

Effect of adding Anti-salinity and enriching organic fertilizer with nano-compound fertilizer NPK on the growth of sour orange seedlings

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Abstract

The experiment was conducted in the fields of the College of Agriculture, University of Diyala, located at 44°45' East longitude and 33°17'41" North latitude, during the 2025-2026 growing season in sandy-clay-loamy soil. The aim was to study the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer on the growth of sour orange seedlings. The experiment was carried out according to a randomized complete block design (RCBD) using a split-plot design with three replications. The experiment included 36 experimental units as a two-factor experiment: three levels of Anti-salinity treatments placed in the main plots, and four levels of sheep manure and NPK nano-compound fertilizer placed in the subplots. Anti-salinity treatments were a control factor of 10 and 20 ml.L⁻¹ per seedling, and the concentrations of sheep manure were 0% (no addition) and 5% (sheep manure). Based on volume and enrichment (5% sheep manure + 5 kg.ha⁻¹ compound nano-fertilizer) and 5 kg.ha⁻¹ compound nano-fertilizer.4 The results were statistically analyzed and the arithmetic means were compared using Duncan's multiple range test at a probability level of 0.05. The results showed the following:

1- The 5% sheep manure treatment outperformed the no-add O1 level for the following traits: nitrogen, phosphorus, potassium, plant height, and chlorophyll content. The treatment means were (2.4933%, 0.64444%, 2.4978%, 137.111 cm, and 58.867 mg.g⁻¹), respectively. The leaf proline concentration was 1.514 mg.g⁻¹ fresh weight.

2- The fourth level of NPK O4 nano-fertilizer achieved the highest means for the following traits. Nitrogen, phosphorus, and potassium averaged (2.753%, 0.7200%, and 2.873%), respectively, compared to the level without O1 addition. The average proline concentration was 1.50444 mg.g⁻¹ fresh weight.

-3The dual interaction between sheep manure and NPK nano-fertilizer at levels two and three for both sheep manure and nano-fertilizer (+) achieved the highest averages for nitrogen, phosphorus, and potassium in the leaves and plant height, with average values for level O3 of (3.48330%, 0.864%, 4.888%, and 143.444 cm), respectively (mg.kg⁻¹ and 411.78 mg.kg⁻¹). The proline concentration in the leaves at the interaction was 1.51000 mg.g⁻¹ fresh weight.

4- The triple interaction (W3O3) of sheep manure, nano-fertilizer, and Anti-salinity achieved the highest average concentrations of nutrients (nitrogen, phosphorus, and potassium, with averages of 3.536%, 0.960%, and 5.183%, respectively) in the plant. This interaction also resulted in the highest plant height, reaching 162.00 cm, while the proline concentration in the leaves reached 1.50667 mg.g⁻¹ fresh weight. Fertilization with the Anti-salinity at a level of 20 ml L⁻¹ per seedling (W3) led to significant effects on most of the studied traits, including total chlorophyll concentrations, which reached 56.542 mg.g⁻¹, and plant height, which reached 142.667 cm. The same treatment also

recorded average concentrations of nitrogen, phosphorus, and potassium. (2.619%), (0.6575%), (3.075%) respectively. The proline concentration at this level was (1.507 mg g⁻¹ fresh weight.)

Keywords: Organic fertilizer, NPK nano-fertilizer, sour orange, enrichment, sheep manure

Introduction

Soil is a vital natural resource for feeding the world's growing population and is essential for achieving most of the Sustainable Development Goals. However, several challenges hinder the growth of fruits and other crops in arid and semi-arid regions, most notably salinity (7). Salinity has significantly contributed to soil deterioration and reduced orchard productivity. Therefore, the need for sustainable agricultural practices that can mitigate the effects of salinity on plants has become apparent. Among these techniques is the use of Anti-salinity, which reduce the accumulation of harmful ions by breaking the bond between sodium and soil particles and replacing it with calcium. This leads to improved physical and chemical soil properties and, consequently, increased fruit yield (5).

Soil is a fundamental natural resource for feeding the growing global population and is essential for achieving most of the Sustainable Development Goals. Fertilizer application models have evolved, particularly the "enrichment" technique, which involves loading NPK nano-fertilizers onto organic fertilizer. This combination offers numerous advantages for both soil and plant health due

Materials and Methods

The field experiment was conducted in a field belonging to the College of Agriculture, University of Diyala, located at longitude 44° 45' East and latitude 33° 17' 41" North. The study targeted a local sour orange variety (*Citrus aurantium* L.) grafted onto American sour orange rootstock aged one year and four months, over a period of approximately one year until 2025. The aim was to evaluate the effect of Anti-salinity and enriching organic fertilizer with nano-NPK fertilizer on the qualitative traits and vegetative growth of seedlings and to address

to its high efficiency, the small size of the nano-fertilizer particles, and the reduction of the negative effects of traditional inorganic fertilizers. It also increases organic carbon, improves long-term fruit quality, and mitigates salinity. (9)

Sour orange (*Citrus aurantium* L.) is one of the oldest citrus species, also known as bitter orange or papyrus orange. This tree is characterized by its strongly aromatic leaves and is one of the most widespread rootstocks thanks to its deep, strong roots, which result in grafted varieties exhibiting excellent traits (6) and greater disease resistance. This study aims to:

1. Investigate the effect of adding a Anti-salinity on improving the traits of sour orange.
2. Investigate the effect of enriching organic fertilizer with NPK nano-fertilizer on improving sour orange growth.
3. Studying the Effect of the Interaction Between Anti-salinity and Nano-Enriched Organic Fertilizer on Modifying and Developing Plants

the salinity stress to which the seedlings are exposed.

This experiment was conducted to study the effect of different levels of organic fertilizer and nano-NPK compound in conjunction with different levels of Anti-salinity on plant growth.

First: Fertilization Levels

1. Factor 1 (control): No addition, denoted as O1

2. Factor 2 (Sheep manure at 5% by volume), denoted as O2

3. Factor 3 (Enriching fertilizer Sheep 5% + 5 kg.ha⁻¹ compound nano-fertilizer (O3)

4. The fourth factor: Compound nano-fertilizer (5 kg.ha⁻¹) (O4)

Second: Salinity control. The salinity control levels were the main treatments and included three levels:

control treatment (W1)

10 mL.L⁻¹ per seedling (W2)

20 mL.L⁻¹ per seedling (W3)

Addition was done in three applications (at planting, 45 days after the first application, and 90 days after the first application).

Studies traits:

Leaf nitrogen content (%): Total nitrogen was estimated using the modified Kjeldahl method. The fifth leaf sample was taken from each main branch, air-dried, and then placed in an electric oven at 70°C until The weight was kept constant, and then the samples were ground using an electric mill. 0.2 g was taken and digested using 4 ml of concentrated sulfuric acid per sample and 1 ml of perchloric acid. The distillation process was then carried out, and the ammonia was received in boric acid, according to the Kjeldal method described by(3)and cited in(2). The ratio was calculated according to the equation:

N%=

$$\frac{\text{Volume of acid consumed in titration} \times \text{Normality of acid} \times 14 \times \text{Average volume}}{\text{Volume of sample taken for distillation} \times \text{Weight of digested sample}} \times 100$$

Phosphorus content in leaves (%): Estimated using ammonium molybdate and ascorbic

acid with a spectrophotometer at a wavelength of 620 nm.

Potassium content in leaves (%): Potassium was estimated using a flame photometer according to Haynes (1980). Figure 1 shows the standard solutions for K.

Proline content in leaves (mg.g dry weight): According to the method of(1), extraction was performed using 10 ml of 3% sulfosalicylic acid on a fresh sample of 5 g of sour orange leaves. The sample was crushed, filtered, and 2 ml of the filtrate was taken. 2 ml of ninhydrin acid reagent and 2 ml of glacial acetic acid were added. The sample and reagent were heated in a water bath for one hour, then cooled. After cooling, 4 ml of toluene was added, and the tube was shaken for 20 seconds and left at room temperature to allow the toluene layer and the proline it carries to separate from the mixture. 1 ml of this surface layer was taken, and the degree of absorption was determined using a spectrometer. The spectrophotometer was used at 520 nm. The proline content was then estimated using the following equation:

$$\text{Proline mg.g}^{-1} \text{ fresh weight} = (\text{Reading} \times 4 \times 5) / (\text{Weight of plant sample g}) \times 1.74$$

Total chlorophyll content (mg/100g ≤ 100g fresh weight): Estimated by randomly taking three leaf samples. The average was then used in each experimental unit using a SPAD-502 chlorophyll meter and measured in SPAD units.

Some traits: sour orange

average of increase in plant height (cm): The distance from the soil surface to the growing tip was measured using a metric tape measure, and the increase was calculated as the difference between the initial, secondary, and final readings

Discussion and Results

Percentage of nitrogen concentrations in leaves

The results in Table 4 show the effect of adding Anti-salinity and enriching organic

fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant

height before application. Regarding fertilizer, the results showed no significant effect of the salt-enriching treatment. The mean values of treatments W1, W2, and W3 were very close, registering 1.0308%, 1.0275%, and 0.9942%, respectively, showing no significant difference between them. Similarly, the effect of adding organic fertilizer with NPK nano-compound fertilizer did not show any significant differences between the mean

values of treatments O1, O2, O3, and O4, which were 0.9422%, 1.0756%, 1.0600%, and 0.9922%. The results also indicated no significant effect of the interaction on this trait, as the values of the interaction treatments were very close, with the highest value recorded for the interaction treatment W1O2 at 1.2267%, while the lowest value was recorded for the interaction treatment W3O4 at 0.9933%.

Table 9. Effect of adding a salinizing agent and enriching organic fertilizer with NPK nano-compound fertilizer and their interaction on nitrogen concentrations in leaves before fertilization (%)

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
1.0308 A	0.9800 a	1.0300 a	1.2267 a	0.8867 a	W1
1.0275 A	1.0033 a	1.0533 a	1.1200 a	0.9333 a	W2
0.9942 A	0.9933 a	1.0300 a	0.9467 a	1.0067 a	W3
	0.9922 A	1.0600 A	1.0756 A	0.9422 A	average Organic fertilizer and nano-compound fertilizer NPK

Percentage of Nitrogen Concentrations in Leaves

The results in Table 4 show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant height after fertilizer application. The results showed no significant effect of the Anti-salinity treatments, as the average values of treatments W1, W2, and W3 were very close, recording 1.0308%, 1.0275%, and 0.9942%,

respectively, without any significant difference between them. However, the effect of adding organic fertilizer with NPK nano-compound fertilizer showed that treatment O3 was excelled, gave 3.4833%, followed by treatment O4 at 2.7533%, and then treatment O2 at 2.4933%, compared to treatment O1 at 1.4522 %, representing an increase of 139.86%. The results also demonstrated a

significant interaction effect on this trait, with treatment W3O3 exhibiting the highest value. 3.5367%, while the lowest value was

observed with the W2O1 treatment, which reached 1.3533%, representing an increase of 161.33%.

Table: Effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and their interaction on nitrogen levels in plant leaves after fertilizer application.

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
2.48667 A	2.7467 B	3.4400 a	2.3100 B	1.4500 C	W1
2.53083 A	2.7200 B	3.4733 a	2.5767 B	1.3533 c	W2
2.61917 A	2.7933 B	3.5367 a	2.5933 B	1.5533 c	W3
	2.7533 B	3.4833 A	2.4933 B	1.4522 C	average Organic fertilizer and nano-compound fertilizer NPK

Percentage of Phosphorus Concentrations in Leaves

The results in the table show the effect of adding Anti-salinity control and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on phosphorus concentrations in leaves before fertilization. The results showed no significant effect on the averages of the salinity control treatments, where treatments W1, W2, and W3 were similar, with averages of 0.10750, 0.10500, and 0.08333%, respectively. As for the effect of adding organic fertilizer with NPK nano-compound

fertilizer, the results showed no significant effect on its own, as the averages of treatments O1, O2, O3, and O4 were similar, with values of 0.095%, 0.106%, 0.093%, and 0.095%, respectively. The results also showed no significant interaction effect on this trait. The W1O2 treatment showed the highest value at 0.12333%, while the lowest values were observed with the W3O1 and W3O3 treatments, which yielded 0.08000%.

Table: Effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on the percentage of phosphorus in plant leaves before fertilization (%)

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
0.10750 A	0.08333 a	0.11000 a	0.12333 a	0.11333 A	W1
0.10500 A	0.12333 a	0.09000 a	0.11333 a	0.09333 A	W2
0.08333 A	0.09000 a	0.08000 a	0.08333 a	0.08000 A	W3
	0.09556 A	0.09333 A	0.10667 A	0.09556 A	average Organic fertilizer and nano-compound fertilizer NPK

Percentage of Phosphorus in Leaves After the Experiment

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on phosphorus concentrations in leaves after fertilization. The results showed a significant effect when adding the Anti-salinity, as treatments W2 and W3, which reached the highest averages of 0.6575028% and 0.64667% respectively, were excelled on the control treatment W1, which reached 0.52083%, with increases of 26.24% and 24.16% respectively. As for the effect of

adding organic fertilizer with NPK nano-compound fertilizer, the results showed the excellency of treatment W3, which gave 0.86444%, compared to the control treatment O1, which reached 0.20444%, with an increase of 322.83%. The results also showed a significant interaction effect on this trait, as treatment W3O3 was excelled, giving the highest value of 0.96000%, while the control treatment O1 was less effective. The lowest value was observed with the W1O1 treatment, reaching 0.16667%, representing an increase of 475.98%.

Table: Effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and their interaction, on phosphorus concentrations in plant leaves after fertilizer application.

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
0.52083 B	0.63667 cd	0.74667 cb	0.53333 d	0.16667 e	W1
0.64667 A	0.73667 cb	0.88667 ab	0.72333 cb	0.24000 E	W2
0.65750 A	0.78667 cb	0.96000 a	0.67667 cd	0.20667 E	W3
	0.72000 B	0.86444 A	0.64444 B	0.20444 C	average Organic fertilizer and nano-compound fertilizer NPK

Percentage of Potassium Concentrations in Leaves Before Fertilization

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on potassium concentrations in sour orange leaves. The results showed a significant effect when adding Anti-salinity, where treatment W3, which reached the highest average of 1.43000%, was excelled to treatment W2, which recorded the lowest value at 1.17000%, representing an increase of 22.22%. Treatment W1 followed, recording an average of 1.31000%. As for the effect of adding

organic fertilizer with NPK nano-compound fertilizer, the results showed no significant differences between the treatments, although treatment O2 was excelled, giving 1.36000%, compared to treatment O3, which recorded the lowest average at 1.20000%, representing an increase of 1.22%. The results also showed a significant interaction effect on this trait, with the W3O1 treatment gave the highest value at 1.6067%, while the W2O1 treatment had the lowest value at 1.0333%, representing a 55.49% increase.

Table: Effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and their interaction, on potassium concentrations in plant leaves before fertilizer application (%)

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
1.31000 AB	1.3767 cab	1.1400 cb	1.4400 ab	1.2833 Cab	W1
1.17000 B	1.2600 cab	1.2267 cab	1.1600 cb	1.0333 C	W2
1.43000 A	1.4000 cab	1.2333 cab	1.4800 ab	1.6067 A	W3
	1.34556 A	1.20000 A	1.36000 A	1.30778 A	average Organic fertilizer and nano-compound fertilizer NPK

Percentage of potassium concentrations in leaves after the end of the study.

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with nano-compound fertilizer NPK and the interaction between them on potassium concentrations in sour orange leaves. The results showed a significant effect when adding the Anti-salinity, as the two treatments W3, which reached the highest average of 3.0758%, were excelled to the control treatment W1, which recorded the lowest average of 2.8783%, with an increase of 6.86%, followed by the treatment W2, which recorded an average of 2.9758%. The effect of adding organic fertilizer with NPK nano-composite fertilizer showed clear and

significant differences between the treatments. Treatment O3 was the most effective, gave the highest average of 1.6467%, representing an increase of 196.89%. This was followed by treatment O4 at 2.8733%, and then treatment O2 at 2.4978%, with increases of 74.49% and 51.69%, respectively, compared to the control treatment O1. The results also demonstrated a significant interaction effect on this trait. Treatment W3O3 exhibited the highest value at 5.1833%, while treatment W3O1 had the lowest value at 1.4600%, representing an increase of 255.02%.

Table: Effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-composite fertilizer, and their interaction, on potassium concentrations in plant leaves after the experiment (%)

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
2.8783 A	2.8733 b	4.7300 a	2.3133 dbc	1.5967 De	W1
2.9758 A	2.7967 b	4.7533 a	2.4700 bc	1.8833 Dec	W2
3.0758 A	2.9500 b	5.1833 a	2.7100 b	1.4600 E	W3
	2.8733 B	4.8889 A	2.4978 B	1.6467 C	average Organic fertilizer and nano-compound fertilizer NPK

Plant Height (cm) Before Fertilization

Table 4 shows the results of adding the salinity control treatment and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant height before fertilizer application. The results showed no significant effect of the salinity control treatment, as the mean values of treatments W1, W2, and W3 were very similar and did not differ significantly from each other. However, the effect of adding organic fertilizer with NPK nano-compound

fertilizer showed that treatments O1 and O4 were excelled, with heights of 113.556 and 113.22 cm, respectively, compared to the control treatment O2 and O3, which reached 108.000 and 109.778 cm. The results also showed a significant interaction effect on this trait, with treatment W2O4 giving the highest value at 132.33 cm, while the lowest value was in the control treatment W2O3 at 83.00 cm, representing an increase of 59.43%.

Table 4. Effect Adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, affects plant height (first stage) cm

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
115.417 A	109.67 cab	115.33 Ab	114.00 cab	122.67 Ab	W1
100.333 A	97.67 cb	83.00 C	100.67 cab	120.00	W2
117.667 A	132.33 A	125.67 Ab	114.67 Ab	98.00 Cb	W3
	113.222 A	108.000 A	109.778 A	113.556 A	average Organic fertilizer and nano-compound fertilizer NPK

Plant Height (cm) 45 Days After Fertilization

The results in Table 5 show the effect of adding the Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant height after fertilizer application. The results showed a significant effect of the Anti-salinity treatments, with treatments W1 and W3 achieving the highest averages of 141.167 and 142.667 cm, respectively, compared to treatment W2, which recorded the lowest value of 126.250 cm, representing a non-significant increase of 12.99%. Regarding the effect of adding organic fertilizer with NPK

nano-compound fertilizer, the results showed that treatment O3 achieved the highest height of 143.444 cm, compared to treatment O1, which recorded the lowest value of 131.556 cm, representing an increase of 9.04%. However, the results also showed a significant interaction effect on this trait, with treatment W3O3 achieving the highest value of 162.00 cm, compared to treatment O1. The interaction W3O1, which recorded the lowest value at 119.00 cm, with an increase of 36.13%, is shown in Table 5.

Table 5: effect of adding the Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant height (second period) cm.

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
141.167 A	136.33 ab	147.67 ab	143.33 ab	137.33 ab	W1
126.250 A	120.33 B	120.67 b	125.67 b	138.33 ab	W2
142.667 A	147.33 Ab	162.00 a	142.33 ab	119.00 b	W3
	134.667 A	143.444 A	137.111 A	131.556 A	average Organic fertilizer and nano-compound fertilizer NPK

Plant Height (cm) After Study Completion

The results in Table 6 show the effect of adding the salinity control treatment and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on plant height before fertilizer application. The results showed no significant effect of the salinity control treatment, as the averages of treatments W1, W2, and W3 were similar. W3 recorded the highest value at 220.750 cm, while treatment W2 recorded the lowest value at 202.333 cm. As for the effect of adding organic fertilizer with NPK nano-compound fertilizer, the results showed the excellency of treatment O3, which gave the

highest value at 226.44 cm, compared to treatment O1, which recorded the lowest value at 199.000 cm, representing an increase of 13.79%. The results also showed a significant interaction effect on this trait, as treatment W3O3 was excelled, giving the highest value at 247.67 cm, compared to the interaction treatment W3O1, which recorded the lowest value at 184.33 cm. Table 6 shows the effect of adding the Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and their interaction, on plant height (third period) in cm, with an increase of 34.36%.

Table 6. Effect of adding Anti-salinity, enriching organic fertilizer with NPK nano-compound fertilizer, and their interaction on plant height (third period) cm

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
214.500 A	205.67 cdb	230.00 ab	215.33 cdb	207.00 Cdb	W1
202.333 A	196.33 cd	201.67 cdb	205.67 cdb	205.67 Cdb	W2
220.750 A	231.67 Ab	247.67 a	219.33 cab	184.33 D	W3
	211.222 AB	226.44 A	213.444 AB	199.000 B	average Organic fertilizer and nano-compound fertilizer NPK

Total Chlorophyll Concentrations in Leaves

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on total chlorophyll concentrations in sour orange seedling leaves. The results showed no significant effect on the average Anti-salinity, as the values for treatments W1, W2, and W3 were similar, gave 45.833, 42.917, and 47.292 mg g⁻¹, respectively. As for the effect of the average addition of organic fertilizer and NPK nano-compound fertilizer, the results showed no significant difference in the average values

of treatments O1, O2, O3, and O4, which recorded 42.456, 45.411, 48.144, and 45.378 mg g⁻¹, respectively. The results also showed a significant interaction effect on this trait. The W3O3 treatment outperformed the W2O1 treatment, gave the highest value of 49.867 mg g⁻¹, representing a 47.10029% increase compared to the W2O1 treatment (33.900 mg g⁻¹). However, this difference was not significant compared to the W2O3 treatment, which yielded a value of 48.933 mg g⁻¹.

Table: Effect of adding the Anti-salinity and enriching organic fertilizer (NPK nano-compound fertilizer) and their interaction on total chlorophyll in plant leaves before fertilizer application (mg g^{-1}).

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
45.833 A	46.000 ab	45.633 ab	43.767 ab	47.933 a	W1
42.917 A	46.000 ab	48.933 a	42.833 ab	33.900 b	W2
47.292 A	44.133 ab	49.867 a	49.633 a	45.533 ab	W3
	45.378 A	48.144 A	45.411 A	42.456 A	average Organic fertilizer and nano-compound fertilizer NPK

Total Chlorophyll Concentrations in Leaves

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on total chlorophyll concentrations in sour orange seedling leaves. The results showed no significant effect of adding Anti-salinity, as the values for treatments W1, W2, and W3 were similar, gave 55.983, 55.300, and 56.542 mg g^{-1} , respectively. As for the effect of the average application of organic fertilizer and NPK nano-compound fertilizer, the results showed no significant difference between the

averages of treatments O1, O2, O3, and O4, which recorded 56.444, 58.867, 55.156, and 53.300 mg g^{-1} , respectively. The results also showed a significant interaction effect on this trait. The W3O3 treatment was excelled, gave the highest value of 59.867 mg g^{-1} , representing a 21.9285% increase over the W2O3 treatment, which had the lowest value of 49.100 mg g^{-1} . However, it did not differ significantly from the W1O3 treatment, which yielded a value of 59.033 mg g^{-1} .

Table: Effect of adding the Anti-salinity and enriching organic fertilizer (NPK nano-compound fertilizer) and their interaction on total chlorophyll in plant leaves after the experiment (mg g^{-1}).

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
55.983 A	53.267 A	56.467 a	61.333 a	52.400 a	W1
55.300 A	56.233 A	49.100 a	58.400 a	57.467 a	W2
56.542 A	50.400 A	59.867 a	56.867 a	59.033 a	W3
	53.300 A	55.156 A	58.867 A	56.444 A	average Organic fertilizer and nano-compound fertilizer NPK

Proline Content in Leaves (mg.g^{-1} fresh weight)

The results in the table show the effect of adding Anti-salinity and enriching organic fertilizer with NPK nano-compound fertilizer, and the interaction between them, on the concentrations of the amino acid proline (mg.g^{-1} fresh weight) in leaves. The results showed no significant effect when adding the Anti-salinity, as treatments W1, W2, and W3 were similar, with averages of 1.50583, 1.50250, and 1.50750 mg.g^{-1} , respectively. Treatment W3 had the highest average of 1.505750 mg.g^{-1} compared to the control treatment W2, which had an average of 1.505250, representing an increase of 0.33%. As for the effect of adding organic fertilizer with NPK nano-compound fertilizer, the results showed the excellency of treatment

O2, which yielded 1.51444 mg.g^{-1} , which did not differ significantly from the control treatment W2. Treatments O3 and O4 recorded concentrations of 1.51000 and 1.50444 mg.g^{-1} , respectively, while the control treatment O1 decreased to 1.49222 mg.g^{-1} , representing an increase of 1.48%. The results also showed no significant interaction effect on this trait, although the W2O2 interaction treatment showed a relatively higher concentration of 1.52667 mg.g^{-1} compared to the W2O1 interaction treatment, which had the lowest concentration of 1.48333 mg.g^{-1} , representing an increase of 2.92%.

Table: Effect of adding Anti-salinity and enriching organic fertilizer (NPK nano-compound fertilizer) and their interaction on the concentration of the amino acid proline (mg.g⁻¹ fresh weight) in leaves after fertilizer application.

Anti-salinity averages	Organic fertilizer and nano-compound fertilizer NPK				Anti-salinity
	O4	O3	O2	O1	
1.50583 A	1.51000 A	1.51667 a	1.50667 a	1.49000 a	W1
1.50250 A	1.49333 A	1.50667 a	1.52667 a	1.48333 a	W2
1.50750 A	1.51000 A	1.50667 a	1.51000 a	1.50333 a	W3
	1.50444 A	1.51000 A	1.51444 A	1.49222 A	average Organic fertilizer and nano-compound fertilizer NPK

Conclusions

1. Fertilization with enriching organic fertilizer using a nano-compound fertilizer at an O3 kg ha⁻¹ level provided adequate amounts of nitrogen, phosphorus, and potassium during the growth stages of sour orange plants.

2. Adding organic fertilizer acid and NPK nano-fertilizer at O2 and O4 kg ha⁻¹ levels increased the availability of nitrogen, phosphorus, and potassium at two stages of plant growth. This was reflected in their Recommendations

Based on the results of this study and under its conditions, we can recommend the following:

1. Add Anti-salinity at a level of 20°C to maintain the availability of nutrients (N, P, and K) in the plant.

concentrations during vegetative growth, leading to increased vegetative growth and overall yield.

3. The interaction between organic fertilizer and NPK nano-compound fertilizer had significant and clear effects on most of the studied traits of sour orange, such as chlorophyll and proline. These traits, in turn, enhance plant productivity.

2. Add organic fertilizer enriched with NPK nano-fertilizer, as this is important for increasing fertilizer efficiency and productivity.

3. Encourage the use of nano-composite fertilizers with organic matter and reduce the use of nano-composite fertilizers alone. This can be achieved by conducting further studies

on adding Anti-salinity to saline soils in general, as this is of great importance in sustainable agriculture. Humic materials can

reduce the need for nano-composite fertilizers, thus reducing agricultural inputs.

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