Tikrit Journal for Agricultural Sciences (2023) 23 (1): 158-167
https://doi.org/10.25130/tjas.23.1.18

TJAS
IRAQI Academic Scientific Journals
العراقية المجلات الأكاديمية العلمية
ISSN:1813-1646 (Print); 2664-0597 (Online)
Tikrit Journal for Agricultural Sciences
Journal Homepage: http://www.tjas.org
E-mail: tjas@tu.edu.iq
TJAS
Tikrit Journal for Agricultural Sciences

A Review of Nano fertilization and its role on growth, yield and quality characteristics of fruit trees

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KEY WORDS:
Nano fertilization, Growth, Production, Horticultural plants

Received: 12/11/2022
Accepted: 16/02/2022
Available online: 31/03/2023

ABSTRACT

Nanotechnology is one of the strategies that have the ability to achieve sustainable agriculture, and it is a promising opportunity in the field of sustainability and the provision of food security and fertilizers in general, important in terms of agricultural production, whether quantitative or qualitative. Despite the availability of various mineral, chelated or organic fertilizer sources for these nutrients and the presence of various methods of addition, the efficiency of using these fertilizers does not exceed 5% of the additive. Therefore, it is preferable to reduce the loss of nutrients through fertilization and work to increase the growth and productivity of crops through the use of nanotechnology and nano_materials through the use of alternative, environmentally friendly and very effective fertilizers called nano-fertilizers. They are materials that contain nutrients or essential and useful plant nutrients prepared in nano-sizes and loaded or coated with materials that make them more efficient, especially when added to the soil. Nanoscience is one of the modern sciences that is concerned with the study of materials on the nanoscale 10-9 meters from 1-100 nanometers and they are called nanomaterials, its physical and chemical properties are different from those when it is in conventional dimensions of more than 100 nanometers, it has physicochemical properties that are fundamentally different compared to its ordinary materials. Different types can be produced from them, and their chemical composition as well as the size and shape of the particles controls their main characteristics.

التسميد النانوي ودوره في زيادة وإنتاجية النباتات البستنية

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الخلاصة

تعد التقنية النانوية احد الاستراتيجيات التي لديها القدرة على تحقيق الزراعة المستدامة وهي الفرصة الواعدة في مجال الاستدامة وتوفير الامن الغذائي والآسمدة بصورة عامة مهمة من ناحية الإنتاج الزراعي سواء الكمي او النوعي، وعلى الرغم من توفر مصادر سمادية مختلفة معدنية ومخلبية او عضوية لهذه المغذيات ووجود طرائق إضافة متنوعة الا ان كفاءة استخدام هذه الأسمدة لا تتجاوز 5% من المضاف. لذلك يفضل الحد من فقد المغذيات من خلال التسميد والعمل على زيادة نمو وانتاجية المحاصيل من خلال استخدام تكنولوجيا النانو والمواد النانوية من خلال استخدام اسمدة بديلة عن الأسمدة التقليدية وصديقة للبيئة وفعالة جدا

تسمى بالأسمدة النانوية وهي عبارة عن مواد تحتوي عناصر مغذية او مغذيات النبات الضرورية والمفيدة المحضرة بحجوم نانوية ومحملة او مغلفة بمواد تجعلها اكثر كفاءة ولاسيما عند الإضافة الى التربة. يعتبر علم النانو هو أحد العلوم الحديثة الذي يهتم بدراسة المواد على المقياس النانوي 10^{-9} من المتر 1-100 نانومتر ويطلق عليها المواد النانوية وتكون خواصها الفيزيائية والكيميائية مختلفة عنها عندما تكون بأبعادها التقليدية والتي تزيد عن 100 نانومتر، إذْ تمتلك خصائص فيزيوكيميائية تختلف جذريا قياسا بموادها العادية. ويمكن انتاج أنواع مختلفة منها، وان تركيبها الكيميائي وكذلك حجم وشكل الجسيمات يتحكم في الصفات الرئيسة لها.

الكلمات المفتاحية: السماد النانوي، نمو ،انتاج، النباتات البستنية.

INTRODUCTION

Agriculture and food security in the world face a large number of challenges, such as low crop production, declining and deteriorating soil health and fertility, and the low efficiency of the use of fertilizers and agrochemicals in general (Ali et al., 2022). Therefore, science has recently discovered the contribution of nano-particles to open new paths in the field of life technologies, agriculture, industry and medicine. Its physical properties have facilitated the opening of the field for its practical use in the agricultural field, as it is used as a chemical fertilizer that increases the growth of crops and improves the soil, which is positively reflected on the quality of the yield and increased productivity (Naderi and Danesh-Shahraki, 2013; and Singh et al., 2017). In light of this, nanomaterials are the tool that helps the challenges facing farmers in managing existing crop technologies by obtaining crops with high productivity while reducing the use of traditional chemical fertilizers (Kumar, 2013). As well as manufacturing special types of safe, environmentally and biologically compatible insecticides and public health insecticides, with the aim of effective and rapid resistance to harmful pests, and targeting them (Jalal et al., 2022 and Shang et al., 2019).

Nanomaterials have all the properties necessary for their use in agriculture, such as effective concentration with their high solubility and good efficiency, and their use in small quantities and good result, so they increase the efficiency of fertilizer use (DeRosa, 2010 and Monreal et al., 2016). Nano-fertilizers can prepare one or more nutrients for plants towards improved growth and productivity with better performance and in lower quantities than conventional fertilizers and with slower nutrient release (Liu and Lal, 2015). This technology has enabled the exploitation of small nanomaterials particles carried on the fertilizer to build the so-called smart fertilizer, which enhances the efficiency of nutrient use and reduces the costs of protecting the environment by intelligently controlling the speed of nutrient release to match the absorption pattern of crops and improving the solubility of insoluble nutrients in the soil, it reduces its adsorption and stability and increases its availability, thus increasing productivity and reducing fertilizer consumption while reducing fertilizer losses through leaching (Ali and Al-juthery, 2017 and Cui et al., 2010).

Given the small size of the particles and the large surface area of the nano-fertilizers, their solubility is high in different solvents such as water, for example. This feature contributes to an increase in the penetration of these particles to the surfaces in contact with them, such as roots and leaves, as it provides more areas for different metabolic reactions in plants, as well as an increase in the rate of photosynthesis, which causes an increase in dry matter production and yield (Qureshi et al., 2018 and Shebl et al., 2019). The addition of nano-fertilizers by foliar spray can enhance the entry of these nutrients directly into the plant system through epidermis penetration and thus reduce the wastage of fertilizers added by other methods that may cause environmental risks (Kumar and Mahil, 2019).

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Positive effects of nanomaterials:

Positive effects vary according to the type of plant, the degree of its development or stage of growth, the type of nanomaterials, the concentration and conditions of exposure to these materials, and these effects include the use of these materials as fertilizers or pesticides (Kole et al., 2013). For example, the addition of nano iron oxide led to an increase in the dry weight of potatoes. The effect of nanomaterials, especially the necessary and beneficial mineral ions for plants, such as zinc oxide, iron, copper, manganese, and nickel nanoparticles, which act as enzymatic aids or regulators of genetic expressions, depends on their concentration, which has a positive effect on these low concentrations, as well as the type of metal, the type of plant and the conditions of addition (Kolbert et al., 2021).

The effect of nano-fertilizers on plants:

The effect of nano-fertilizers depends on the types of plants grown and on the added nano-fertilizers, as some compounds such as nitrogen and phosphorous act as growth-stimulating elements. It regulates the growth of plants and also increases crop productivity. Phosphate fertilizers increase the availability of phosphorous in the soil and increase the uptake of phosphorous by the roots. Zinc enters as a catalyst in the dissolution of phosphate fertilizers, as it increases the activity of the enzyme phosphatase and phytase by 84-108% (Vishwakarma et al., 2018) .

In a study conducted on bean plant treated with some types of nano-fertilizers, there was an increased in root length, root size, chlorophyll and protein content in leaves, and also maintained soil fertility by enhancing the soil microbial community (Raliya et al., 2016).

Also in another study, where the seeds of the cabbage plant were treated with several different concentrations of nano-nitrogen fertilizer, it promoted growth by increasing the number of leaves, leaf area, plant height, and plant content of chlorophyll and carbohydrates, which led to an increase in growth, development and crop yield (Arora et al., 2012).

Interaction of nano-fertilizers with plants:

Nano fertilizers have exceptional interaction and surface area compared to other conventional fertilizers (Service, 2003). Which is the result of physical and chemical properties eccentric. The presence of nano-fertilizers in the surrounding environment leads to inevitable interactions with the biological components, and thus causes physical and chemical changes such as dissolution by biomolecules and oxidation and reduction reactions. The plant has many interactions with the external environment. Which affects plants directly because these interactions lead to many anatomical and morphological changes, as the change depends on the concentration and nature of the nano-fertilizers (Rico et al., 2015).

When the nano-fertilizers are completely dissolved, the nano-material turns into a mineral form, which changes its properties and fate in the plant species, where the plant roots secrete the organic acids necessary for the biotransformation of the nano-fertilizers, and the transformation of the nano-fertilizers occurs outside the roots, Also, after entering the plant roots, metallic nanoparticles are changed, subject to valences to oxidation-reduction reactions in the soil, which leads to the transformation of these molecules through their interaction with biological oxidation and reduction factors to the plant and when nano-fertilizers interact with plant cells. Reactive Oxygen Species (ROS) are highly released because these stresses, which in turn affect plant biomolecules, specifically stimulate carbon nanotubes and the accumulation of reactive oxygen species (López-Moreno et al., 2010).

The effect of nano-fertilizers on the root and shoots:

Nano fertilizers affect not only photosynthesis and seed germination, but also the growth of roots, buds and shoots, it can activate or inhibit roots and seedling length because various nanoparticles have different effects on root and buds' growth in different types of plants, the morphology of the nano fertilizers plays a vital role in root growth (Gruyer et al., 2013). In a study conducted by Syu et al. (2014) on the roots of seedlings of Arabidopsis thaliana plants when using different concentrations of iron chelated nano fertilizer, it showed an effect on root growth and physiological changes of plants. When treated with different levels of nano-nitrogen fertilizer, it increased the number of leaves and leaf area in the plant and its content of chlorophyll and carbohydrates, which led to an increase in growth, development and crop yield (Arora et al., 2012 and Gopinath et al., 2014). In a study conducted by Kumar et al. (2013), when adding nano-zinc fertilizer increased the speed of seed germination and antioxidants, and enhanced the plant's ability to increase the absorption of water and nutrients and thus increase the effect on different growth characteristics.

Effect of nano fertilizer concentrations on growth characteristics:

The fertilizer management process is one of the most important factors affecting the success of crop cultivation, its quality and quantity. Nano fertilizer is one of the most advanced modern technologies in treating the deficiency of nutrients in plants compared to conventional fertilizers, as the use of nano fertilizer improves the efficiency of fertilizer use and reduces the loss of elements (Giraldo et al., 2014 and Jameel, 2018).The addition of nano-fertilizers led to positive results in many researches. El-Sayed et al. (2017) found in an experiment conducted on "Zaghloul" date palm trees when spraying with regular (Zn, Fe and Mn) elements (25, 50 and 100 mg). L-1) and nanoparticles (2.5, 5.0, 10.0 and 20.0 mg L-1) showed that the concentrations of elements in both the normal and nano formulas contributed to giving the highest values for the vegetative growth characteristics of trees compared to the control treatment and for both seasons of the study. The addition of nano-fertilizers led to positive results in many researches. El-Sayed et al. (2017) found in an experiment conducted on "Zaghloul" date palm trees when spraying with regular (Zn, Fe and Mn) elements (25, 50 and 100 mg). L-1) and nanoparticles (2.5, 5.0, 10.0 and 20.0 mg L-1) showed that the concentrations of elements in both the normal and nano formulas contributed to giving the highest values for the vegetative growth characteristics of trees compared to the control treatment and for both seasons of the study. The addition of nano-fertilizers led to positive results in many researches.

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The researcher Abou El-Nasr et al. (2015) studied the treatment of “Le-Conte” pear seedlings with iron oxide nanoparticles at concentrations (25, 125 and 250 mg L-1) and they noticed that the concentration (250 mg L-1) had a significant effect on the dry weight of seedlings for the first season (17.29 gm). It also caused an increase in the values of leaf area (9.58 and 10.34 cm2) and leaf content of total chlorophyll (1.74 and 1.85 mg g-1 fresh weight), nitrogen (1.87 and 2.47%), iron (51.80 and 43.65 mg L-1) and total carbohydrates. (18.50 and 10.09%) for the two seasons, respectively, compared to the control treatment.

Sohrab et al. (2016) confirmed the existence of significant differences when treating pomegranate trees "var. Ardestani" with nano-zinc at two concentrations (60 and 120 mg L-1) and nano-boron at both concentrations (3.25 and 6.5 mg L-1), all nano treatments contributed to giving the best values for the leaves' content of nutrients (N, P, K, Fe and Zn) compared to the control treatment. In a study conducted by Al-Khalifawi (2017) on Moringa seedlings, chelated iron nanoparticles were used in concentrations (1, 2, 3 and 4 g L-1) and it was found that the concentration (2 g L-1) achieved the highest levels of nitrogen, phosphorous and potassium in the leaves. While the concentration (1 gm L-1) outperformed in increasing the leaves content of zinc, while the concentration (4 gm L-1) achieved the highest level of iron and carbohydrates in the leaves.

Davarpanah et al. (2017) confirmed that fertilizing Ardestani pomegranate trees using nano-nitrogen at concentrations (0.25 and 0.50 g N L-1) caused the highest significant increase in the nitrogen content of leaves, especially at high concentration treatment which reached 2.13 and 2.04% for the two seasons, respectively, and all of the other elements (K, P, Fe and Zn) were not affected significantly by the study factor for both seasons.

Jayvanth et al. (2017) observed in an experiment conducted on strawberry plants, cultivar "Chandler" when spraying with different concentrations of iron oxide and nano-zinc (50, 100 and 150 mg L-1) a significant increase in the number of leaves at all concentrations of the two elements compared to the control treatment. In another experiment carried out on mango trees of the cultivars "Zebda and Ewasy", the trees were sprayed with nano-zinc at two concentrations (0.5 and 1 g L-1), it was noted that both concentrations gave the highest values for the leaves content of chlorophyll and the elements N, P, K and Zn for both study varieties compared to the control treatment (Zagzog and Gad, 2017). While El-Sayed (2018) observed when spraying a number of ordinary and nano-elements, including iron and zinc, at a concentration of (0.05%) for ordinary and (0.005, 0.01, 0.02 and 0.04%) for nanoparticles on the date palm of the variety "Sakuti", the concentrations of iron, normal and nano-zinc contributed to giving the highest values for the vegetative growth characteristics of trees compared to the control treatment and for both seasons of the study.

Elsheery et.al (2018) found that spraying mango trees cultivar "Ewais" with nano-zinc at concentrations (50, 100 and 150 mg L-1) significantly increased leaf area and its content of elements N, P, K and total carbohydrates at all zinc concentrations compared to the control treatment for both study seasons. Hagagg et al. (2018) found that in an experiment conducted on olive seedlings of "kalamata" variety, they were sprayed with NPK nano-fertilizer in concentrations (0.05, 0.1, 0.15 and 0.2%), and they found that the concentration (0.2%) gave the highest values for the traits (dry weight of shoot and root, leaf area and leaf content of relative chlorophyll and N, P and K) compared to the treatment of not adding nano-fertilizers, and they respectively amounted to (24.19 g, 7.6 g, 10.1 cm^2, 87.7 SPAD units, 2.77%, 0.23% and 1.10%). In another study on olive seedlings of "Aggizi" cultivar, Hagagg et al. (2018) observed when spraying with nano-NPK fertilizer in concentrations (0.05, 0.1, 0.15 and 0.2%) and comparing it with the levels of conventional non-nano NPK fertilizers (25%, 50% and 100%) that Spraying with nano-NPK fertilizer (0.2%) it gave the highest values for the traits (dry weight of shoot and root and leaf content of N, P and K) compared to the non-fertilizer treatment and they were respectively (21.10 g, 10.68 g, 1.34%, 0.122% and 1.07%). Mustafa et al. (2018) conducted an experiment about spraying "Sultani" fig seedlings with four concentrations of balanced nano-NPK (100, 200, 300 and 400 mg L-1), as well as spraying seedlings of a control treatment at a concentration (500 mg L-1) from ordinary (non-nano) NPK fertilizer, the results of the experiment showed an increase in the leaf area and the dry weight of the leaves when spraying with concentrations of all nano-fertilizers compared to the regular fertilizer, the concentration (300 mg L-1) achieved the highest values for the two traits, respectively, (187.63 cm2 and 1.84 g), and the fertilizer at all levels contributed to an increase in the nitrogen and phosphorous content of the leaves compared to the regular fertilizer.

The effect of nano-fertilizers on the quantitative and qualitative characteristics of fruits:

Jayvanth et al. (2017) observed in an experiment conducted on strawberry plants "Chandler" variety when spraying with different concentrations of iron oxide and nano-zinc (50, 100 and 150 mg L-1) a significant increase in the number of fruits and the yield of one tree at all concentrations of the two elements compared to the control treatments. Abdelaziz et al. (2019) conducted a study on the treatment of mango trees cultivar "Keitte" with different concentrations of nano-boron (5, 10 and 20 mg L-1) and compared them with the concentrations of normal boron (50, 100 and 200 mg L-1), It was noted that the concentration (20 mg L-1) achieved the highest values for the characteristics (number of fruits, weight of fruits, total yield and content of fruits of TSS, total sugars and ascorbic acid) and it reached (77.0, 83.0 fruits of tree-1 and 394.0, 392g and 30.3, 32.6 kg tree-1 and 12.1, 12.2% and 8.9, 9.0% and 48.3, 48.0 mg 100 ml-1 juice) for the two study seasons, respectively. On the other hand, the above concentration of nano-boron caused the acidity of fruits to be reduced to the lowest level (0.829 and 0.824%) for the two study seasons, respectively.

Refaai (2014) indicated that when studying the effect of spraying with nano-boron element in concentrations (0.025, 0.05 and 0.1%) on palm trees of the "Zaghloul" variety, the highest values were for the traits (length and diameter of the fruit, weight of the punch, the total yield of the tree, and the total sugars and TSS content of the fruits), and that at concentration (0.1%) and it reached (5.82, 5.86 cm and 2.31, 2.36 cm and 13.2, 13.3 kg and 132.0, 133.0 kg palm-1 and 20.2%, 20.0% and 28.3, 29.1%) for the two study seasons, respectively. Sohrab et al. (2016) found significant differences when treating Ardestani pomegranate trees with nano-zinc at the two concentrations (60 and 120 mg L-1) and nano-boron at the two concentrations (3.25 and 6.5 mg L-1), all nano treatments contributed to giving the best yield and content of TSS, total sugars and anthocyanin pigment in the fruit juice compared to the control treatment. Davarpanash et al. (2017) confirmed that fertilizing Ardestani pomegranate trees with nano-nitrogen at concentrations (0.25 and 0.50 g N L-1) caused the highest significant increase in yield, number of fruits and their content of TSS, which amounted to (62.8, 70.1 fruits tree-1, 17.8, 21.9 kg tree-1 and 18.3, 18.6%) for the two study seasons, respectively. El-Sayed et al. (2017) also found in an experiment conducted on date palm trees cultivar "Zaghloul" when spraying with regular (Zn, Fe and Mn) elements at concentrations (25, 50 and 100 mg L-1) each, and nano at concentrations (2.5, 5.0, 10.0 and 20.0 mg L-1) each. The nano concentration (20.0 mg L-1) for the three elements was characterized by giving the highest values for fruit weight, fruit diameter, punch weight, total yield, TSS, reducing sugars and it reached (20.5, 20.7 g and 2.39, 2.45 cm3 and 13.3, 13.5 kg and 133.0, 135.0 kg and 31.1, 31.3% and 18.0, 18.1% for the two seasons, respectively, On the other hand, the above concentration contributed to reducing the acidity in fruits to the lowest level (0.221 and 0.218%) for the two study seasons, respectively.

Zagzog and Gad (2017) indicated in an experiment conducted on mango trees of the cultivars "Zebda and Ewasy" as the trees were sprayed with nano-zinc at two concentrations (0.5 and 1g L-1), it was found that both concentrations gave the largest number and weight of fruits, total yield of the tree, and the percentage of TSS in fruits in both cultivars of study compared to the control treatment. Both concentrations of zinc nanoparticles also contributed to reducing the percentage of deformed fruits compared to the control treatment. While Al-Zubaidi (2018) found that spraying palm trees of the “Khastawi” variety with the compound (Optimus Plus) produced according to nanotechnology, which contains (nitrogen 5%, amino acids 30% and organic nitrogen 3%) at a rate of (2 ml L-1) had a significant effect on the increase in fruit weight, punch weight, total yield and dry matter percentage in the fruits reached 4.80 g, 7.62 kg, 38.10 kg and 32.03% respectively. El-Sayed (2018) also found when spraying a number of ordinary and nano-elements, including iron and zinc, at a concentration of (0.05%) for ordinary and (0.005, 0.01, 0.02 and 0.04%) for nanoparticles on the date palm variety "Sakuti", that the concentrations of iron, ordinary and nano-zinc contributed to giving the highest values for all quantitative and qualitative yield traits compared to the control treatment and for both seasons of the study. Elsheery et al. (2018) found that spraying mango trees cultivar "Ewais" with nano-zinc at concentrations (50, 100 and 150 mg L-1) significantly contributed to an increase in the number of fruits, their weight, length and their content of TSS and total sugars, as well as reducing the percentage of deformed fruits and acidity in fruits at all zinc concentrations compared to the control treatment and for both seasons of the study.

El-Said et al. (2019) also found when spraying “Flame Seedless” grape with nano-zinc at concentrations (0.4, 0.8 and 1.2 mg L-1) and compared it with normal zinc at the two concentrations (140 mg L-1 zinc sulfate and 565 mg L-1 chelated zinc), there was an improvement in all the characteristics of the yield and its components when treated with nano and ordinary zinc compared to the control treatment. While AL-Akaishy et al. (2020) found that spraying lemon trees with the compound (Optimus Plus), the produce according to nanotechnology, which contains (nitrogen 5%, amino acids 30%, and organic nitrogen 3%) at a rate of 1 and 2 ml L-1, Significantly affected the increase in the number of fruits and the total yield, especially at the concentration (2 ml L-1) and it reached (136.3 fruits tree-1 and 10.67 kg tree-1), respectively. While the concentration (1 ml L-1) achieved the highest fruit weight (78.84 gm fruit-1). Davarpanah et al. (2020) found that when spraying pomegranate trees "Ardestani" with nano iron in the form of ($FeSO_4$) at concentrations (1.3 and 2.6 µmol), there was a significant increase in the traits (number of fruits, the total yield of the tree, the content of the fruits of TSS, the total sugars, and the iron content of leaves), especially at concentration (2.6 µmol) with (56.3, 64.0 fruits Tree-1, 16.2, 19.5 kg tree-1, 17.9, 18.0%, 15.20, 15.15%, and 128.8, 150.0 mg kg-1) for the two years of study, respectively.

CONCLUSION

The use of nano-fertilizers is a substitute for traditional fertilizers and works to increase the growth and productivity of crops and is environmentally friendly and very effective.

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