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Optimizing Sour Orange Growth and Chemical Properties through Foliar Application of Nano and Organic Fertilizers

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This study, conducted at the Lath House of Agriculture College, Al-Qasim Green University during the 2021-2022 growth season, aimed to evaluate the effects of KHARZA nanoparticles (NPs) and organic fertilizer (Nutirgreen) on sour orange seedlings. Different concentrations of KHARZA NPs (0, 1, 2, and 3 g L^{-1}) and organic fertilizer (0, 1.5, 3, and 4.5 ml L^{-1}) were applied. The experimental design followed a randomized complete block design (RCBD) with two factors, each having four treatments, and each treatment replicated thrice. Our findings reveal that spraying KHARZA NPs at a concentration of 3 g.L^{-1} significantly enhanced various vegetative parameters, such as plant height, stem diameter, leaf number, and leaf area, alongside improvements in chemical properties such as mineral concentration, chlorophyll content, and carbohydrate levels in leaves. Similarly, applying organic fertilizer at a rate of 4.5 ml L^{-1} led to notable enhancements in both vegetative and chemical characteristics compared to the control group. Notably, combined application of KHARZA NPs at 3 g L^{-1} and organic fertilizer at 4.5 ml L^{-1} resulted in synergistic effects, yielding the most favorable outcomes in terms of vegetative growth and chemical properties. These results underscore the potential of utilizing KHARZA nanoparticles and organic fertilizers in enhancing the growth and physiological properties of sour orange seedlings, offering promising avenues for sustainable agricultural practices.
Keywords: Optimizing**,** spray nutrients**,** KHARZA, organic fertilizer, growth, orange seedlings.

INTRODUCTION

Sour orange (*Citrus aurantium* L.) is valued for its tolerance to hot conditions and nutritional benefits. It is a huge shrub tree that grows to a height of 5 to 15 meters. White blooms grow in single or small clusters, and when the fruits ripen, they become round, green, and then yellow or orange (Manner *et al*., 2006). Because sour orange trees can tolerate hot conditions, they are widely cultivated in Iraq. Because of this, its juice is frequently substituted for lemon juice in Iraqi cuisine. Citrus fruits are regarded as an invaluable source of vitamins, carotenoids, flavonoids, and active chemicals that have been shown to have antifungal, anticancer, and heart disease-prevention properties (Samanta *et al*., 2023). In biological systems, micronutrients like boron, zinc, manganese, and other related elements are essential for the production of primary and secondary compounds (Hess, 2012). Moreover, micronutrients are important for vegetative growth, blooming, fruit setting, and biomass yield (Vishekaii *et al*., 2019). A vast range of micronutrient compounds are available on the global market, and Nano products are already very popular among them and have significantly advanced agriculture (Sharma *et al*., 2018). Plants can absorb nutrients more efficiently when leaves are more accessible to them because to the design of nanoparticles (NPs) (Akintelu *et al*., 2021). There are many sources of nutrient effects on different morphological and physiological in Citrus plants, not just microelements, such as organic fertilizer. Micronutrients and organic fertilizers play crucial roles in enhancing plant growth and fruit yield.

Organic fertilizers are obtained from several sources, such as from animals, plants, or industrial waste, which are solid, liquid, or decomposed. Organic fertilizer is added to trees in several ways with recommended quantities for each crop and according to their type, soil's current environmental circumstances, as well as compost's solid-to-liquid ratio (Meemken and Qaim, 2018; Jafar and Yaakob, 2013). Because organic fertilizers contain certain organic acids, such as folic and humic acids, amino acids, and other substances, they provide the nutrients that fruit trees require. They are cheap and easy to use, and the percentage of their pollution to the environment is low and contributes to improving the soil's physiological, chemical, and vital characteristics. Organic fertilizers, rich in organic compounds and nutrients,

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contribute positively to soil quality and plant growth. Thus, this is reflected positively in improving different plant production (Ameen and Hamdani, 2022; Al-A'areji *et al*., 2014).

Another type of fertilizer that affects the production of different *Citrus aurantium* L. plants is Neutergreen fertilizer. One of the most important types of fertilizer is Neutergreen, which has organic nitrogen that is converted by soil microorganisms into mineral nitrogen that is absorbed by seedlings and encourages the accumulation of chlorophyll. (Al-A'areji *et al*., 2014). Nano products, including KHARZA nanoparticles, have revolutionized agriculture by improving nutrient absorption efficiency. Moreover, Neutergreen fertilizer increases the amount of organic carbon, which makes up all organic compounds and makes up roughly 50% of the dry weight of most plants (Roper *et al*., 1996). In addition, liquid organic fertilizers increase the soil content from available nutrients ready for plants. This will reflect positively on the characteristics of vegetative growth, and the range of plant leaves from mineral elements, which is considered necessary for plant growth (Meddich *et al*., 2020). A study by Alalaf *et al*. (2022) found that the effect of ground application and spraying with Siapton organic fertilizer containing several amino acids in three concentrations (0, 2 and 4 ml L^{-1}) has a significant impact on the vegetative growth of orange seedlings. The same study showed considerable effect when the ground application of the fertilizer on the organic matter of the seedlings. Also, when compared to control seedlings, the interaction between these treatments has a positive effect on every aspect of vegetative growth, including the greatest rate of the plant, number of branches, number of leaves, and leaf area. Previous studies highlight the positive effects of organic and micronutrient fertilizers on citrus plant growth. Neutergreen fertilizer, with organic nitrogen, promotes chlorophyll accumulation and enhances soil nutrient availability. Another study showed that the highest averages of the amount of chlorophyll in the leaves were obtained by combining the compound fertilizer NPK with liquid organic fertilizer Amino Alexin at a concentration of 5ml L^{-1} (Qaba and Al A'araji *et al*., 2020). Moreover, it increases the concentration of carbohydrates in the leaves, leaf area, number of branches, seedlings height, and shoot's dry weight (Qaba, 2019). In general, products with nutrients are added to the soil. Nonetheless, studies have shown that micronutrient foliar spray is more dependable; additionally, exogenous application has the drawbacks of high concentrations, uniform nutrient distribution, and faster plant absorption stimulation (Umar *et al*., 1999). This research aims to use many combinations of NPs (KHARZA) and Organic fertilizer foliar applications to detect their impact on the growth vegetative traits of sour orange seedlings.

MATERIALS AND METHODS

The experiment was conducted in Babil governorate, Iraq, during the 2022 vegetative growth season. Soil analysis revealed a loamy sandy texture with specific chemical properties (Table 1).

Six-month-old sour orange seedlings were used, and grown in standardized conditions. seedlings were planted in black plastic pots measuring 60 cm in height and 30 cm in diameter. KHARZA nanoparticles and Nutirgreen organic fertilizer were applied through the foliar spray at various concentrations (Mahdi *et al*., 2019; Hamzah *et al*., 2023). Nanoparticles (NPs) were purchased from Khazra Products (SASh Co., Flat 2, Abdollahzadeh St., Keshavarz Blvd., Tehran, Iran). Three foliar spray applications of varying NPs concentrations (0, 1, 2, and 3) g L^{-1} were conducted during the spring season, the 1st spray was on 20/3/2022, 2nd on 5/4/2022 and 3rd on 20/4/2022. Two days following each prior foliar spray, Organic Fertilizer (0, 1.5, 3, and 4.5) ml L^{-1} was applied. Organic fertilizer (Nutirgreen) were purchased from (Green Has Italia S.p.A. C.so Alba, 85/89,12043 Canale (CN) - ITALY) (Table 2). In fall season, the same treatments (NPs and organic fertilizer) were repeated on 20/8/2022, 5/9/2022 and 20/9/2022. Using a hand sprayer, every plant was uniformly sprayed on both sides of the leaves in the early morning hours for better absorption and long-lasting effects (Hamza and Farqad, 2020; Ibrahim *et al*., 2018; Ibrahim *et al*., 2019). All that was used in the control treatment was distilled water.

***Studied characteristics*:** Many characteristics have been studied such as plant growth characteristics and chemical properties were evaluated after five months. These included measuring the height of the plants by using the measuring tape (cm) from the soil surface till the end of the plants and the

Table 1. showed the Physical and chemical characteristics of the experiment soil.

Texture	Loam	Clay	Sand	EC	pH	Available nutrients g. kg^{-1}			
	g. kg^{-1} soil			dS. m^{-1}	soil paste	N	P	K	Organic material
Loamy sandy	125	65	810	1.4	7.25	3.4	6.3	3.45	7.1

Table 2. Organic fertilizer (Nutirgreen) content.

Elements	Organic nitrogen	Organic nitrogen dissolved in water	Organic carbon	Amino acids	Other elements
Percentage %	8.00	8.00	23.50	50.00	10.50

average was taken. Stem diameter was measured with the digital vernier calipers (mm). Each plant's total number of leaves was counted, and the average was then determined. Four leaves were randomly selected from the shoot center, and the leaf area was measured (cm^2) using a digital planimeter. The total leaf area was then computed as fallow (leaf area x number of leaves). Chlorophyll content was measured by using five greenness leaf from seedlings of sour orange by a portable chlorophyll meter (SPAD-502, Japan). the percentage of Carbohydrates were determined from the orang plants by digestion method outlined by (Ani and Abel, 2018). The spectrophotometer was used to estimate the phosphor (P) content, the flame photometer was used to determine the potassium (K) content, and the micro Kieldahl technique was used to assess the nitrogen (N) content of the leaf.

***Statistical Analysis*:** The shade house experiment comprised 16 treatments, 3 repetitions, and 3 seedlings per unit. Statistical analysis was conducted using the Completely Randomized Block Design (CRBD) with Genstat software. The results were subjected to variance analysis using an ANOVA table, and at the 5% probability level, the Least Significant Difference (LSD) was used to examine the statistical differences between the variables.

RESULTS

The combination of Nutrigreen 4.5 ml L^{-1} and NPs 3 g L^{-1} significantly enhanced plant height, stem diameter, leaf number, leaf area, chlorophyll content, carbohydrate percentage, and leaf mineral content compared to control treatments. The interaction between NPs and organic fertilizer produced the most favorable results across all parameters assessed.

***Effect of Nutrigreen and nanoparticles on plant height and stem diameter of sour orange*:** The results in Table 3 showed the effect of Nutrigreen and NPs on the height of sour orange plants; their interaction resulted in a maximum height of 53.30 cm for the Nutrigreen 4. ml L^{-1} treatment and NPs 3g L^{-1}, where plant high was observed to be 25.80 cm, and the control treatment yielded the lowest value. The administration of Nutrigreen 4.5ml L^{-1} via interaction with NPs 3g L^{-1} is demonstrated by the results in Table 3 displayed a noteworthy variation in the mean stem diameter, measuring 4.91 mm, in contrast to the control treatment that displayed the lowest mean (1.30 mm).

***Effect of Nutrigreen and nanoparticles on leaf number and leaf area of sour orange*:** The lowest average of leaf area and number was seen in orang seedlings that had not received any Nutrigreen or NPs treatment (Table 3). In contrast, the average number of leaves per plant and leaf area rose significantly after the foliar application of both Nutrigreen 4.5ml L^{-1} and NPs 3g L^{-1} to 72.95 leaves/plant and 37.87 cm^2, respectively. In comparison with the relevant control seedlings (37.81 leaves per plant and 13.70 cm^2). A regulated sequence that starts with cell division and progresses through proliferation, differentiation, and elongation is used to determine the size and shape of plant organs. The addition of liquid organic fertilizer was important in giving a lower pH to the soil and with a significant difference from the comparison treatment.

Table 3. Influence of Nutrigreen and NPs applied topically at different doses on some vegetative development indices in sour orange seedlings.

NPs (g L^{-1})	Nutrigreen (ml L^{-1})	Plant height (cm)	Stem diameter (mm)	Leaves number	Leaf area (cm^2)
0.0	0.00	25.80	1.30	40.67	13.70
	1.5	29.65	1.60	45.25	18.20
	3	31.34	1.93	53.81	20.50
	4.5	34.50	2.50	61.34	22.80
1.0	0.00	31.97	1.66	46.78	20.20
	1.5	35.90	2.19	55.83	23.61
	3	38.44	3.08	60.79	24.11
	4.5	48.15	3.54	66.59	28.77
2.0	0.0	33.81	2.58	57.02	24.41
	1.5	38.90	2.95	58.16	26.72
	3	39.40	3.15	63.20	28.37
	4.5	42.84	3.75	68.45	29.53
3.0	0.0	35.58	3.25	66.94	26.57
	1.5	39.85	3.58	68.76	29.10
	3	42.45	3.89	71.23	34.54
	4.5	53.30	4.91	72.95	37.87
LSD at 5% level		NPs (A)= 2.624	A= 0.29	A=2.965	A=2.272
		N (B)= 2.624	B= 0.29	B= 2.965	B=2.272
		A x B= 5.248	A x B=0.57	A x B=5.930	A x B=4.544

***Effect of nutrigreen and nanoparticles on chlorophyll content (SPAD)of sour orange*:** The administration of Nutrigreen and NPs to the orang seedlings significantly impacted the amount of chlorophyll (Table 4). Comparably, the control resulted in a decrease in the average chlorophyll content in leaves 30.71 SPAD, whereas the combination of Nutrigreen 4.5 ml L^{-1} and NPs 3 g L^{-1} had a substantial impact, yielding 62.63 SPAD. Chlorophyll content is one of the main parameters associated with plant photosynthesis. It is often regulated by nitrogen and phosphorus, which are also necessary for the production of ATP (adenosine triphosphate), which is the product of chlorophyll biosynthesis.

Table 4. Effect of foliar application of Nutrigreen and NPs at various concentrations in some chemical characteristics of sour orange seedlings.

NPs (g L^{-1})	Nutrigreen (mg L^{-1})	Chlorophyll (SPAD)	Carbohydrate (%)
0.0	0.0	30.71	9.66
	1.5	34.90	11.15
	3.0	40.30	14.80
	4.5	44.40	17.88
1.0	0.0	43.94	15.76
	1.5	44.51	18.40
	3.0	45.55	19.36
	4.5	47.11	20.25
2.0	0.0	45.43	20.30
	1.5	46.74	21.34
	3.0	48.47	23.10
	4.5	49.60	24.36
3.0	0.0	50.37	25.43
	1.5	51.39	30.79
	3.0	54.10	36.82
	4.5	62.63	40.23
LSD at 5% level		NPs (A)=3.145 N (B)= 3.145 A x B= 6.290	A= 2.793 B= 2.793 A x B= 5.586

***Effect of Nutrigreen and nanoparticles on carbohydrate percentage of sour orange*:** The information pertaining to the carbohydrate content is displayed in Table 4 and is expressed as a percentage. The results revealed notable differences between the treatments, with control seedlings achieving the lowest percentage of similar indices (9.66%) and Nutrigreen 4.5 ml L^{-1} and NPs 3 g L^{-1} interacting to produce the greatest average of carbohydrates (40.23%).

***Effect of Nutrigreen and nanoparticles on leaf mineral content of sour orange*:** The interaction between Nutrigreen 4.5 ml L^{-1} and NPs 3 g L^{-1} showed a noticeable rise in leaves percentages of N (2.89%), P (0.54%), and K (1.88%) in comparison with the control seedlings, which obtained the lowest average of this trait N (1.05%), P (0.10%), and K (0.70%). These results were obtained from Table 4, which outlines the leaf mineral content (percentage of nitrogen, phosphorus, and potassium).

DISSCUSION

The study underscores the positive impact of foliar application of KHARZA nanoparticles and organic fertilizer on sour orange seedlings. The results of the study demonstrate the significant positive impact of Nutrigreen (4.5 ml L^{-1}) and KHARZA nanoparticles (3 g L^{-1}) on the growth and chemical characteristics of sour orange seedlings. Comparable findings in lemon plants and Sudan grass hybrid support the notion that Nano-fertilizer concentrations can influence stem diameter and plant height positively (Al-Jilihawi and Merza, 2020; Mohsan, 2021). The study also aligns with previous research indicating that the combination of organic fertilizers and nanoparticles enhances plant growth (Vishekaii *et al*., 2019; Akintelu *et al*., 2021).

The observed increase in leaf number and area, attributed to Nutrigreen and NPs, emphasizes the importance of organic matter-containing fertilizers in improving soil characteristics. The enhanced availability of major nutrients and microelements positively affects plant growth, corroborating findings by Barakat *et al.* (2012). The study suggests that the organic acids produced through the breakdown of organic matter in the soil, facilitated by nanoparticles, contribute to soil acidity regulation and nutrient absorption efficiency (Srivastava *et al*., 2021). The result corresponding with the finding by Mohsan (2021) on Sudan grass hybrid plants showed that the values of leaves number, and leaf area were 23 leaves per plant, 9750.16cm^2 respectively, which were obtained from 15 g L^{-1} application of organic fertilizer and Nano-fertilizer. On the other hand, the value of control plants was the lowest.

By playing an essential function in metabolism, transport, and the breakdown of organic matter in organic fertilizer, nanoparticles (NPs) applied topically can control and modify the characteristics of organic fertilizer, leading to the production of numerous organic acids, including humic and fulvic acid. Also, Carbon dioxide, which dissolves in the ground solution, forms carbonic acid, which ionizes to Bicarbonate and hydrogen ions in the ground solution, which leads to a decrease in the degree of soil interaction, and then dissolves many nutrients in the soil and makes it more suitable for absorption by plants roots (Srivastava *et al.*, 2021). Moreover, enhancing the soil's physical characteristics, which is reflected in the growth, development of roots and plant hormone synthesis (Shireen *et al*., 2018). This finding is consistent with earlier research showing the plant more efficiently and readily absorbs nanoparticles to meet its nutritional needs (Vishekaii *et al*., 2019; Akintelu *et al*., 2021).

The impact of Nutrigreen and NPs on chlorophyll content supports the vital role of these fertilizers in promoting photosynthesis. The increase in chlorophyll content is consistent with studies on olive and sweet cherry trees, emphasizing the positive effect of foliar application of NPs on the photosynthetic apparatus (Tombuloglu *et al.,* 2020; Vishekaii *et al.,* 2019).

The current study proved that the Nutrigreen and NPs had a role in improving the carbohydrate percentage and leaf mineral content, especially the high concentrations of it; it gave the best results as shown in (Tables 4). Due to their important function in metabolism and photosynthetic dispersion, carbohydrates' tendency to aggregate in leaves indicates a favorable response to NPs applied topically (Vishekaii *et al*., 2019). As a notable difference from the comparison treatment, the addition of liquid organic fertilizer was crucial in lowering the soil's pH. This could be explained by the significance of Nutrigreen, a liquid organic fertilizer. Additionally, the study's findings regarding carbohydrate percentage and leaf mineral content highlight the role of Nutrigreen and NPs, particularly at higher concentrations, in enhancing these parameters. The improved efficiency of the photosynthetic process and nutrient absorption contribute to the observed positive effects (Siddiqui *et al*., 2015). The decrease in soil pH due to Nutrigreen application aligns with previous studies indicating the importance of liquid organic fertilizers in soil pH regulation (Ahmed *et al*., 2018; Al-Zuhairi, 2017). Simple processing and the microbial breakdown of organic matter in the soil can result in the production of hydrogen sulfide and ammonia gas, which can then be oxidized in the soil to form inorganic acids like nitric acid and sulfuric acid, reducing the interaction of the soil (Tisdale *et al.,* 1985).

Similarly, findings confirmed by the results by Al- Zuhairi (2017) in his study on seedlings of three citrus rootstocks bitter orange, lemone *Volca Mariana*, *Sonicle stromelo*, and another study by Ahmed *et al*. (2018) in his experiment on seedlings of local orange, *Citrus sinensis* L. the addition of organic fertilizers led to a decrease in the degree of soil interaction when the treated and untreated seedlings are contrasted, which led to an increase in the availability of nutrients. Moreover, nutrients which contain organic matter, have great importance in improving the physical, chemical, and biological properties of the soil, which leads to an increase in the readiness of major nutrients and microelements, and this is reflected positively in improving plant growth (Barakat *et al.,* 2012). A recent study demonstrated that it has been suggested that NPs have an impact on nutrients and provide clear support for N, P, and K translocation. Following NPs foliar spraying, there has been a noticeable rise in occurrences, especially in leaves, as documented in olive (Vishekaii *et al*., 2019).

***Conclusion*:** In conclusion, the foliar application of KHARZA nanoparticles (NPs) and organic fertilizer (Nutirgreen) significantly enhances the vegetative growth and chemical characteristics of sour orange seedlings. This approach not only reduces fertilizer costs but also mitigates pollution risks. The study suggests that the application of nano-fertilizer at 3 g L^{-1} and organic fertilizer at 4.5 ml L^{-1} yields optimal results. Furthermore, the synergistic interaction between NPs and organic fertilizer at the same concentrations demonstrates superior performance across all assessed characteristics. The findings of this study have implications for the improvement of various growth characteristics in different fruit and plant types when utilizing nano-fertilizers and organic fertilizers. Further research is warranted to explore optimal dosage and application methods for maximum efficacy. These fertilizers can be used with other fruit plants and also for other plant types to improve different growth characteristics and the researcher can investigate the long-term effects of foliar application on fruit yield and quality.

***Authors contributions statement*:** M. Ibrahim wrote, designed, prepared, reviewed and finalized the draft. L.M. Hamzah designed, completed the experiments and analyzed the data.

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***SDG's Addressed*:** Zero hunger, Responsible Consumption and Production.

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