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Effect of foliar spraying with fertilizer of nano NPK on vegetative growth and fruit quality of the local Navel Orange cultivar

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Abstract

This study was conducted to evaluate the effect of foliar spraying with several concentrations of fertilizer of nano-NPK on improving vegetative growth, crop characteristics and fruit quality of the variety of Navel orange under the conditions of Karbala Governorate during the agricultural season 2024. The results of the study indicated that foliar spraying with nano-NPK fertilizer significantly affected all vegetative growth characteristics. The 750 mg/L treatment recorded the highest averages in chlorophyll content, leaf area, branch length, and number of leaves per branch, which in general led to a clear improvement in the plant's physiological efficiency. Increasing the concentration to 1000 mg/L did not result in any significant improvement in the studied traits. Regarding productive traits, the treatment with a concentration of 750 mg/L also outperformed, yielding the highest average fruit weight (206.1 g), the highest number of fruits (269 fruits/tree), and the highest yield per tree (54.9 kg), compared to the other treatments. This reflects the effect of adding nano-fertilizers in increasing the efficiency of photosynthetic product transport and enhancing fruit set. Regarding fruit characteristics and quality, the treatment with a concentration of 750 mg/L achieved the highest values for fruit length and diameter, juice content, total soluble solids (TSS), and TSS/acidity ratio, along with a significant decrease in total acidity. Therefore, the use of foliar spraying with nano-NPK is an effective field management technique for improving vegetative growth, yield, and fruit quality of the local Iraqi Navel Orange cultivar.

Keywords: Foliar spray; Nano NPK; Fruit quality; Navel Orange

1. Introduction

Orange trees (*Citrus sinensis* L.) are among the most important citrus trees in the world, thanks to their high nutritional and economic value. Their fruit is an important source of vitamins, sugars, and organic acids [1]. Navel oranges are considered one of the most popular types of oranges in Iraq and the nearby region due to the quality of their fruit and consumer demand [2], however, it is usually significantly affected by the mineral fertilization programs followed by the Iraqi farmer during the growing season, especially in winter [3]. The optimal performance of citrus trees (in terms of vegetative growth or production) is greatly affected by the availability of macronutrients, especially nitrogen, phosphorus and potassium, which play a major role in activating metabolic processes, regulating carbohydrate transport, and chlorophyll formation, as well as improving fruit set and growth [4]. Nutritional imbalance usually leads to stunted growth, reduced fruit count, and even lower fruit weight [5]. Nanotechnology has emerged as a modern trend in plant nutrition, including fruit trees, as nanoparticles can act as carriers of the three essential nutrients involved in basic physiological processes, improving absorption, increasing nutrient utilization efficiency, and reducing added quantities [6]. [7] It was mentioned that foliar spraying with nano-fertilizers, especially nano-NPK, has contributed to improving the vegetative growth of fruit trees, including citrus, by increasing branch length, leaf area, number of leaves, and chlorophyll content. The results indicated that the use of nano-NPK fertilizer led to an increase in chlorophyll content of 18-30% compared to the control treatment, which significantly improved photosynthetic efficiency and overall growth [8]. Foliar spraying with nano-NPK fertilizer also significantly improved fruit quality, with an increase

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in the number of fruits ranging from 15-35% and an increase in the average fruit weight of 20% compared to conventional fertilizers, which was reflected in an increase in the overall productivity of the trees [9], [10]. The results of several studies have indicated that the use of nano-fertilizers, including NPK nano-fertilizers, has contributed to improved fruit quality, such as increased fruit length and diameter, increased juice content, and increased total soluble solids (TSS) and TSS-to-acidity ratio. Both [11 and 10] observed that spraying with NPK nano-fertilizers led to a 10-18% increase in TSS, with a relative decrease in total acidity, compared to control treatments.

Studies investigating the effect of foliar spraying with NPK nano-fertilizer on navel orange trees under local environmental conditions in Iraq remain very limited, particularly regarding the relationship between vegetative growth, yield characteristics, and fruit quality. Therefore, this study was conducted to evaluate the effect of different concentrations of nano-NPK fertilizer applied as a foliar spray on improving vegetative growth and fruit quality of the local Navel Orange cultivar grown in Karbala Governorate.

2. Materials and Methods

2.1. Experimental Location and Plant Material

The experiment was conducted during the 2024 growing season in a fruit orchard belonging to a farmer located in Karbala Governorate, about 100 km southwest of Baghdad. 5-6 year old Navel Orange (*Citrus sinensis* L.) trees, grafted onto Citrus aurantium rootstock, were selected. They were uniform in growth and size and were grown under standardized agricultural service conditions in terms of irrigation, soil fertilization, and pest control.

2.2. Nano-Fertilizer Used

A commercially available, nano-prepared NPK nano-fertilizer containing the macronutrients (nitrogen, phosphorus, and potassium) was used. The nanoparticle sizes of the fertilizer ranged from 20 to 50 nm. The fertilizer was used according to the manufacturer's recommendations, with the concentrations adjusted according to the experimental design.

2.3. Experimental Design and Treatments

The experiment was conducted using a randomized complete block design (RCBD) with three replicates (each replicate representing one tree) and five treatments: T0 (control), which involved spraying with distilled water only; T1 (250 mg/L NPK nano-fertilizer); T2 (500 mg/L NPK nano-fertilizer); T3 (750 mg/L NPK nano-fertilizer); and T4 (1000 mg/L NPK nano-fertilizer). Spraying was carried out during the growing season in the early morning hours. The physiological stages are (the first spray was before flowering, the second spray was after fruit set, and the third spray was during the fruit growth stage) using a manual sprayer until the leaves are completely wet. In order to improve the spread of the solution on the leaf surface, a non-ionic spreading agent was added.

2.4. Studied Traits

Vegetative growth, productivity, and fruit quality traits were estimated according to standard methods used in fruit tree research as reported in [12], [13]

2.4.1. Vegetative growth traits

These were assessed at the end of the season and included:

- Branch length (cm): Measured the lengths of randomly selected branches from the current season.
- Number of leaves/ Branch: The leaves on the selected branches were counted.
- Leaf area (cm^2): Estimated using a leaf area meter or an approved standard equation.
- Chlorophyll content: Measured using a SPAD device on fully grown leaves.

2.4.2. Productive traits

The following traits were recorded at fruit maturity:

- Number of fruits/tree
- Average fruit weight (g)
- Tree yield (kg): Calculated by multiplying the number of fruits by the average fruit weight

2.4.3. Fruit quality traits

A random sample of fruits from each tree was used to estimate the following:

- Fruit length and diameter (mm): Using a digital caliper
- Juice percentage (%): Calculated as the ratio of juice weight to total fruit weight
- Total soluble solids (TSS): Estimated using a refractometer (°Brix)
- Total acidity (%): Estimated by titration and expressed in citric acid according to [14].
- TSS/acidity ratio: Calculated As an indicator of fruit quality and marketability, according to [13].

2.5. Statistical analysis

Using analysis of variance (ANOVA), the data were analyzed, and the means were compared using the least significant difference (LSD) test at a probability level of 0.05, as described in [15], using a standard statistical software program.

3. Results

3.1. Effect of foliar spraying with nano NPK fertilizer on vegetative growth traits

As observed in Table (1), foliar spraying with nano-NPK fertilizer significantly improved all studied vegetative growth traits of Navel orange trees compared to the control treatment. As observed in Table (1), foliar spraying with nano-NPK fertilizer significantly improved all studied vegetative growth traits of the Navel orange variety compared to the control treatment. Treatment T3 (750 mg/L concentration) outperformed the other treatments in chlorophyll content (52.2), leaf area (60.4 cm^2), number of leaves per branch (32.6), and branch length (46.8 cm), while the 1000 mg/L (T4) treatment did not differ significantly in most traits. An improvement in photosynthetic efficiency is observed due to the significant increase in chlorophyll content at concentration T3. This may be attributed to the pivotal role of nitrogen in the formation of chlorophyll and proteins, with phosphorus contributing to energy transfer processes, and potassium improving photosynthetic efficiency and regulating stomatal opening.

These results are consistent with those reported by [9] in their study of the effects of NPK nano-fertilizers on citrus trees. They confirmed that moderate concentrations of NPK nano-fertilizer significantly improved vegetative growth traits compared to high concentrations and the control group. This was attributed to increased uptake efficiency and faster translocation of nutrients within plant tissues due to the small size of the nanoparticles and their increased effective surface area.

Table 1 Effect of Nano NPK Fertilizer Concentrations on Vegetative Growth traits of Navel Orange Trees

Treatment	Branch length (cm)	No. of leaves/branch	Leaf area (cm^2)	Chlorophyll content (SPAD)
T0 (Control)	33.1 d	21.2 d	42.2 d	39.0 d
T1 (250 mg/L)	39.7 c	25.5 c	49.1 c	43.3 c
T2 (500 mg/L)	45.9 b	30.3 b	56.6 b	48.7 b
T3 (750 mg/L)	48.9 a	32.6 a	60.4 a	52.2 a
T4 (1000 mg/L)	46.8 ab	31.4 ab	57.3 ab	50.3 ab
LSD (0.05)	3.2	2.0	3.8	3.0

Note: Values that share the same letter do not differ significantly at the 0.05 level.

3.2. Effect of Nano NPK Fertilizer on Productive Traits

Data from table (2) as well as figure (1) show a gradual and noticeable improvement with increasing concentration of the nano-NPK fertilizer compared to the control treatment. Spraying with a concentration of 250 mg/L resulted in a significant increase in the number and weight of fruits as well as tree productivity, while concentrations of 500 and 750 mg/L showed even greater increases in the average of all studied traits. Spraying with a concentration of 750 mg/L achieved the highest average results, significantly outperforming all other treatments and proving its high efficiency in promoting fruit set and growth, with 269 fruits per tree, an average fruit weight of 206.1 grams, and a tree yield of 54.9 kg, indicating In contrast, increasing the concentration to 1000 mg/L did not lead to any further significant improvement compared to the optimum concentration, indicating a physiological limit to the response, which may be

related to surface saturation of the leaves or a decrease in nutrient uptake efficiency at high concentrations. This improved productivity is attributed to the role of nano-NPK fertilizer in enhancing photosynthetic efficiency and improving the translocation of photosynthetic products to the fruit, in addition to the vital role of potassium in improving fruit set and increasing fruit size. These results are consistent with what [16] indicated in their study of citrus trees, where they confirmed the superiority of medium- to high-concentration nano-NPK in improving fruit number, weight, and tree yield compared to conventional fertilizers.

Table 2 Effect of nano-NPK fertilizer on the productive traits of Navel Orange trees

Treatment	Number of fruits/tree	Average fruit weight (g)	Tree yield (kg)
T0	184 d	164.9 d	30.4 d
T1 (250 mg\ L)	211 c	178.3 c	37.7 c
T2 (500 mg\ L)	246 b	193.2 b	47.3 b
T3 (750 mg\ L)	269 a	206.1 a	54.9 a
T4 (1000 mg\ L)	256 ab	197.9 ab	50.5 ab
LSD (0.05)	20	12	6.5

In Figure (1), the ± standard error was represented by the mean bars, while the significant differences between the treatments were indicated by different letters at the top of the bars according to the LSD test at a statistical significance level of $p \leq 0.05$.

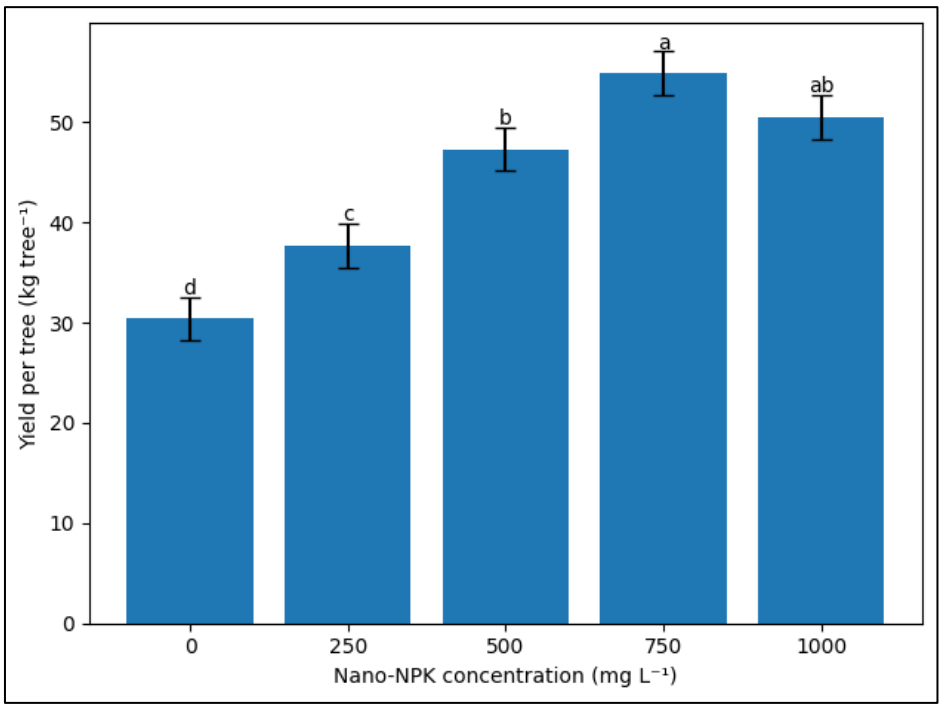

Figure 1 Effect of foliar spraying with nano-NPK fertilizer at different concentrations on Navel orange tree

3.3. Effect of foliar spraying with nano-NPK fertilizer on fruit quality traits

The results in Table (3) show that all fertilizer treatments outperformed treatment T0 in fruit diameter, length, juice content, total soluble solids (TSS), and TSS/acidity ratio, with a significant decrease in acidity. Treatment T3 (750 mg/L) registered the highest values for fruit diameter, length, juice content, and TSS, as well as the highest TSS/acidity ratio, indicating an overall improvement in the physical and chemical traits of the fruit. The increased availability and absorption of nutrients through the leaves may be attributed to the high efficiency of nano-fertilizers, which has had a positive impact on photosynthesis, carbohydrate transport, and sugar accumulation in the fruit during the growth and ripening stages.

Furthermore, increasing the fertilizer concentration to 1000 mg/L (T4) did not significantly outperform the 750 mg/L concentration in most traits. This suggests an optimal concentration for the nano-fertilizer, and that excessive increases may not lead to any further significant improvement, which aligns with the principle of the physiological response of plants to highly efficient fertilizers. Furthermore, the decrease in acidity and the increase in TSS and TSS/Acidity values in nano-treatments, especially T3, are an important indicator of improved taste and marketability of the fruit, as these qualities are directly related to juice quality and consumer preferences. These results are consistent with what was indicated by [18, 17] who showed that the use of compound nano-fertilizers (NPK) in fruit trees led to a significant improvement in the physical and chemical properties of the fruit as a result of increased absorption efficiency and reduced nutrient loss, as well as improved photosynthetic efficiency and the transfer of photosynthetic products to the economic organs.

Table 3 Effect of spraying with nano-NPK on fruit quality traits

Treatment	Fruit diameter (mm)	Fruit length (mm)	Juice (%)	TSS (°Brix)	Acidity (%)	TSS/Acidity
T0 (Control)	69.3 d	71.3 d	42.9 d	9.5 d	1.22 a	7.8 d
T1 (250 mg/L)	72.6 c	74.5 c	46.4 c	10.5 c	1.14 ab	9.1 c
T2 (500 mg/L)	76.7 b	78.8 b	50.3 b	11.4 b	1.07 bc	10.4 b
T3 (750 mg/L)	79.5 a	81.9 a	53.8 a	12.2 a	1.03 c	11.8 a
T4 (1000 mg/L)	78.2 ab	80.4 ab	51.2 ab	11.6 ab	1.04 bc	11.2 ab
LSD (0.05)	2.8	3.0	2.5	0.8	0.10	1.0

4. Conclusion

The results indicated that spraying Navel Orange trees with nano-NPK fertilizer significantly improved vegetative growth, yield, and fruit quality in Karbala Governorate. A concentration of 750 mg/L was found to be optimal, resulting in superior yield and high fruit quality, thus highlighting the effectiveness of this type of foliar fertilization as an efficient and sustainable nutrient management strategy.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Authors' contributions

The authors' contributions included conducting the field experiment, laboratory and statistical analyses, and writing the manuscript.

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