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EFFECT OF FOLIAR SPRAY WITH SOME CHEMICAL SUBSTANCES ON GROWTH, YIELD AND REDUCING FRUIT SUNBURN OF MURCOTT MANDARIN TREES

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ABSTRACT: This study was conducted on 4-year-old Murcott mandarin (*Citrus reticulata* L.) trees that were budded on Volkamer lemon (*Citrus volkameriana* L.) trees grown in sandy soil at a distance of 3 × 6 meters under drip irrigation in a private citrus orchard in the Wady El-Mollak region of the Sharkia Governorate, Egypt. The study was conducted over the course of two consecutive seasons, 2020 and 2021. Nine treatments were applied in this experiment as follow: T1-Control (water spray), T2-4% kaolin ($Al_4Si_4O_{10}$ $(OH)_8$), T3-4% potassium silicate (K_2SiO_3), T4- 4% calcium carbonate ($CaCO_3$), T5-2 cm/l metalusite, T6-1% titanium oxide nano particles (Ti_2O_3 NPs), T7-4% titanium oxide normal particles (Ti_2O_3), T8-1% zinc oxide nano particles (ZnO NPs) and T9-4% zinc oxide normal particles (ZnO). The results indicated that all treatments increased total yield per tree (kg) and per feddan (ton) and fruit weight (g) and also fruits number/tree compared to control treatment. The highest total yield was gained by trees sprayed with Metalusite, titanium oxide, zinc oxide in two forms nano and normal without differences between them in the two seasons. The trees sprayed with Metalusite or titanium oxide nano particles gained least number and percentages of sunburned fruits/ tree in both seasons, followed by trees sprayed with titanium oxide normal particles. The longest branch was recorded for trees sprayed with potassium silicate, Metalusite, titanium oxide nano and normal particles in the two seasons. The thinner branches were for control trees in the both seasons. The highest number of leaves per branch were gained for trees sprayed with titanium oxide nano particles, while, lowest number of leaves/branch were for trees sprayed with kaolin in the two seasons. The largest leaf area was recorded for trees sprayed by Metalusite and zinc oxide nano or normal particles followed by trees sprayed with titanium oxide nano or normal particles, while, the smallest leaf area was for control trees in the two seasons. The uppermost values of leaf fresh and dry weights (g) were for trees sprayed by titanium oxide or zinc oxide in nano or normal particles followed by trees sprayed with Metalusite in the both seasons. All tested trees gave leaves contained higher total chlorophyll insignificant differences between them compared to the untreated control in the two seasons.

Key words: Murcott mandarin, titanium oxide, Metalusite, kaolin, calcium carbonate, fruit sunburned, yield.

INTRODUCTION

One of the most significant fruit trees in the world, citrus is the most popular crop in Egypt. During the past few decades, Egypt's citrus cultivation area has grown significantly, reaching approximately 469912 feddan with 429778.6 fed., fruiting area and producing about 4388325 tons with an average of 10.21 tons/fad., (**SMA, 2020**), split between the new, reclaimed soil and the old soil at a rate of 55.73% and 44.27%, respectively. According to FAO estimates from 2017, the combined fruiting areas of tangerine and mandarin varieties span 109609.5 fed., yielding an average of 9.48 tons/fed., or approximately 1038753 tons, or 25.5% of the world's citrus crop. Murcott trees have an upright growth style and are moderately sized and vigorous. The fruit

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usually hangs close to the tree's exterior. When the fruit load on the tree is moderate, the fruit size is medium. When fully grown, the flesh is a rich orange color, with a yellowish-orange peel. Its thin, silky rind peels quite easily. Seeds per fruit about 10-20 as well as commercial harvest season is through January to March **(Futch and Jackson, 2003)**. Mandarin fruits are Egypt's second most popular export variety, after orange fruits. One of the common mandarins is Murcott (*Citrus reticulate* L.). The Murcott Tangerine features a thin, smooth, and easy-to-peel skin, revealing juicy. Its vibrant orange color and luscious texture make it a visually appealing fruit. The fruit is mostly borne terminally, where it is susceptible to wind, sunburn, and frost damage. The trees are strong, bushy, and have willowy branches **(James, 1990)**.

In agricultural products grown in arid and semi-arid environments, sunburn is a major concern that can result in losses of up to 40–60% in some years. When fruits are exposed to hot air and UV radiation from the sun, their surfaces overheat and result in sunburn. Because of Egypt's high summer temperatures and low relative humidity, sunburn in mandarin oranges causes growers significant annual financial losses, particularly when reclaiming new ground. The main cause of damage is ultraviolet (UV) radiation, which is more prevalent at higher elevations. Sunburn and cell death are mostly caused by excess energy absorption. Climate, cultivars, hormones, nutrition, and soil moisture all affect the frequency and severity of sunburns (**Schrader *et al*., 2003**).

Warmer temperatures brought on by high temperatures and intense sunshine will induce an increase in fruit sunburn as a result of climate change. Because solar radiation fluctuates so much, it is impossible to pinpoint an exact air temperature that causes sunburns. Fruit sunburn was produced between 11 a.m. and 3 p.m. at the highest solar radiation, with air temperatures between 32 and 35 degrees Celsius and intense sunlight (**Park *et al*., 2022**). Damage from sunburn, which can range from 0.9 to 19.13% for various types (**Singh *et al*., 2012**). According to **Schrader *et al.* (2001) and Racsko *et al*. (2005)**, sunburn has an impact on fruit quality.

Different applications of kaolin clay (1.3%, 1.5%, 1.6%, 1.8%, 2%, 2.2%, 2.4% and 2.7 %) are designed to lessen fruit sunburn of various kinds (**Itmec *et al*., 2020**). Because of its capacity to alter the plant canopy's microenvironment due to the particles' reflective quality, kaolin-based particle films can lessen insect, heat, and UV stress in horticultural crops (**Glenn, 2012**). The average net photosynthesis, stomatal conductance, and transpiration rate of mango leaves treated with kaolin were higher than those of untreated and bentonite-treated leaves (**Chamchaiyaporn *et al*., 2013**).

Zinc (Zn) is a vital micronutrient for plants. Fruit cracking, sunburn, and color loss are managed using a variety of horticultural practices, such as spraying micronutrients like zinc during the fruit's development cycle (**Saei *et al*., 2014**). Because zinc sulfate has metabolic effects on transport and water uptake, applying it as a foliar spray reduced fruit cracking and increased yield (**Sadeghzadeh, 2013**).

The plant may obtain all the silicon and potassium it needs for healthy growth from potassium silicate, which is 100% accessible. Both the plant's outward defenses and internal mechanisms are strengthened by potassium silicate. A family of inorganic chemicals is known as potassium silicates. $K_2SiO_3$is the formula for the most prevalent potassium silicate; samples of this silicate have varied water contents. According to **Lagally *et al.* (2005)**, these are colorless liquids or white solids.

Plant development is thought to benefit from the element titanium (Ti). Ti application seems to raise concentrations of some important macro- and micronutrient elements. Ti chelates have been shown through experiments to stimulate the activity of certain enzymes and to aid in the growth of young plants (**Botia *et al*., 2002**). When subjected to prolonged illumination, titanium nanoparticles prevent the green plastid from aging by improving light absorption and the conversion of photovoltaic energy to electrical and chemical energy. Additionally, by enhancing nitrogen metabolism and cell growth, titanium nanoparticles increase plant weight (**Hong *et al*., 2005**).

The primary component of agricultural lime, calcium carbonate (CaCO3), is created when calcium ions in hard water combine with carbonate ions to form limescale (**Strumińska-**

Parulska, 2015). Reduced softening of fresh fruit has been achieved with smaller amounts of calcium carbonate. Due to its ability to promote the development of lignin and cellulose as well as the translocation and formation of carbohydrates, high calcium content in fruit can increase fruit retention, sustain membrane permeability, and slow down the ripening process during storage (**Aguayo *et al*., 2008**). Foliar application of $ZnSO_4$ and $CaCO_3$ (each at 3% and 4%) significantly increased the fruit diameter, fruit weight, TSS, juice percentage, total antioxidants, ascorbic acid, total phenolics, flavonoids and carotenoids contents. $ZnSO_4$ at 4% gave the best results for Kinnow fruit yield and quality **(Zaman *et al*., 2019)**.

Throughout the three years of the study, there were no statistically significant variations in the nut weights, grades, or hazelnut yield with foliar spray multi mineral Metalosite as compared to the untreated control (**Olsen and Cacka, 2009**). Conversely, foliar Ca-Metalusite treatments increased citrus yield by about 20% on average compared to trees that did not get any Ca supplementation, according to **Nelson *et al.* (2012)**.

This study aims to explore the effects of several chemical compounds (such as kaolin, potassium silicate, Metalusite, titanium, calcium carbonate and zinc oxide as normal and nano particles) on the growth and yield of Murcott mandarin trees, as well as their ability to reduce fruit sunburn.

MATERIALS AND METHODS

In a private citrus orchard located in the Wady El-Mollak region of Sharkia Governorate, Egypt, four-year-old Murcott mandarin (*Citrus reticulata*) trees that were budded on Volkamer lemons (*Citrus volkameriana* L.) grown in sandy soil at a distance of three × six meters under drip irrigation were the subjects of this study, which was conducted over the course of two consecutive seasons in 2020 and 2021. The following nine foliar spray treatments were used in the experiment:

T1 - Control (water spray)

T2 - 4% kaolin ($Al4Si_4O_{10}$ $(OH)_8$);

T3 - 4% potassium silicate at (K_2SiO_3);

T4 - 4% calcium carbonate ($CaCO_3$);

T5 – 2 cm/l metalusite Mult;

T6- 1%T titanium oxide nano particles (Ti_2O_3 NPs);

T7 - 4% titanium oxide normal particles (Ti_2O_3);

T8 - 1% zinc oxide nano particles (ZnO NPs) and

T9 - 4% zinc oxide normal particles (ZnO).

Metalusite Mult chelated form contained of 1% Ca +1% Mg + 0.5 % Fe + 0.5% Zn + 0.5% Mn + 0.25 % Cu + 0.1% Mol + 12% amino acid.

In both seasons, the trees sprayed four times on the first of each month, from May to August. In order to ascertain the fruit's physical and chemical properties, the gathered fruits from both seasons were sent right away to the fruit laboratory of the Horticulture Department, College of Agriculture, Zagazig University. The following criteria were used to assess the treatments:

Total yield and its components

1. Total yield per tree (kg) and per feddan (ton).
2. Fruits number per branch and per tree.
3. Fruit weight (g) and size (cm^3).
4. Number of sunburned fruits/tree and percentage of sunburned fruits/tree (%).

Vegetative growth

1. Leaves number/ branch.
2. Branch length (cm) and thickness (mm).
3. Leaves number per branch.
4. Leaf area (cm^2): Average leaf surface area (cm^2) according to the equation reported by **Redday *et al*. (1981)** where:

Leaf area = blade width x blade length x 0.62

5. Leaf fresh and dry weights (g). Average leaf fresh and dry weights (g) twenty leaves / replicate before and by weighing after being dried at 70ºC until constant weight.
6. Leaf water content (%) was calculated as follows:

Leaf water content (%) = leaf fresh weight (g) – leaf dry weight (g) ÷ leaf fresh weight (g) x100

7. Leaf total chlorophyll content: Leaf total chlorophyll content was determined by Chlorophyll Meter TYS-A (2033112619) (CHL) SPAD

Statistical Analysis

Snedecor and Cochran (1989) stated that the one-way analysis of variance (ANOVA) technique was used to test the acquired data. Three replications of each treatment were included in the randomized full block design. The **Duncan (1958)** test was used to segregate and compare the treatment means at the 0.05 level of significance.

RESULTS

Total yield and its Components

Total yield per tree (kg) and per feddan (ton)

Table 1 shows that over the two seasons, there was a substantial difference in the fruit output of Murcott mandarin per tree and per feddan (ton) due to the studied treatments. However, the highest total yield was gained by trees sprayed by Metalusite (59.84 and 47.10 Kg/tree and 14.36 and 11.30 ton/fed.), titanium oxide nano (61.86 and 43.68 Kg/tree and 14.85 and 10.48 ton/fed.), titanium oxide normal particles (63.92 and 40.84 Kg/tree and15.34 and9.80 ton/fed.), zinc oxide nano (67.36 and 46.92 Kg/tree and16.17 and 11.26 ton/fed.) and zinc oxide normal (60.78 and 38.63 Kg/tree and 14.59 and 9.27 ton/fed.) in 1^{st} and 2^{nd} seasons, respectively with non-significant differences between them. Furthermore, the control trees (sprayed with water) gave the lowest yield/tree (kg) and yield/ fed. (ton) in the two consecutive seasons, respectively. Intermediate yields were obtained with the other tested treatments.

Number of fruits per branch and per tree

As shown in Table 2 the number of fruits per tree and per branch were significantly affected by the tested treatments. The treatments of titanium oxide nano and normal particles and zinc oxide nano recorded highest fruits number / tree (375 and 260, 420 and 263.33 and 394.33 and 293.33) in 1^{st} and 2^{nd} seasons, respectively, without significant differences between them, as well as the treatment of Metalusite in the second season only. The treatments of potassium silicate and calcium carbonate gave the least number of fruits/trees in the first season only, while, the treatments of control and kaolin gave the least number of fruits/trees in the second season and without significant differences between them. The other tested fertilization treatments produced intermediate fruit No./ tree.

Tabulated data demonstrate that, the lowest fruits number per branch were from treatments of titanium oxide normal and zinc oxide normal particles in the first season and from Metalusite treatment the second season. The other tested treatments produced higher values of fruits number per branch in the both seasons.

Number and percentage of sunburned fruits per tree

The data in Table 3 unequivocally demonstrate that the treatments of foliar spraying in both seasons had a significant impact on the quantity and percentage of burnt fruits per tree. The trees that were sprayed with calcium carbonate at 4% or zinc oxide nanoparticles at 1% (28.33 and 32.67, 33.33 and 32.00, and 37.33 and 30.00) in the first and second seasons, respectively, as well as kaolin at 4% and potassium silicate at 4% in the first season, as well as zinc oxide normal at 4% in the second season, had the highest number of sunburned fruits / trees. In the first and second seasons, plants sprayed with 1% titanium oxide nanoparticles had the fewest number of burnt fruits and/or trees (14.33 and 20.33, respectively).

In the first and second seasons, respectively, the trees sprayed with Metalusite at 2 cm/l or titanium oxide nanoparticles at 1% gained the least amount of sunburned fruits/tree (4.47 and 7.22 and 3.82 and 7.82%), while the trees sprayed with zinc oxide normal particles at 4% (4.43%) in the first season and the trees sprayed with titanium oxide normal particles at 4% (5.40 and 8.99 %) in the second season, gained the most, according to the current study.

Fruit weight and size

The weight of Murcott mandarin fruits was clearly impacted by the treatments under investigation throughout the course of the two seasons, as Table 4 makes clear. In comparison with the control in both seasons, all foliar spray treatments-nano or regular particles-increased fruit

Table 1. Effect of some chemicals in nano or normal particles form on total yield per tree (kg) and per feddan (ton) of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Total yield/ tree (kg)		Total yield/ fed. (ton)	
	First season	Second season	First season	Second season
Control (spraying water)	49.98 cd	30.87 b	12.00 cd	7.41 c
Kaolin (Al4Si4O10 (OH) 8) at 4%	52.10 bcd	32.21 b	12.50 bcd	7.73 bc
Potassium silicate at (K2SiO3) 4%	50.79 bcd	32.37 b	12.19 bcd	7.77 bc
Calcium carbonate (CaCO3) at 4%	48.12 d	33.20 b	11.55 d	7.97 bc
Metalusite at 2 cm/l	59.84 abc	47.10 a	14.36 abc	11.30 a
Titanium oxide nano particles (Ti2O3 NPs) at 1%	61.86 ab	43.68 a	14.85 ab	10.48 a
Titanium oxide normal particles (Ti2O3) at 4%	63.92 a	40.84 ab	15.34 a	9.80 ab
Zinc oxide nano particles (ZnO NPs) at 1%	67.36 a	46.92 a	16.17 a	11.26 a
Zinc oxide normal particles (ZnO) at 4%	60.78 abc	38.63 ab	14.59 abc	9.27 abc

Table 2. Effect of some chemicals in nano or normal particles form on fruits number per branch and per tree of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Fruits number / branch		Fruits number / tree	
	First season	Second season	First season	Second season
Control (spraying water)	17.50 abc	19.17 ab	330.00 cd	195.67 c
Kaolin (Al4Si4O10 (OH) 8) at 4%	20.83 ab	18.33 ab	326.00 cd	199.33 c
Potassium silicate at (K2SiO3) 4%	21.67 a	20.67 a	311.33 d	210.00 bc
Calcium carbonate (CaCO3) at 4%	19.00 abc	20.00 ab	295.00 d	207.00 bc
Metalusite at 2 cm/l	19.67 ab	15.17 b	350.33 bcd	300.00 a
Titanium oxide nano particles (Ti2O3 NPs) at 1%	21.67 a	19.33 ab	375.00 abc	260.00 ab
Titanium oxide normal particles (Ti2O3) at 4%	16.67 bc	17.33 ab	420.00 a	263.33 ab
Zinc oxide nano particles (ZnO NPs) at 1%	18.33 abc	18.00 ab	394.33 ab	293.33 a
Zinc oxide normal particles (ZnO) at 4%	15.33 c	16.33 ab	353.67 bcd	231.67 bc

Table 3. Effect of some chemicals in nano or normal particles form on number and percentage sunburned fruits per tree of Murcott mandarin (2020 and 2021 seasons)

Treatments	Number of sunburned fruits/tree		Percentage of sunburned fruits/tree	
	First season	Second season	First season	Second season
Control (spraying water)	28.33 ab	32.67a	8.58 ab	16.70 a
Kaolin (Al4Si4O10 (OH) 8) at 4%	25.00 ab	22.00 b	7.67 ab	11.04 ab
Potassium silicate at (K2SiO3) 4%	32.00 a	21.33 c	10.28a	10.16 ab
Calcium carbonate (CaCO3) at 4%	33.33 a	32.00 a	11.30 a	15.46 a
Metalusite at 2 cm/l	15.67 c	21.67 bc	4.47 cd	7.22 d
Titanium oxide nano particles (Ti2O3 NPs) at 1%	14.33d	20.33 d	3.82 d	7.82 d
Titanium oxide normal particles (Ti2O3) at 4%	22.67b	23.67 b	5.40 bc	8.99bc
Zinc oxide nano particles (ZnO NPs) at 1%	37.33 a	30.00 a	9.47 ab	10.23 ab
Zinc oxide normal particles (ZnO) at 4%	15.67 c	32.67 a	4.43 d	14.10 a

Table 4. Effect of some chemicals in nano or normal particles form on fruit weight (g) and size (cm^3) of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Fruit weight (g)		Fruit size (cm^3)	
	First season	Second season	First season	Second season
Control (spraying water)	151.00 c	154.00 b	146.30 e	151.76 e
Kaolin (Al4Si4O10 (OH) 8) at 4%	159.33 abc	163.67 ab	173.00 b	163.00 bcd
Potassium silicate at (K2SiO3) 4%	162.67 abc	157.67 ab	164.33 c	162.75 bcd
Calcium carbonate (CaCO3) at 4%	163.00 abc	160.33 ab	179.22 a	159.89 cde
Metalusite at 2 cm/l	170.33 a	157.67 ab	168.33 bc	165.63 bc
Titanium oxide nano particles (Ti2O3 NPs) at 1%	165.33 ab	167.67 a	168.99 bc	169.40 ab
Titanium oxide normal particles (Ti2O3) at 4%	152.33 bc	155.33 ab	155.20 d	155.67 de
Zinc oxide nano particles (ZnO NPs) at 1%	170.67 a	160.00 ab	170.55 b	159.11 cde
Zinc oxide normal particles (ZnO) at 4%	172.00 a	167.00 ab	167.22 bc	174.22 a

weight. The first season alone saw a non-significant rise (152.33 g) in titanium oxide normal particles (Ti_2O_3) treated at 4% compared to the control (151.00 g).

The obtain results indicated that, the highest fruit size was recorded by spraying calcium carbonate ($CaCO_3$) at 4% (179.22 cm^3) in the first season, while in the second season was by spraying titanium oxide nano particles (Ti_2O_3 NPs) at 1% (169.40 cm^3) and also by spraying zinc oxide normal particles (ZnO) at 4% (174.22 cm^3). The lowest values of fruit size were from the control (146.30 and 151.76 cm^3) in the first and second seasons, respectively. The other tested treatments produced intermediate fruit size in both seasons.

Vegetative Growth

Branch length (cm):

As shown in Table 5, branch length (cm) was significantly affected by the tested treatments in the two seasons. However, the longest branch was recorded for trees sprayed with potassium silicate at 4% (155.00 and 173.33 cm), Metalusite at 2 cm/l (143.33 and 168.33 cm), titanium oxide nano particles at 1% (158.33 and 181.67 cm) and titanium oxide normal particles at 4% (148.33 and 168.33 cm) in the two seasons, respectively, and also control (156.67 cm) in the first season compared with other treatments. The shortest branch was recorded for trees sprayed with kaolin at 4% (126.67 and 148.33 cm) in the both seasons, respectively. The other tested treatments produced intermediate values of branch length.

Branch thickness (mm)

Statistical analysis indicated that, the effect of the studied treatments on branch thickness (mm) had significantly affected in the two seasons (Table 5). Branches of trees sprayed with titanium oxide nano particles at 1% showed the largest thickness (3.902 and 3.856 mm) in the two seasons, respectively, without significant differences with treatments of kaolin, potassium silicate, calcium carbonate, Metalusite and titanium oxide normal particles in the first season only. The thinner branches were for trees sprayed water (control) (3.490 and 3.374 mm) in the first season and second season, respectively. The other sprayed treatments produced intermediate values of branch thickness.

Leaves number per branch

Data presented in Table 6, revealed that the tested treatments significantly affected leaves number per branch in the both seasons. The highest number of leaves per branch were gained for trees sprayed with titanium oxide nano particles at 1% (366.67 and 366.67) in the two seasons, respectively. The lowest number of leaves per branch were for trees sprayed with kaolin at 4% (220.00 and 246.67) in the first and second season, respectively.

Leaf area (cm^2)

It is clear from Table 6 that the tested treatments significantly affected leaf area (cm^2) in the both seasons. Murcott mandarin leaf area ranged between 11.40 -13.50 cm^2 in the first season and 10.69 - 13.83 cm^2 in the second season. The largest leaf area was recorded for trees sprayed by Metalusite at 2 cm/l or zinc oxide nano particles at 1% or zinc oxide normal particles at 4% (13.50 and13.47, 13.27 and 13.83 and 13.47 and 13.50 cm^2 in the first and second season, respectively. Spraying trees with water (control) produced the smallest leaf area (11.40 and 10.69 cm^2) in the two seasons, respectively. The other sprayed treatments produced intermediate values of leaf area (cm^2).

Leaf fresh and dry weights (g)

Data presented in Table 7 illustrated that the tested treatments significantly affected leaf fresh and dry weight of Murcott mandarin trees in the two seasons. Trees sprayed with titanium oxide nano particles at 1% gained the highest leaf fresh weight (0.437 and 0.410 g), while trees sprayed with water gave least fresh weight of leaf (0.320 and 0.333g) in the first and second season, respectively. Leaves of the trees sprayed with water, kaolin and potassium silicate at 4% had low values of leaf fresh weight in the second season without significant differences between them. However, leaves of the trees sprayed with Metalusite at 2 cm/l, titanium oxide nano particles at 1%, zinc oxide nano particles at 1% and zinc oxide normal particles at 4% had high values of leaf fresh weight in the second season without significant differences between them. The other tested treatments produced intermediate values of leaf fresh weight.

Table 5. Effect of some chemicals in nano or normal particles form on branch length and thickness of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Branch length (cm)		Branch thickness (mm)	
	First season	Second season	First season	Second season
Control (spraying water)	156.67ab	165.00 bcd	3.490 d	3.374 e
Kaolin (Al4Si4O10 (OH) 8) at 4%	126.67 e	148.33 e	3.705 abc	3.553 d
Potassium silicate at (K2SiO3) 4%	155.00 abc	173.33 ab	3.737 abc	3.552 d
Calcium carbonate (CaCO3) at 4%	133.33 de	150.00 de	3.755 ab	3.712 bc
Metalusite at 2 cm/l	143.33 a-d	168.33 abc	3.734 abc	3.692 bc
Titanium oxide nano particles (Ti2O3 NPs) at 1%	158.33 a	181.67 a	3.902 a	3.856 a
Titanium oxide normal particles (Ti2O3) at 4%	148.33 a-d	168.33 abc	3.758 ab	3.725 b
Zinc oxide nano particles (ZnO NPs) at 1%	140.00 cde	155.00 cde	3.527 cd	3.674 bcd
Zinc oxide normal particles (ZnO) at 4%	141.67 b-e	163.33 b-e	3.597bcd	3.593 cd

Table 6. Effect of some chemicals in nano or normal particles form on leaves number per branch and leaf area (cm^2) of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Leaves number per branch		Leaf area (cm^2)	
	First season	Second season	First season	Second season
Control (spraying water)	313.33 c	306.67 cd	11.40 f	10.69 e
Kaolin (Al4Si4O10 (OH) 8) at 4%	220.00 f	246.67 h	11.90 e	12.73 c
Potassium silicate at (K2SiO3) 4%	260.00 d	275.00 g	11.77 ef	12.17 d
Calcium carbonate (CaCO3) at 4%	241.67 e	271.67 fg	12.70 d	12.57 c
Metalusite at 2 cm/l	340.00 b	316.67 c	13.50 a	13.47 ab
Titanium oxide nano particles (Ti2O3 NPs) at 1%	366.67 a	366.67 a	13.00 bcd	12.77 c
Titanium oxide normal particles (Ti2O3) at 4%	315.00 c	335.00 b	12.97 cd	13.40 b
Zinc oxide nano particles (ZnO NPs) at 1%	275.00 d	300.00 de	13.27 abc	13.83 a
Zinc oxide normal particles (ZnO) at 4%	311.67 c	286.67 ef	13.47 ab	13.50 ab

Table 7. Effect of some chemicals in nano or normal particles form on Leaf fresh and dry weights of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Leaf fresh weight (g)		Leaf dry weight (g)	
	First season	Second season	First season	Second season
Control (spraying water)	0.320 f	0.333 c	0.136 d	0.128 ef
Kaolin (Al4Si4O10 (OH) 8) at 4%	0.343 e	0.333 c	0.126 e	0.126 f
Potassium silicate at (K2SiO3) 4%	0.363cd	0.333 c	0.148 b	0.132 e
Calcium carbonate (CaCO3) at 4%	0.357 de	0.363 b	0.147 bc	0.145 d
Metalusite at 2 cm/l	0.357 de	0.390 a	0.135 d	0.161 b
Titanium oxide nano particles (Ti2O3 NPs) at 1%	0.437 a	0.410 a	0.163 a	0.172 a
Titanium oxide normal particles (Ti2O3) at 4%	0.390 b	0.360 b	0.161 a	0.148 d
Zinc oxide nano particles (ZnO NPs) at 1%	0.380 bc	0.407 a	0.159 a	0.168 a
Zinc oxide normal particles (ZnO) at 4%	0.350 de	0.390 a	0.141 cd	0.155 c

Regarding leaf dry weight, the results showed that the highest values of leaf dry weight were recorded for trees sprayed by titanium oxide nano particles at 1% and zinc oxide nano particles at 1% (0.163 and 0.172 and 0.159 and 0.168 g) in the first and second season, respectively, and also trees sprayed by titanium oxide normal particles at 4% had high value (0.161g) in the first season only. The lowest values of leaf dry weight were from trees sprayed with water (control) or kaolin at 4% (0.136 and 0.128 and 0.126 and 0.126 g) in the two seasons, respectively. The other sprayed treatments produced intermediate values of leaf dry weight.

Leaf water content (%)

Data in Table 8 showed that the studied treatments significantly affected leaf water content (%) in the two seasons. Leaves of the trees sprayed with kaolin at 4% or Metalusite at 2 cm/l or titanium oxide nano particles at 1% contained the highest leaf water content (63.27, 62.13 and 62.64%) in the first season, respectively. While in the second season, the highest leaf water content was gained by sprayed trees with water or kaolin at 4% or potassium silicate at 4% or calcium carbonate at 4% or zinc oxide normal particles at 4%. Leaves of the trees sprayed with water (control) contained the lowest leaf water content in the first season only. Anyhow, leaf water content ranged between 57.48 – 62.64 and 58.63 – 62.06 % in the first and second season, respectively.

Leaf total chlorophyll content

It is observed from Table 8 that the studied treatments significantly affected leaf total chlorophyll content in the two seasons. All tested treatments gave leaves contained the higher total chlorophyll without significant differences between them compared to the control in the two seasons. The lowest values were from leaves of the trees control. The treatment of kaolin at 4% produced intermediate values of leaf total chlorophyll content.

DISCUSSION

The results obtained were consistent with those reported by **Gullo *et al.* (2020), Mohsen and Ibrahim (2021), Almutairi *et al*. (2022) and Abd El-Wahed *et al*. (2024)** and showed that all treatments enhanced fruit weight (g) and overall yield per tree (kg), per feddan (kg), as compared to the control treatment.

Contrarily, **Olsen and Cacka (2009)** showed that there were no statistically significant differences in yield, nut weights or grades for Multi Mineral Metalusite or any of the treatments compared to the untreated check plot.

Table (8) Effect of some chemicals in nano or normal particles form on leaf water content and total chlorophyll of Murcott mandarin trees (2020 and 2021 seasons)

Treatments	Leaf water content (%)		Total chlorophyll (SPAD)	
	First season	Second season	First season	Second season
Control (spraying water)	57.48 c	61.64 a	57.20 b	53.43 c
Kaolin (Al4Si4O10 (OH) 8) at 4%	63.27 a	62.06 a	60.53 ab	57.77 bc
Potassium silicate at (K2SiO3) 4%	59.17 b	60.50 ab	67.07 a	63.97 ab
Calcium carbonate (CaCO3) at 4%	58.77 bc	60.08 ab	62.60 ab	62.90 ab
Metalusite at 2 cm/l	62.13 a	58.70 b	61.77 ab	67.30 a
Titanium oxide nano particles (Ti2O3 NPs) at 1%	62.64 a	57.92 b	65.97 a	62.50 ab
Titanium oxide normal particles (Ti2O3) at 4%	58.62 bc	58.79 b	63.37 ab	67.30 a
Zinc oxide nano particles (ZnO NPs) at 1%	58.25 bc	58.63 b	64.40 ab	64.37 ab
Zinc oxide normal particles (ZnO) at 4%	59.71 b	60.17 ab	64.67 ab	61.90 ab

Gullo *et al.* (2020) demonstrated how kaolin could enhance clementine (*Citrus clementina*) photosynthetic production and performance. Moreover, during two summers, Kaolin was sprayed on tree canopies once a month, which enhanced the color of the fruit and raised the average yield per tree overall.

According to **Mohsen and Ibrahim (2021)**, the optimal treatment for improving Murrcot tangerine yield, fruit weight, fruit dimensions, peel thickness, and TSS% was a combination of 2% kaolin and 0.3% (3 ml/l) potassium silicate.

ZnONPs and B_2O_3NPs were applied to completely bloomed Wonderful pomegranate trees six weeks after full bloom and one month before harvest, as demonstrated by **Abd El-Wahed *et al*. (2024)**. This treatment increased growth and yield.

According to **Viorica *et al.* (2017)**, applying an amino acid-based foliar fertilizer to apple trees increased their yield and fruit weight characteristics significantly when compared to the control. According to **Ilie *et al.* (2018)**, all foliar sprays of amino acids were very successful at increasing the \Redix\ apple cultivar's yield and fruit quality when compared to the unfertilized control. According to **Mohamed *et al*. (2020)**, spraying amino acids and micronutrients will result in healthy, Manfalouty pomegranate fruits with an acceptable yield and the greatest possible fruit quality. According to **Almutairi *et al.* (2022)**, when amino acids were sprayed to guava trees instead of leaving them untreated, the fruit output increased along with the mineral content, chlorophyll, and shoot length and diameter.

The obtained results for kaolin or calcium carbonates foliar spraying on chlorophyll content and vegetative growth of Murcott mandarin were in line those reported by **Tasi *et al*. (2013)** and **Ramirez-Godoy *et al*. (2018). Tasi *et al*. (2013)** indicated that, calcium carbonate spraying was less effective in controlling sunscald, and resulted in the lowest photosynthetic rate. According to **Ramirez-Godoy *et al*. (2018)**, when kaolin was used instead of the other control and imidacloprid treatments, citrus plants' photosynthetic rate was reduced by 25%. Additionally, trees treated with kaolin clay showed a reduction in leaf temperature of about 5 degrees Celsius, notable variations in the relative concentration of chlorophyll (SPAD values). Additionally, using kaolin can assist control leaf temperature, particularly in situations where heat stress episodes are anticipated.

Kaolin-based particle films can reduce insect, heat, and ultraviolet stress in horticultural crops because of their ability to modify the microenvironment of the plant canopy as a result of the reflective nature of the particles **(Glenn, 2012).** Mango leaves sprayed with kaolin had higher average net photosynthesis, stomatal conductance and transpiration rate than in untreated leaves **(Chamchaiyaporn *et al*., 2013).**

Because the reflective nature of kaolin-based particle films allows them to alter the microclimate of the plant canopy, they can lessen insect, heat, and UV stress in horticulture crops **(Glenn, 2012)**. The average net photosynthesis, stomatal conductance, and transpiration rate of mango leaves treated with kaolin were higher than those of untreated leaves **(Chamchaiyaporn *et al*., 2013**).

The present study showed that, the beneficial effects of foliar application of calcium carbonate Metalusite, titanium, zinc oxide on enhancing growth of Murcott mandarin trees are in agreement with those found by **Botia *et al*. (2002), Chao and Choi (2005) and Saleh (2020).** Ti chelates have the ability to stimulate certain enzymes' activity and aid in the growth of young plants (**Botia *et al*., 2002**). Furthermore, it has been noted that applying Ti to crop production might lessen the severity of illness, encourage plant development, and boost photosynthetic rate (**Chao and Choi, 2005**). According to **Alcaraz *et al.* (1991)**, the application of Ti to various crops led to notable increases in yield, biomass production, accelerated ripening, fruit quality, increased photosynthesis, increased protein and chlorophyll synthesis, and enhanced enzymatic activity of catalase, peroxidase, nitrate reductase and nitrogenase. ZnO's biocompatibility in offering a highly active surface area is one of its more significant qualities (**Saleh, 2020**).

In addition to improving light absorption and the conversion of photovoltaic energy into electrical and chemical energy, titanium nanoparticles push carbon dioxide to prevent green plastid aging when exposed to prolonged light. Furthermore, titanium nanoparticles promote cell growth by enhancing nitrogen and/or photosynthesis, which increases plant weight (**Hong *et al*., 2005**). According to **Shoarian *et al*. (2020)**, the use of nano-TiO_2 resulted in the greatest significant activity level of catalase and superoxide dismutase enzyme activity.

Many enzymes, including as RNA and DNA polymerases, aldolases, isomerases, transphosphorylases, and dehydrogenases, depend on zinc to function. It also supports the production of tryptophan, cell division, the preservation of membrane structure, and photosynthesis. It aids in protein synthesis regulation as a cofactor **(Liu *et al*., 2021)**. The concentration, application technique, and size of ZnO particles all have a significant impact on how effective they are at blocking UV light. Applications using ZnO molecule suspensions provide superior UV protection capabilities **(Alebeid and Zhao, 2017)**.

Subbarayappa *et al*. (2017) investigate the effects of various boron sources on pomegranate quality and yield maximization (var. Bhagwa). The T12 (NPK + foliar spray 0.017% B Metalusite) treatment resulted in a notable improvement in yield contributing factors such as fruit number/ plant, fruit weight/plant, and fruit yield/plant. This was followed by the T11 (NPK + foliar spray 0.0085% B Metalusite) treatment.

Conclusions

Briefly, the highest total yield of Murcott mandarin trees and fruit weight (g) were gained by trees sprayed with Metalusite, titanium oxide and zinc oxide in the two forms nano and normal and also uppermost values of leaf area and leaf fresh and dry weights (g). The trees sprayed with Metalusite or titanium oxide nano particles gained least number and percentages of sunburned fruits/tree. The trees sprayed with titanium oxide nano or normal forms recorded longest and thicken branch (mm). The control trees (sprayed with water) gave smallest leaf area and thinner branch. The highest number of leaves per branch were gained for trees sprayed with titanium oxide nano particles, while, lowest number of leaves/branch were for trees sprayed with kaolin.

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تأثير الرش الورقي ببعض المواد الكيميائية على النمو والمحصول وتقليل الثمار المصابة بلسعة الشمس لأشجار اليوسفي الموركيت

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أجري هذا البحث خلال موسمين متتاليين 2020 و2021 على أشجار اليوسفي موركيت (*Citrus reticulata*) عمر 4 سنوات مطعومة على ليمون فولكامير (*Citrus volkameriana* L.) مزروعة في تربة رملية على مسافة 3×6 م تحت نظام الري بالتنقيط وحصولها عل نفس العمليات البستانية في بستان موالح خاص في منطقة وادي الملاك، محافظة الشرقية، مصر. تضمنت التجربة 9 معاملات كالتالي: T1 – معاملة المقارنة الكنترول (رش الماء)، T2 - الكاولين ($Al_4Si_4O_{10}$ (OH) $_8$) بمعدل 4%، T3 - سيليكات البوتاسيوم عند 4% (K_2SiO_3)، T4 - كربونات الكالسيوم (CaCO3) بمعدل 4 %، T5 - ميتالوسيت بمعدل 2 سم/لتر، T6 - جزيئات أكسيد التيتانيوم النانوية (Ti2O3 NPs) بمعدل 1%، T7 - جزيئات أكسيد التيتانيوم العادية (Ti2O3) بمعدل 4%، T8 - جزيئات أكسيد الزنك النانوية (ZnO NPs) بمعدل 1 % و T9 - جزيئات أكسيد الزنك العادية (ZnO) بمعدل4%. أشارت النتائج إلى أن جميع المعاملات أدت إلى زيادة إنتاجية الشجرة الكلية (كجم) والفدان (طن) ووزن الثمرة (جم) وكذلك عدد الثمار/شجرة مقارنة بمعاملة المقارنة. وكان أعلى محصول كلى للشجرة (كجم) وللفدان (طن) للأشجار التي تم رشها بالميتالوسايت وأكسيد التيتانيوم وأكسيد الزنك بصورتيه النانو والعادي دون وجود اختلافات بينها في الموسمين. أعطت الأشجار التي تم رشها بجزيئات الميتالوسيت أو أكسيد التيتانيوم النانوية على أقل عدد ونسب للثمار المصابة بلسعة الشمس/الشجرة في الموسمين، تليها الأشجار التي تم رشها بجزيئات أكسيد التيتانيوم العادية. وسجل أطول فرع للأشجار التي تم رشها بسليكات البوتاسيوم والميتالوسيت وأكسيد التيتانيوم النانوي والجزيئات العادية في الموسمين. وكانت الفروع الرفيعة في السمك للأشجار المقارنة (الكنترول) في كلا الموسمين. كان أعلى عدد أوراق/فرع للأشجار التي تم رشها بجزيئات النانو أكسيد التيتانيوم، بينما كان أقل عدد من الأوراق/الفرع للأشجار التي تم رشها بالكاولين في الموسمين. وسجلت أكبر مساحة ورقة للأشجار التي تم رشها بمادة الميتالوسيت وأكسيد الزنك النانوي أو الجسيمات العادية تليها الأشجار التي تم رشها بأكسيد التيتانيوم النانوي أو الجسيمات العادية، بينما كانت أصغر مساحة ورقة لأشجار المقارنة الكنترول في الموسمين. وكانت أعلى قيم للأوزان الغضة والجافة للورقة (جم) من الأشجار التي تم رشها بأكسيد التيتانيوم أو أكسيد الزنك بجزيئات النانو أو العادية تليها الأشجار التي تم رشها بمادة الميتالوسيت في كلا الموسمين. إحتوت أوراق الأشجار المختبرة على نسبة أعلى من الكلوروفيل الكلي دون وجود فروق معنوية بينها مقارنة بالكنترول الغير معامل في الموسمين.

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