced via green synthesis using Citrus limon peel extract (Rodino, et al., 2019) [34].
Polylactic acid nano composite films containing bergamot essential oil, TiO_2 nano particles and Ag nano particles prevent weight loss, increase fruit firmness and extend the shelf life of

mango by 15 days (Chi, et al., 2019) [10]. Nano composite edible coated films with glycerol and ZnO nanoparticles enhance the quality and storability of mango fruit (Dubey et al., 2019) [15]. Alginate and chitosan-based edible fruit coatings have been demonstrated to be suitable for guava fruit packaging, and it has been demonstrated that incorporating nano ZnO into both chitosan and alginate has a significant antibacterial effect and increases the fruit's shelf life by 20 days (Arroyo et al. 2019) [4].

Conclusion

In addition to enhancing nutrient management in contemporary agriculture and boosting fruit storage capacity, applying nanotechnology to fruit trees greatly enhances fruit quality and boosts tree productivity. Additionally, it was mentioned that the soil is preserved when nano-fertilizer is used in agricultural fields. By reducing the amount of fertilizer needed, it reduces pollution and benefits the farmer's financial return. Further investigation into the effects of different nano-fertilizers on fruit trees is highly recommended, as is the examination of novel fruit tree species to determine their reactions to nano fertilizers.

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