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Effect of Nano-Fertilizers on Fruit Crops: A Review

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ABSTRACT: Many challenges face global agricultural systems, including the problem of feeding orchids due to the deterioration of many agricultural soils as a result of contamination with chemical fertilizers residues, as well as improving the growth and productivity of fruit trees and obtaining good quality fruits, which is largely dependent on the availability of quantities. In order to achieve food safety, researchers tended to find ways to increase the efficiency of fertilizer use without being exposed to losses or pollution, so nanotechnology is a useful tool for agricultural development, especially in fertilization programme, as nano fertilizers are an effective alkaline fertilizer. They have several benefits due to their use in less amount, the speed with which they are absorbed by the plant and their great stability under a variety of situations, allowing them to be stored for extended periods of time. By enhancing agricultural productivity, improving crop quality and maintaining crop sustainability, nanotechnology may play a greater role. This study reveals that nanotechnology could be used to generate cutting edge techniques towards promoting productivity and quality of fruit crops to ensure food and nutritional security of ever increasing population of the world.

Keywords: Nano Fertilization, Fruit trees, Nutrients.

INTRODUCTION

With the growing global population, agriculture production must expand by 70% by 2050 to feed the world's population, which will grow by 110 percent. It is vital to validate novel and future break through and technologies in increasing horticulture crop cultivation, yield and productivity in order to attain global food security, enhanced food output and food productivity. Horticultural produce can benefit from nanotechnology in terms of production, processing, storage, packaging and transportation (Mousavi and Rezai, 2011; Ditta, *et al.,* 2015). The application of nanotechnology can greatly improve energy, economics, environment and soil microorganisms and fertilizer products' long-term integration (Derosa *et al.,* 2010).

To feed the world's growing population, issues such as uneven fertilization, nutrient inadequacies, fertilizer use efficiency and the loss of organic matter in soil must be addressed. This necessitates that the development of a multi-functional nano-based fertilizer composition. Massive volumes of fertilizers are necessary to improve soil fertility and promote crop output (Li, *et al.,* 2014). Chemical fertilizer is necessary to restore the world's soil fertility, which has been severely deteriorated to the tune of 40% owing to intensive agricultural techniques (Dijk and Meijerinck, 2014).

Fertilizers provide one-third of agriculture and horticulture production, aside from the efficiency of other agricultural inputs. Traditional fertilizer, on the other hand, only achieves 15-40% efficiency. Traditional fertilizer performance for nitrogen 30-40 percent, phosphorous 15-20 percent, and potassium 70 percent has been consistent over decades (Subramanian *et al.,* 2015). Encapsulating fertilizer in nano particles can improve nutrient uptake. Nano fertilizers may be the greatest option for overcoming chronic eutrophication issues and improving nutrient use efficiency in order to alleviate macro and micronutrient deficit (Shukla, *et al.,* 2019).

A. Nano-fertilizers

A fertilizer is any synthetic or natural 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). 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). However, the most essential qualities of nano-fertilizers are (i) individual particle sizes of less than 100 nm (ii) a bulk size of less than 100 nm and (iii) environmental safety and durability. A nano-fertilizer's nano size and aggregates are retained through interactions with soil particles or crop plant roots, which is another feature. The form and size of nanoparticles have a major impact on their reactivity (Dimkpa and Bindraban, 2017). Nano-fertilizers' most important features are increased nutrient use efficiency, active ingredient regulation, and less residual influence on soil biodiversity. Nano-fertilizer efficacy is determined by three aspects: internal factors, external factors and administration method. Method of nano formulation preparation, particle size of nano formulation and surface coating are all intrinsic variables. Soil depth, pH, soil texture, temperature, organic matter, and microbial activity are examples of extrinsic factors, all are influence the application of nano fertilizers. Furthermore, the absorption, action and bioavailability of nano-fertilizers are influenced by the route of method of application through plant roots or leaves (foliar).

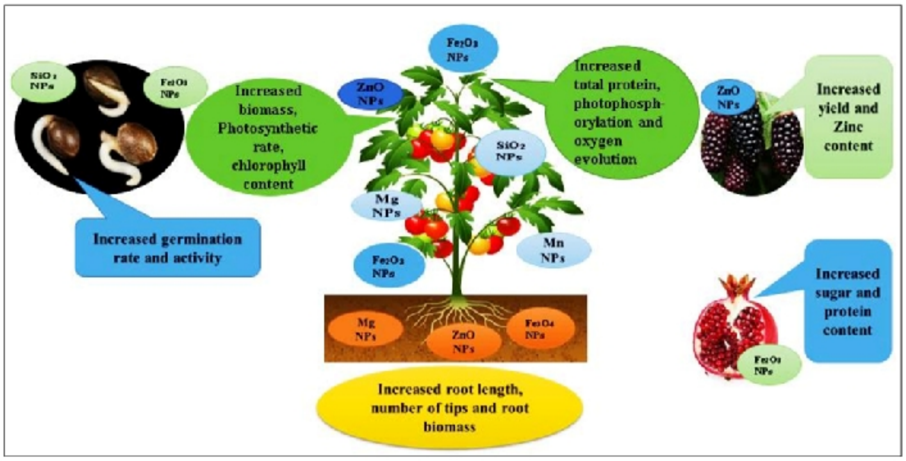

Fig. 1. Improvements in seed germination, plant development and biomass or yield generation by using several types of nano fertilizers are depicted in this diagram (Zhao *et al.,* 2020).

B. Conventional fertilizer versus nano fertilizers

The most prevalent technique of application is spraying or broadcasting conventional fertilizers on crops. One of the major factors that determines the mode of application is the final concentration of fertilizers reaching the plant. However, due to chemical leaching, drift runoff, evaporation and hydrolysis by soil moisture, photolytic and microbial degradation, only a small fraction of the final concentration (far below the minimum desired concentration) reaches the targeted site. 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).

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), lowers soil micro flora and inhibits nitrogen fixation. As a result, it's critical to maximize the use of chemical fertilization to meet crop nutrient requirements while reducing the danger of contamination. As a result, various approaches must be tested in order to deliver the essential nutrients for plant development and crop production while maintaining a healthy soil structure and a clean environment (Miransari, 2011). Nanotechnology has enabled researchers to examine nano scale or nano structured materials as a fertilizer carrier or controlled release vector for the creation of so called smart fertilizers as new facilities to increase nutrient use efficiency and reduce pollution costs (Chinnamuthu and Boopati, 2009). 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. Surface coatings of nano materials on fertilizer particles retain the material more tightly owing to surface tension than traditional surfaces, assisting in the regulated release of the substance (Brady and Weil, 1999). The delivery of agrochemical substances such as fertilizer to the plant, which supplies macro and micronutrients, is a significant component of nanotechnology application in agriculture. 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). 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).

C. Advantages of nano-fertilizers

To fulfil the ever growing demands of an ever increasing human population, the agricultural economy is under increasing strain. Chemical fertilizers are widely employed in a number of methods and are considered crucial for enhancing agricultural productivity (Feregrino, *et al.,* 2018). However, crop utilization is often less than half of the fertilizer applied (Chen, 2018), and the remaining minerals meant for the targeted location may leach down, becoming fixed in soil or contributing to water pollution. 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). 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. As a result, creating slow release fertilizers is crucial not only for enhancing crop yield and quality, but also for ensuring the long term viability of horticultural production.

The horticulture industry is currently under a lot of pressure to achieve significant efficiency in terms of food security by employing alternatives to chemical fertilizers (Liu and Lal, 2015). If worldwide horticulture output and demand are to be met in an economically and environmentally sustainable way, new ideas and technologies are necessary. Nano materials are defined as materials with a particle size of less than 100 nanometers in at least one dimension (Kah, 2015). 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). Nanotechnology has a significant relevance for the design and usage of novel fertilizers due to the unique qualities of nano materials such as high surface to volume ratio, controlled release kinetics to specified areas and sorption capacity. Nano fertilizers are nutrients coated with nano material for the controlled and gradual release of one or more nutrients to meet plants critical nutritional needs. These smart fertilizers are now being viewed as a viable option (Rameshaiah, *et al.,* 2015), to the point that, in certain circumstances, they are regarded to be the preferable kind of fertilizer over traditional ones (Iavicoli, *et al.,* 2017).

The combination of nano materials with fertilizers results in enhanced and effective absorption of nutritional elements and important chemicals for plants due to the high reactivity of nano materials (Prasad, *et al.,* 2017). The effectiveness of nano fertilizers is determined by a number of parameters. Both intrinsic and extrinsic variables, as well as the exposure route, will have a significant impact on the uptake, distribution and accumulation of nano fertilizers in crops. The most important intrinsic elements influencing the efficiency of nano particle application are particle size and surface coatings, while external factors such as organic matter, soil texture and soil pH will also have a significant impact on its potential application. Furthermore, because nano fertilizers may be absorbed by both plant roots and leaves, the exposure route and manner of administration have a significant impact on nano fertilizer behaviour, bioavailability and absorption in crops (Ma, *et al.,* 2018).

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. Farmers can boost crop development by taking advantage of this gradual nutrient delivery since nutrients are delivered to plants consistently throughout time. Nutrients, for example, can be supplied slowly over 40-50 days rather than the 4–10 days required by traditional fertilizers (Fig. 2).

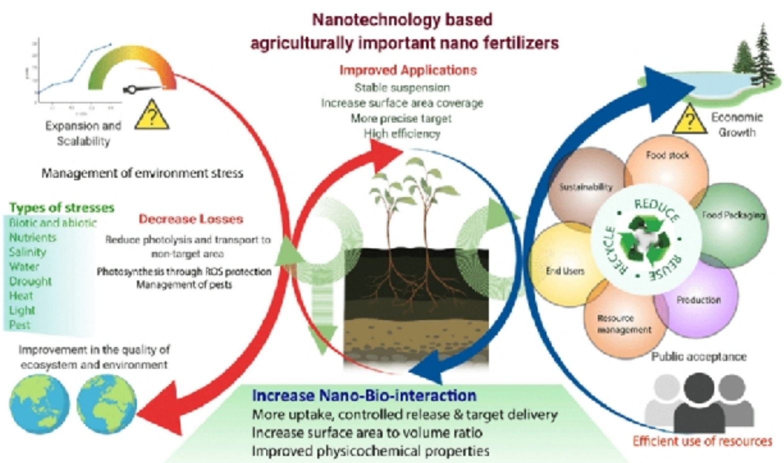

Fig. 2. Wings of nano fertilizers advantages (Mittal *et al.,* 2020).

D. Manufacturing of Nano-fertilizers

Nano materials for nano fertilizers can be prepared by different approaches: physical (top-down), chemical (bottom-up), and biological (biosynthetic) approaches. The top-down approach is based on size reduction of relatively large particles into smaller particles of nano scale by mechanical attrition. Examples of top-down approach are pearl/ball milling, micro fluidizer technology, high pressure homogenization, nano morph technology, nano cochleate technology and controlled flow cavitation technology. The limitation in this approach is the low control on the size of 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. The control of toxicity and particle size are two of the most appealing properties of NPs. Nano fertilizer preparation should be done with caution in order to ensure that it is both efficient and cost effective.

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.

(i) Macronutrient Nano-fertilizers. Macronutrients are essential nutrient components that must be consumed in much bigger amounts for optimal plant growth and productivity. One or more of these nutrient components is usually combined with nano particles in order to provide a proper ratio of nutrients elements to the target crops while also reducing their extent amount and improving their use efficiency. In macronutrient nano fertilizers, one or more nutritious components are encapsulated with specific nano particles. By 2020, the amount of nitrogen, phosphorus and potassium used in crop production is predicted to reach 265 million tonnes. Nitrogen source nano fertilizers, such as zeolites, mesoporous silica nano materials and hydroxyapatite, have a slow or controlled release. 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.

(ii) Micronutrient Nano-fertilizers. 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. Manganese is also important for plant growth, both physiologically and metabolically. As a co-factor, it also aids plant tolerance to a variety of environmental conditions by modulating various enzyme activities. If the soil is weak in this micronutrient, nano Mn fertilizer promotes agricultural plant development and yield. In general, prescribed dosages of any micronutrient are critical for horticultural plant development and productivity. As a result, soil investigation is required before suggesting the use of nano fertilizers as a micronutrient analysis.

(iii) Biofertilizers Based Nano-fertilizers. 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). 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. In the development of nano biofertilizers, the interaction of nano particles with microorganisms, as well as the shelf life and dispersion of biofertilizers, are all important factors to consider. The interaction of gold nano particles with rhizobacteria that promote plant development has been shown to be advantageous (Malusa, *et al.,* 2012). Because silver nano particles interfere with biological processes in microorganisms, such as modifying cell membrane shape and function, they cannot be used with biofertilizer. The shelf life of biofertilizers is a limiting factor in these formulations, however with the use of nano materials, this can be increased. 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). 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). However, because nano scale constructions are often smaller than cells, there is a basic issue in the creation of nano biofertilizers. In this context, macroscopic filters built of radically aligned carbon nano tube walls that can absorb *Escherichia coli* might be a potential technique for collecting and delivering other microbes from fermentation processes to plants (Vandergheynst, *et al.,* 2007). As a result, nano biofertilizers have the potential to overcome some of the limitations of biofertilizers, but further study and development is required.

MECHANISM OF UPTAKE

Nano-fertilizers can enter plant tissue from the roots or the tops. Although the precise absorption and translocation of NPs by plant cells is unknown, multiple results support the assertion that NP uptake by plants is primarily influenced by the size, shape and contact behavior of nano particles with the cell wall. The cell wall's size exclusion limit (5-20 nm) works as a barrier, preventing bigger particles from entering plant cells. Surface functionalization of NPs can be used to enlarge pores or induce the formation of new pores. Ion channels, endocytosis, complex formation with membrane transporters and root exudates are all possibilities. Encapsulated nutrients are protected from soil filtration by nano carriers, which maintain them in the soil near the roots. Encapsulated components can penetrate the soil network by hydrogen bonds, molecular force, surface tension, or viscous force, allowing them to expand their spatial scale. NPs can penetrate foliar treatments through stomata holes or cuticles. The cuticles of leaves are the initial barrier that prevents NPs smaller than 5 nm from passing through. NPs can enter the circulatory system through stomatal pores and travel through the apoplastic or sympathetic pathways.

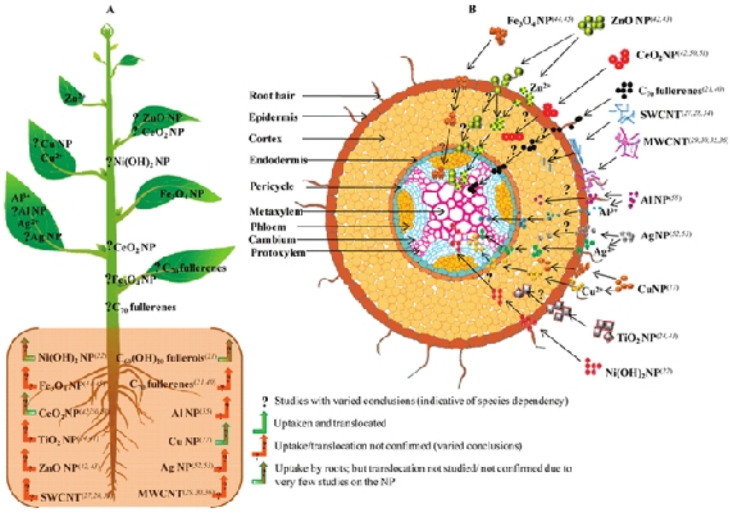

Fig. 3. Uptake mechanism of nano fertilizer.

A. Limitations of nano-fertilizers

In the field of sustainable agriculture, recent advancements have surely seen the effective usage of nano-fertilizers to boost crop output. However, the intentional use of this technology in agricultural activities might have a number of unforeseen and irreversible consequences. In this case, new environmental and health safety hazards may limit the use of this technology in the production of horticultural crops. Phytotoxicity from nano particles is also an issue in this field, since various plants react differently to different nano materials at different doses (Ashkavand, *et al.,* 2018). As a result, it is critical to think about the benefits of nano fertilizers as well as their draw backs before putting them on the market. 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). This includes not just individuals who have been exposed to nano fertilizer manufacture, but also those who have 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. Nano material risk assessment and hazard identification, as well as the life cycle evaluation of nano materials or fertilizers and toxicological research aims, are critical. This is especially true in view of the buildup of nano particles in plants and the resulting health hazards. Indeed, the use of nano fertilizers derived from nano materials has raised serious questions regarding food safety, human health and food security (Lopez-Moreno, *et al.,* 2018).

APPLICATIONS OF NANOTECHNOLOGY ON FRUIT CROPS

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). 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). Under salt stress circumstances, spraying blue berries with nano calcium resulted in improved vegetative growth and chlorophyll content in the leaves (Sabir, *et al.,* 2014). Another research compared the use of nano boron to boron sprayed on mango tree leaves and the results revealed that using boron via nanotechnology increased overall yield and chemical qualities of fruits, as well as the quantity of chlorophyll and elements N, P, K, Mn, Mg, B, Zn and Fe in the leaves (Ahmed, *et al.,* 2019). Mango tree spraying with nano zinc resulted in improved fruit weight, increased yield, increased chlorophyll and carotene content in the leaves, and raised the concentration of elements N, P, K and Zn (Zagzog and Gad, 2017). 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). 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). Treating loquat fruits with nano silicon reduced weight loss and maintained the T.S.S ratio, as well as increasing the content of glucose and fructose in the fruits and increasing their ability to withstand cold, all of which helped to extend the shelf life of fruits, could be stored in refrigerated stores and maintain their quality (Song, *et al.,* 2016).

The use of nutrients and the injection of nano NPK fertilizers in date palm increasing vegetative growth and production (Jubeir, *et al.,* 2019). The reactions of potted plants of the apple cultivars Red Delicious, Golden Delicious and Starking Delicious were tested after they were fed nano biofertilizer at 0, 1, 2 and 3 g/pot. The 1 g/pot dosage had a greater impact on apple plant growth. All of the treatments significantly increased plant height, stem diameter, leaf area and chlorophyll levels, according to the findings (Mohasedat, *et al.,* 2018). Nano-fertilizer treatment of bitter almond seeds enhanced seed germination by 50% at younger stages when compared to chemical fertilizer treatment (Badran and Savin, 2018). Flame Seedless grapevines were foliar fertilized with orgland, active-Fe, boron-10, amino-Zn and super Fe nano-fertilizers at concentrations of 0.1 or 0.2 percent amino minerals during three growth phases. When the vine was treated with amino mineral nano-fertilizer at 0.1 percent, the best production, enhanced berry colouring and finest quality fruits were found (Wassel, *et al.*, 2017).

When compared to traditional NPK with nano-NPK exhibited a favorable influence on the growth rate, yield and many fruit characteristics of the (Cultivar Zaghloul) date palm under Minia conditions. Furthermore, in compared to traditional NPK, these good effects of nano NPK created from modest dosages demonstrated that boosting nutrient use efficiency in nano form. Furthermore, they ascribed an increase in nutrient use efficiency to another factor, whereas nutrients would be given to plants in a controlled manner depending on crop demands using nano-NPK (Roshdy and Refaai, 2016). Nano fertilizers have a positive impact on the growth of olive seedlings. They also discovered that substituting half of the recommended dose of mineral fertilizers (0.5 g/seedling as soil application) with nano fertilizers applied as a foliar application at (0.2 percent) three times (June, July and August) improved most of the recorded vegetative growth parameters on Aggizi olive seedlings without causing deficiency symptoms. They also came to the conclusion that nano NPK has a promising future as a fertilizer alternative (Hagagg, *et al.*, 2018). When nano-fertilizes were treated at high levels (300 and 400 ppm) as foliar application on Sultani Fig cultivar, growth metrics (leaf fresh weight, leaf dry weight and leaf area) were enhanced when compared to traditional fertilizer (500 ppm). 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 20g N/vine/year), (Abdelhak, 2018) 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. In contrast to other treatments (T_1 Tap water only (control), T_2 zinc sulphate at 565 ppm, T_3 zinc EDTA at 140 ppm, T_5 nano zinc at 0.8 ppm, and T_6 nano zinc at 1.2 ppm), treating Flame Seedless grapes with 0.4 percent (T_4) of nano zinc produced significantly higher vegetative growth parameters, nutrient content and recorded fruit quality characters. (Emamifar, *et al.,* (2011) found that employing packaging materials containing silver and ZnO nano particles decreased microbial growth rates in orange juice and extended the shelf life of fresh orange juice by up to 28 days without affecting sensorial metrics. According to (Zandi, *et al.*, 2013), strawberries, like many other fruits and vegetables, are subject to quality changes after harvesting, with weight losses of up to 40% possible during storage. They also found that when compared to traditional polymer packaging, nano composite packaging (nano-silver based on polyethylene and polypropylene and nano-silicate based on polyethylene and polypropylene) extended shelf life and preserved strawberry fruit quality criteria. Furthermore, weight losses were decreased more by nano-silicate based polyethylene or polypropylene than by nano silver-based polyethylene and polypropylene. There is a considerable difference in the number of acids between nano containers and normal polymer containers for preserving strawberry over storage duration, according to (Yang *et al.*, 2010). Furthermore, they claimed that strawberry in nano containers is more marketable than strawberry in ordinary polymer containers, and that this is due to the fact that nano containers store more humidity and allow less oxygen to enter and exit. (Gad, *et al.*, 2016) 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) 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 40^0C, Mazafati date (*Phoenix dactylifera* L.) packaging containing 2 percent zinc oxide improved the quality and shelf life of the fruits (Sadeghipour, *et al.*, 2019). 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). 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). Mango fruit quality and storability are improved by nano composite edible coated films containing glycerol and ZnO nano particles (Dubey, *et al.,* 2019). Guava fruit packaging alginate and chitosan-based edible fruit coatings have been shown to be appropriate and adding nano ZnO to both chitosan and alginate has been proven to have an effective antibacterial activity as well as extending the fruit shelf life by 20 days (Arroyo, *et al.* 2019). Gray mould and soil-borne diseases are suppressed by spraying apple fruits with ZnO, CuO and Ag NPs at concentrations of 100 and 1000 g/mL for four days. The post-harvest fruit quality and enzyme activity of the cell wall of apple fruit cv. Red Delicious were enhanced after pre harvest treatment of nano calcium (Ranjbar, *et al*., 2019). In an apple orchard between 2016 and 2018, evaluate the influence of a nanotechnology based foliar fertilizer (Bistep) with 1, 3, and 5 l/ha doses on yield and fruit quality measures. According to our findings, using the 5 l/ha Bistep treatment boosted crop load by 29% in the third year of the trial when compared to the control treatments. Fruit weight improved year after year, with all treatments having greater fruit weight values than the control (3.0-13.0 percent growth). Because of the foliar fertilizer, the color of the fruit surface rose by 2-18%. (Csihon *et al.,* 2021). The nano-fertilizer Lithovit treatment yielded the greatest overall phenol concentration, as well as all individual hydroxycinnamic and hydroxybenzoic acid derivatives. Fertilization, particularly nitrogen fertilization, showed primarily negative effects on strawberry flavor, but nano-fertilization with Lithovit increased strawberry phenolic content and scent (Cvelbar *et al.,* 2021). The fruit set increased after being treated with nano-N_1. In both years, U_1 boosted fruit output efficiency. U_1 treatment mostly influenced fruit consuming quality features. Nitrogen treatments influenced the mineral components, chlorophyll and carbohydrate content of leaves in the summer and fall. Nano-N_2 treatment was used to produce the highest oil % possible. However, as a result of spraying U_1, oil output rose as fruit load increased (Rohi Vishekai, *et al.*, 2019). In comparison to the control, the concentration of micro elements (Zn, Fe, Cu and Mn) in leaves rose considerably in all treatments, especially when sprayed in two stages. In addition, with the exception of fruit abscission, the relationship between spraying duration and cultivar was significant in all examined parameters. Shokufeh cultivar with fertilizer spraying in two phases (T_1 and T_2) had the highest percentages of initial and final fruit set and yield per shoot, whereas control had the lowest percentage of initial and final fruit set in all studied cultivars (Kamiab and Zamanibahramabadi 2016).

Jubeir and Ahmed (2019) found that fertilization by injection resulted in a considerable increase in fruit pulp weight (4.56 g) and bunch weight (7.21 kg). The treatment (F_2) resulted in increased fruit pulp (4.64 g) and bunch weight (7.35kg). At (F_3), the greatest proportion of phosphorus was found (0.24 percent). Fruit nitrogen content increased by (0.83 to 0.87 percent) and protein content increased by (5.20 to 5.45 percent) in the F_4 and F_5 treatments, respectively, with the maximum level of potassium at (1.18 percent). As a result, it was determined that utilizing nano-fertilizer and NPK improves date palm fruit qualities. According to Khan, *et al.,* (2019), the highest yield was recorded under conventional orchard in nano N application @ 300 ppm in both years (28.15 and 29.89 tons/ha), and the highest yield was recorded under organic apple cultivation in application of Humic acid @ 0.15 percent in both years (19.96 and 20.97 tons/ha). The experiment's economic evaluation found that using P nano fertilizer at 50 ppm resulted in the greatest net B:C ratio of 6.31, while using humic acid at 0.15 percent resulted in the highest B:C ratio of 5.51. The results of the effect of nano-fertilizer on lime at four concentration levels (0, 0.5, 1 and 1.5 ml/liter) and potassium chelate (0, 2, 3 and 4 ml/liter) showed that all of the tested plant growth indicators were significantly affected treatment of 1.5 ml/liter optimus plus and 4 ml/liter potassium chelate was the most effective treatment among all the treatments and interactions and resulted in the highest values of all tested parameters. Seedling height, number of branches, stem diameter, number of leaves, leaf area, total chlorophyll content and dissolved carbohydrates increased by 66.9%, 146.8%, 64.24 %, 129.71 %, 37.52 %, 143.41 % and 91.31 %, respectively, when compared to the untreated control (Amin, *et al.,* 2020). In the first and second seasons, Genaidy, *et al*., (2020) when compared to the control treatment, the influence on qualitative and quantitative features of the Picual cultivar of olive leaves mineral content and pigments, fruit set percent, fruit drop percent, fruit yield and fruit physical and chemical characteristics was found. Furthermore, spraying with nano-boron at 20 ppm + nano zinc at 200 ppm (T_8) was shown to be the most effective treatment for getting the greatest final fruit set, which resulted in the highest fruit yield, highest seed oil percent and lowest acidity in the first and second season.

CONCLUSION

Besides improving nutrient management in modern agriculture and increasing the storing potential of fruits, the use of nano on fruit trees contributes very effectively to improving the quality of fruits and increasing the productivity of trees. It was also noted that the use of nano-fertilizer in the agricultural field preserves the soil. It minimizes pollution by lowering the quantity of fertilizer required, which has a favorable impact on the farmer's financial return. We urge that additional research be done on the effects of various nano-fertilizers on fruit trees, as well as the study of new types of fruit trees to see how they respond to nano-fertilizers.

FUTURE SCOPE

Future studies must be focused on generating comprehensive knowledge in these underexplored areas in order to introduce this novel frontier in horticulture. Consequently, nano fertilizer application safety and the study of the toxicity of different nano particles used for nano fertilizer production must be a research priority.

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