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EFFECT OF NATURAL SPRAYS ON MANGO TREES UNDER HEAT STRESS FROM CLIMATE CHANGE UNDER DESERT CONDITIONS

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A field experiment was conducted during (2023 and 2024) seasons in private orchard situated in Abo Ghaleb Road (Alexandria Desert Road) Giza Governorate, Egypt. Foliar spray treatments were administered to an (18) years old mango *Mangifera indica* cv. Keitt. A randomized complete block design was used for the experiment and three types of materials were used; at three concentrations for each: kaolin at 2, 4 and 6%, calcium carbonate at 2, 4 and 6%, and titanium dioxide at 50, 100, 150 ppm to overcome the problems of climate change, especially high temperatures and their impact on growth, productivity, quality and prevent the injury of sunburn on fruits which causes economic losses. Treatments were sprayed in three different dates of two seasons (at the first week of June, July and August) compared with trees untreated (spraying water only) on vegetative growth, yield, fruit quality and nutritional status. Results showed that spraying titanium dioxide at 150 ppm improved trees growth characteristics, nutritional status, yield, fruit's chemical and physical characteristics. In addition, a positive effect on reducing number and percentages of sunburned fruits/tree this effect was clear detected under this experiment conditions.

Keywords: mango, kaolin, calcium carbonate, titanium dioxide and heat stress

INTRODUCTION

The mango tree (*Mangifera indica* L.) is an evergreen tree that belongs to the family Anacardiaceae. Southeast Asia is where it originated and is widely cultivated throughout a range of tropical and subtropical areas (Galán, 2017 and Welay et al., 2021).

Climate change is without a doubt the most urgent environmental issue facing the planet today. According to Appels et al. (2011), ecosystems, wildlife, food chains and eventually human life will all be significantly impacted by climate change. Climate change affects average and extreme temperatures, precipitation patterns, crop yields and the range and introduction of pests and weeds as well as the length of the growing season (California Natural Resources Agency, 2009).

Climate change is making it harder to grow mangoes in some parts of the world. This is because of things like high temperatures and salty soil or irrigation water, which lower the quality of the fruit and make it less productive (Kumar and Kumar, 2016 and Mahmood et al., 2024).

Mango, apple, apricot, cherry and litchi fruits ripen prematurely under high temperatures and moisture stress and are more susceptible to sunburn and heat-induced cracking (Kumar and Kumar, 2016). In this climate change, mango fruit quality is declining (Rajan et al. (2011).

Sunburn is a physiological problem that happens to mango trees when they are exposed to too much heat and UV rays, especially when the fruit is fully ripe late in the season. This problem weakens the fruit's skin, causing dark or dead spots that make it less marketable and less healthy. It also costs growers money because they lose money on yield (Schrader et al., 2008; Lal and Sahu, 2017 and Hamdy et al., 2022).

To reduce the effects of sunburn and its side effects on reducing the quality and productivity of mango cv. Keitt, we used three materials in this research, which are as follows: kaolin ($Al_2Si_2O_5OH_4$) is the primary component of kaolin, a natural substance that is clay. Treatments with kaolin clay have been effectively used on a variety of fruit species to enhance fruit quality and yield and reduce fruit sunburn. Kaolin works well to lessen sunburn on a variety of fruit crops (Colavita et al., 2011; Alvarez et al., 2015 and Kerns and Wright, 2000). Kaolin works well to lessen sunburn on a variety of fruit crops (Colavita et al., 2011; Vatandoost et al., 2014 and Aly et al., 2010). Because kaolin particles lower the temperature of the leaf surface and fruits, they form films on them that reflect sunlight, preventing sunburn and enhancing fruit quality (Ennab et al., 2017 and Baiea et al., 2018). Additionally, Ennab et al. (2017) found that kaolin foliar treatments at 3 and 4% reduced the temperature of the leaves and fruit and were more effective in minimizing the number of "Balady" mandarin plants' fruit sunburn (Glenn, 2009 and Alvarez et al., 2015), cleared that kaolin was quite successful at lowering the temperature of apple fruits; reflected sunlight reduces the fruit's surface temperature, minimizing sunburn damage and increasing fruit quality and output.

The solid calcium carbonate ($CaCO_3$) is colorless, tasteless and harmless. Among the most prevalent and extensively distributed minerals, it can be found in seashells, limestone, marble, eggshells and other biominerals. It has been utilized for many different applications, such as a neutralizing agent, filler, flux and in cement, due to its inexpensive cost and innocuous nature (McGregor, 1963 and Sheikholeslami and Ong, 2003). Foliar application of $CaCO_3$ at 3 and 4% for Kinnow mandarin significantly increased the fruit diameter, fruit weight, total soluble solids (TSS), juice percentage, total antioxidants, ascorbic acid, total phenolics, flavonoids and carotenoids contents (Zaman et al., 2019).

One of the most common elements is titanium dioxide (TiO_2) is a white pigment and UV blocker consumer goods, agriculture and energy. TiO_2 is thought to be good for plant growth and development. Low quantities of TiO_2 applied to roots or leaves have been shown to boost crop performance by strengthening stress tolerance, increasing chlorophyll content and photosynthesis, boosting nutrient uptake and activating certain enzymes tolerance and improving crop yield and quality. Due to their photoprotective and photocatalytic roles, TiO_2 is also used for plant protection and environmental remediation (Indrajeet and Vivek, 2020). TiO_2 can be synthesized as a natural way and widely used in commercial items like toothpaste and sunscreen, industrial goods like paints, lacquers and paper and water purification (Wen et al., 2015). Mahmood et al. (2024) found that spraying trees of Murcott mandarin with TiO_2 gained the highest total yield and fruit weight and also uppermost values of leaf area and leaf fresh and dry weights and least number and percentages of sunburned (fruits/tree).

This study aims to reduce the damage caused to mango trees, especially late ones such as Keitt mango trees, during the summer season, using a foliar spraying mechanism with materials that reflect radiation, especially ultraviolet rays and reduce the resulting effect.

MATERIALS AND METHODS

The current study was conducted in the seasons of 2023 and 2024 on Keitt mango trees budded on seedling rootstocks (Succary), grown in sandy soil within a private orchard with a drip irrigation system situated at Abo Ghaleb Road (Alexandria Desert Road) Giza Governorate, Egypt. The chosen trees were planted seven by seven meters apart, were eighteen years old, strong and had almost equal vigor, the selected trees received the public horticultural techniques. Soil and water analysis are showing in Table (1, 2 and 3) carried out in the soil and water laboratory of the central laboratory, Faculty of Agriculture, Ain Shams University.

Table (1). Some physical properties of the experimental soil.

Soil depth (cm)	Partical size distribution							
	C. Sand (%)	F. Sand (%)	Silt (%)	Clay (%)	F.C. (%)	W.P. (%)	B.D. (g/cm^3)	Texture
0 – 30	92.8	3.7	2.0	1.5	10	4.8	1.83	Sandy
30 – 60	91.5	1.8	0.2	6.5	11	6.3	1.79	Sandy
60 – 90	93.1	0.6	0.4	5.9	13	5.5	1.72	Sandy

C. Sand: coarse sand; F. Sand: fine sand; F.C.: field capacity; W.P.: wilting point; B.D.: bulk density.

Table (2): Some chemical properties of the experimental soil.

Soil depth (cm)	pH	EC (ds/m)	TDS (ppm)	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
				Soluble cations (meq/L)				Soluble anions (meq/L)			
0 – 30	6.9	2.50	1600.0	9.52	1.30	13.88	0.30	--	0.8	8.97	15.23
30 – 60	7.1	3.03	1939.2	9.60	6.90	13.60	0.20	--	1.8	4.70	23.80
60 – 90	7.3	2.48	1587.2	10.20	3.21	11.20	0.19	--	0.8	7.60	16.40

TDS: total dissolved salts.

Table (3): Some chemical properties of the used irrigation water.

pH	EC (ds/m)	TDS (ppm)	Soluble cations (meq/L)				Soluble anions (meq/L)			
			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
6.9	3.26	2086.4	12	1.22	19.28	0.1	-	0.8	9.8	22

Selected trees were sprayed in three different dates of two seasons (at the first week of June, July and August) by aqueous solution with three materials kaolin at three concentrations (2, 4 and 6%), $CaCO_3$ at 2, 4 and 6% and TiO_2 at 50, 100 and 150 ppm until the point of runoff water was even sprayed on the control.

The ten treatments involved in the current study were as follows:

T_1 - Kaolin ($Al_4Si_4O_{10}$ (OH) 8) 2%
T_2 - Kaolin ($Al_4Si_4O_{10}$ (OH) 8) 4%
T_3 - Kaolin ($Al_4Si_4O_{10}$ (OH) 8) 6%
T_4 - Calcium carbonate ($CaCO_3$) 2%
T_5 - Calcium carbonate ($CaCO_3$) 4%
T_6 - Calcium carbonate ($CaCO_3$) 6%
T_7 - Titanium dioxide (TiO_2) 50 ppm
T_8 - Titanium dioxide (TiO_2) 100 ppm
T_9 - Titanium dioxide (TiO_2) 150 ppm
T_{10} - Control (water spray)

1. Data Analysis

A completely randomized block design was used to organize the treatments, with three trees and three replicates for each treatment and data analysis was done using new least significant difference (LSD) test at 5% to differentiate among the ten treatment means (Gomez and Gomez, 1984 and Mead et al., 1993).

The following parameters were measured for both seasons

2. Vegetative Growth

2.1. Leaf total chlorophyll

Leaf total chlorophyll was measured in field, at the month of September, in fresh leaves, by using SPAD-502 Minolta chlorophyll meter.

2.2. Leaf area (cm^2)

Leaf area was determined with a leaf area meter, leaf samples were taken at the first week of month of September of each season, and the third and fourth leaves were taken from the bottom of the branch.

2.3. Yield and fruit quality

Fruit samples were collected five fruits per each replicate at last week of September

- Fruit weight (g), number of fruits/trees, total yield/tree (kg), fruit length (cm), fruit diameter (cm), fruit thickness (cm), pulp weight (g), seed weight (g), peel weight (g), pulp (%), pulp/peel ratio and pulp/seed ratio.
- Total sugars (%), reducing sugars (%) and non-reducing sugars (%): were determined according to James (1995) and estimation was made on the basis of fresh weight.
- A drop of juice was placed in the digital refractometer's reading cell to measure TSS. Additionally, the juice's titratable acidity (TA) was measured using the Boland (1990) approach.

2.4. Leaf mineral content

Nitrogen was determined by modified micro-Keldahl according to Jackson (1973). Phosphorus, potassium, iron, manganese, copper and zinc were determined in leaves. Leaf samples were digested using nitric acid and hydrogen peroxide in Microwave Digestion Labstation closed system, Ethos Pro, Milestone, Italy. Inductivity Coupled Argon Plasma, ICAP 6500 Duo, Thermo Scientific, England, was used to measure the results. Merck, Germany, provided a 1000 mg/L multi-element certified stander system for instrument standardization (Stefánsson, 2007).

The following formula was used to count the number of sunburned fruits per tree and determine the percentage of sunburned fruits per tree:

Percentage of sunburned fruits per tree = (Number of sunburned fruits per tree / Total number of fruits per tree) x100

Results and Discussion

1. Vegetative Growth

Leaf total chlorophyll and leaf area

Concerning the results in Table (4), leaf total chlorophyll and leaf area were affected significantly by all spraying with all treatments in both seasons. Whoever, T_9 produced the highest leaf total chlorophyll (46.8 in the 1st and 47.9 in the 2nd season) and high leaf area (68.7 and 67.7 cm^2 in both seasons). On the other side, T_{10} gave the lowest significant values for leaf total chlorophyll and leaf area in both seasons.

These results mean that TiO_2 increased vegetative growth on Keitt mango tree may be due to that TiO_2 plays a role in improving the growth and quality of mango crops by affecting photosynthesis and enhancing nutrient uptake. TiO_2 is believed to increase the efficiency of photosynthesis, leading to increasing the production of carbohydrates and sugars, thus improving growth and increasing fruit size. It may also improve nutrient uptake from the soil, enhancing overall tree growth and improving fruit quality. Servin et al.

(2013) found that the accumulation of the total chlorophyll content in cucumber leaves was by the treatment of TiO_2 with nutrients.

Table (4). Effect of foliar spraying with natural materials on leaf total chlorophyll and leaf area of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Leaf total chlorophyll		Leaf area (cm^2)	
	2023	2024	2024	2023
T_1	41.2 d	43.5 c	56.7 c	55.8 d
T_2	38.7 f	38.7 d	52.6 ef	52.2 f
T_3	38.6 f	39.6 d	52.4 fg	51.4 g
T_4	40.7 e	43.2 c	51.8 g	50.6 h
T_5	38.3 g	38.4 d	53.1 e	50.6 h
T_6	41.7 c	42.4 c	53.9 d	52.8 e
T_7	41.8 c	43.6 c	57.2 c	56.2 c
T_8	43.3 b	45.6 b	64.3 b	63.4 b
T_9	46.8 a	47.9 a	68.7 a	67.7 a
T_{10}	37.3 h	33.4 e	48.4 h	48.3 i

(T_1) Kaolin at 2 %, (T_2) Kaolin at 4 %, (T_3) Kaolin at 6 %, (T_4) Calcium carbonate at 2%, (T5) Calcium carbonate at 4%, (T6) Calcium carbonate at 6%, (T7) Titanium dioxide at 50 ppm, (T8) Titanium dioxide at 100 ppm, (T9) Titanium dioxide at 150 ppm, and (T10) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

In addition, Ti applied through the roots or leaves have been reported to promote plant growth, delay chloroplast aging, increase chlorophyll content and photosynthesis, boost nutrient uptake, improve stress tolerance and stimulate the activity of particular enzymes to improve agricultural performance (Indrajeet and Vivek, 2020)

Furthermore, Nasab et al. (2018) found that the growth properties of thyme plants were significantly impacted by the use of TiO_2 as a spray under abiotic stress factors.Ti chelates have the ability to stimulate certain enzymes activity and aid in the growth of young plants (Botia et al., 2002).

2. Yield and Fruit Quality

Fruit weight, number of fruits/tree and yield/tree

The data in Table (5) unequivocally demonstrate that all treatments of foliar spraying with natural materials in both seasons had a significant impact on fruit weight, number of fruits/tree and yield/tree. In this respect, T_5, T_8 and T_9 gave the highest fruit weight in the both seasons. Concerning number of fruits/trees T_9 gave highest significant value (47.0) in both seasons. Finally, T_9 gave highest significant value of yield/tree (22.9 kg/tree in both seasons) compared to other treatments and control treatment.

This results from considering that TiO_2 treatments were also effective in promoting the photosynthesis of Keitt mango trees leaves, the accumulation of chlorophylls and the promotion of photosynthesis that was induced by TiO_2

treatment might explain why the yield of Keitt mango trees were so greatly improved by TiO_2. Furthermore, Hong et al. (2005) proposed that the activation of photochemical reactions in spinach chloroplasts may be connected to photosynthesis facilitated by TiO_2.

Table (5). Effect of foliar spraying with natural materials on fruit weight, number of fruits/trees, and yield/tree of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Fruit weight (g)		Number of fruits/tree		Yield/tree (kg)	
	2023	2024	2023	2024	2023	2024
T_1	474.9 c	475.1 c	38.0 cd	39.0 b	18.0 d	18.5 b
T_2	480.4 b	480.6 b	39.0 c	39.0 b	18.7 c	18.7 b
T_3	432.9 e	433.1 e	31.0 e	32.0 c	13.4 f	13.9 d
T_4	427.9 f	428.1 g	37.0 d	38.0 b	15.8 e	16.1 c
T_5	489.9 a	490.1 a	22.0 f	23.0 d	10.7 g	11.1 e
T_6	459.4 d	463.6 d	16.0 g	17.0 e	7.3 i	7.9 g
T_7	457.9 d	454.1 e	21.0 f	22.0 d	9.6 h	10.0 f
T_8	489.9 a	490.1 a	45.0 b	46.0 a	22.0 b	22.7 a
T_9	491.9 a	492.1 a	47.0 a	47.0 a	22.9 a	22.9 a
T_{10}	426.4 f	426.6 g	15.0 g	16.0 e	6.4 j	6.7 h

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

Alcaraz et al. (1991) reported that 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. In addition, foliar spraying in coriander with bulk TiO_2 at 2 g/L greatly enhanced essential oil production, umbel count, seed yield and plant height compared to untreated controls (Rania et al., 2022). These results are in harmony with those obtained by Mahmood et al. (2024), who found that, the highest total yield of Murcott mandarin trees and fruit weight were gained by trees sprayed with TiO_2 and also uppermost values of leaf area and leaf fresh and dry weights.

3. Fruit Physical Characteristics

3.1. Fruit length, fruit diameter, and fruit thickness

According to data in Table (6), there were notable variations in the physical characteristics (fruit length, fruit diameter and fruit thickness) of the fruit across all treatments in both seasons. T_9 gave the highest significant value of fruit length (13.2 cm) in both seasons, in addition, fruit diameter, in both seasons, T_5, T_8 and T_9 showed the most significant benefit when compared to the other treatments. Regarding fruit thickness, T_6, T_8 and T_9 provided the most significant values when compared to the other treatments. In contrast, T_{10} had the lowest significant values for the physical properties of the fruit during both seasons.

Table (6). Effect of foliar spraying with natural materials on fruit length, fruit diameter, and fruit thickness of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Fruit length (cm)		Fruit diameter (cm)		Fruit thickness (cm)	
	2023	2024	2023	2024	2023	2024
T_1	12.7 b	12.8 b	8.5 d	8.5 d	6.8 b	6.9 b
T_2	12.4 c	12.7 b	8.9 b	8.9 b	6.7 b	6.8 c
T_3	12.7 b	12.8 b	8.8 c	8.7 c	6.8 b	6.8 bc
T_4	12.3 cd	12.5 c	8.7 c	8.7 c	6.5 c	6.5 d
T_5	12.7 b	12.8 b	9.3 a	9.2 a	6.8 b	6.8 bc
T_6	12.2 de	12.3 d	8.3 e	8.3 e	7.2 a	7.2 a
T_7	12.3 ce	12.2 d	8.4 de	8.3 e	6.8 b	6.8 bc
T_8	12.8 b	12.7 b	9.3 a	9.3 a	7.2 a	7.2 a
T_9	13.2 a	13.2 a	9.4 a	9.3 a	7.2 a	7.3 a
T_{10}	12.1 e	12.1 d	8.3 e	8.2 e	6.4 c	6.4 e

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

3.2. Pulp weight, seed weight and peel weight

The data presented in Table (7) clearly indicate that, foliar spraying with natural materials on pulp weight, seed weight and peel weight of Keitt mango trees caused a significant promotion of fruit quality in terms of reducing peel weight and seed weight and increasing pulp weight compared with the check treatment. T_9 produced the highest pulp weight and the lowest peel and seed weights in both seasons, respectively. The untreated trees showed negative effects from pulp weight, seed weight, and peel weight. Similar outcomes were reported for the seasons of 2023 and 2024.

3.3. Pulp %, pulp/peel ratio and pulp/seed ratio

Data in Table (8) show clearly that using materials greatly increased pulp%, pulp/peel ratio and pulp/seed ratio in comparison to T_{10}. T_9 gave the highest pulp percentage (74.2 and 74.3%) and the highest pulp/peel ratio and pulp/seed ratio in both seasons, respectively. On the other hand, T_{10} had negative impacts on pulp percentage, pulp/peel ratio and pulp/seed ratio. Similar results were noted for the seasons of 2023 and 2024.

Table (7). Effect of foliar spraying with natural materials on pulp weight, seed weight and peel weight of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Pulp weight (g)		Seed weight (g)		Peel weight (g)	
	2023	2024	2023	2024	2023	2024
T_1	315.7 f	316.3 f	52.6 d	52.4 d	106.6bc	106.4bc
T_2	336.2 c	336.8 c	52.6 d	52.4 d	91.6 e	91.4 e
T_3	272.7 i	273.3 i	52.6 d	52.4 d	107.6 b	107.4 b
T_4	281.2 h	281.8 h	54.6 c	54.4 c	92.1 e	91.9 e
T_5	329.7 d	330.3 d	54.6 c	54.4 c	105.6 c	105.4 c
T_6	317.2 e	317.8 e	52.1 de	55.9 b	90.1 f	89.9 f
T_7	302.7 g	303.3 g	56.1 b	51.9 de	99.1 d	98.9 d
T_8	356.7 b	357.3 b	51.1 e	50.9 e	82.1 g	81.9 g
T_9	365.2 a	365.8 a	48.1 f	47.9 f	78.6 h	78.4 h
T_{10}	253.2 j	253.8 j	58.6 a	58.4 a	114.6 a	114.4 a

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

Table (8). Effect of foliar spraying with natural materials on pulp percentage, pulp/peel ratio and pulp/seed ratio of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Pulp (%)		Pulp/peel ratio		Pulp/seed ratio	
	2023	2024	2023	2024	2023	2024
T_1	66.5 f	66.6 f	3.0 f	3.0 f	6.0 d	6.0 d
T_2	70.0 c	70.1 c	3.7 c	3.7 c	6.4 c	6.4 c
T_3	63.0 i	63.1 h	2.5 g	2.5 g	5.1 f	5.2 f
T_4	65.7 h	65.8 g	3.0 ef	3.0 ef	5.1 f	5.1 f
T_5	67.3 e	67.4 e	3.1 e	3.1 e	6.0 d	6.0 d
T_6	69.0 d	68.5 d	3.5 d	3.5 d	6.1 d	5.7 e
T_7	66.1 g	66.8 f	3.0 ef	3.0 ef	5.4 e	5.8 e
T_8	72.8 b	72.9 b	4.3 b	4.3 b	7.0 b	7.0 b
T_9	74.2 a	74.3 a	4.6 a	4.6 a	7.5 a	7.6 a
T_{10}	59.4 j	59.5 i	2.2 h	2.2 h	4.3 g	4.3 g]

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

4. Fruit Chemical Characteristics

4.1. Total sugars (%), reducing sugars (%) and non-reducing sugars (%)

Data represented in Table (9) show that, foliar spraying with different materials of Keitt mango trees caused a significant promotion of total sugars (%), reducing sugars (%) and non-reducing sugars (%) were significantly lower in the control treatment T_{10} than those recorded by all natural materials in both seasons. T_9 treatment gave approximately the highest value of total sugars (18.8 and 20.6% in the 1st and 2nd, respectively). As for, reducing sugars T_9 and T_8 gave the highest value in the first season but T_9 gave the highest value in the second season. However, T_9 gave the best value of non reducing sugars in the first season. In addition, in the second season T_9 and T_8 gave the highest value of non-reducing sugars.

Table (9). Effect of foliar spraying with natural materials on total sugars, reducing sugars and non-reducing sugars of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Total sugars (%)		Reducing sugars (%)		Non-reducing sugars (%)	
	2023	2024	2023	2024	2023	2024
T_1	14.8 h	16.9 g	4.1 f	4.3 g	10.7 e	12.6 e
T_2	15.7 f	17.8 e	5.2 b	5.2 c	10.5 f	12.6 e
T_3	15.6 f	17.7 e	4.4 e	4.8 e	11.2 d	12.9 d
T_4	15.2 g	17.3 f	4.7 d	4.7 f	10.5 f	12.6 e
T_5	17.2 d	19.0 c	4.5 e	4.3 g	12.7 b	14.7 a
T_6	16.2 e	18.3 d	5.0 c	5.1 d	11.2 d	13.2 c
T_7	17.5 c	19.2 c	5.3 b	5.2 c	12.2 c	14.0 b
T_8	18.4 b	20.1 b	5.7 a	5.3 b	12.7 b	14.8 a
T_9	18.8 a	20.6 a	5.6 a	5.7 a	13.2 a	14.9 a
T_{10}	14.2 i	16.1 h	4.0 f	3.7 h	10.2 g	12.4 f

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

4.2. Total soluble solids and acidity

Data in Table (10) show a significant difference among treatments in both seasons as for TSS and acidity in the juice. Result of use foliar spraying with natural materials of Keitt mango trees. T_9 gave the highest percentage of TSS and the lowest percentage of acidity in the 1st and 2nd season. On the other side, T_{10} had the lowest values in TSS and the highest percentage of acidity.

These results suggest that treatments of TiO_2 on Keitt mango trees plants during cultivation were quite efficient in promoting fruit quality and quantity. Ti form TiO_2 had a favorable impact on plant development of tomato (Abdel Latef et al., 2018; Carbajal-Vazquez et al., 2020 and Gohari et al., 2020).

Similar observations were made in tomato fruits that showed increases in TSS by TiO_2 treatment (Nishizawa et al., 2008). Because Ti stimulates the tomato's phosphofructokinase enzyme, it may also rise TSS (Simon et al., 1991). In the presence of Ti the plant would have a lower concentration of free organic acids at harvest (Wongmetha et al., 2015).

Table (10). Effect of foliar spraying with natural materials on TSS and acidity of Keitt mango trees during 2023 and 2024 seasons.

Treatment	TSS		Acidity (%)	
	2023	2024	2023	2024
T_1	16.1 h	15.2 d-f	0.24 c	0.14 d
T_2	17.8 fg	19.2 bc	0.31 b	0.13 de
T_3	17.1 g	16.5 d	0.32 b	0.16 c
T_4	18.6 de	14.6 ef	0.23 c	0.16 c
T_5	18.2 ef	14.9 ef	0.23 c	0.16 c
T_6	19.2 cd	16.1 de	0.31 b	0.18 b
T_7	19.5 bc	20.2 b	0.23 c	0.16 c
T_8	20.0 b	18.2 c	0.18 d	0.12 e
T_9	21.2 a	23.2 a	0.16 e	0.12 e
T_{10}	16.1 h	14.0 f	0.34 a	0.22 a

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

5. Leaf Mineral Content

5.1. Leaf macronutrients

Data represented in Table (11) reveal that all natural materials of Keitt mango trees significantly increased the leaf macronutrients (N, P and K) as compared with control in both seasons. Furthermore, T_9 recorded the highest value of nitrogen percentage (2.6 and 3.0%), phosphorus percentage (0.82 and 0.83%) and potassium percentage (2.7 and 3.0%) in both seasons, respectively. In succession, T_{10} trees showed unfavorable effects on leaf macronutrients.

5.2. Leaf micronutrients

Table (12) shows the effect of foliar spraying with natural materials on leaf micronutrients during the 2023 and 2024 seasons of Keitt mango trees. Leaf micronutrients were affected significantly by all natural materials in both seasons. Furthermore, T_9 produced the highest leaf iron content (280.1 ppm in the 1^{st} and 283.0 ppm in the 2^{nd} season), manganese (58.0 ppm in the 1^{st} and 60.0 ppm in the 2^{nd} season), leaf copper content (38.0 ppm and 41.0 ppm in both seasons) and leaf zinc content (36.0 and 38.0 ppm in both seasons), respectively. However, in both seasons, the trees sprayed with water T_{10} had the lowest values of leaf micronutrients.

Table (11). Effect of foliar spraying with natural materials on some leaf macronutrients of Keitt mango trees during 2023 and 2024 seasons.

Treatment	N (%)		P (%)		K (%)	
	2023	2024	2023	2024	2023	2024
T_1	1.9 g	2.4 e	0.48 h	0.58 e	1.8 g	2.0 f
T_2	2.3 e	2.4 e	0.48 h	0.58 e	2.1 e	2.3 d
T_3	2.1 f	2.2 f	0.68 c	0.78 bc	2.1 e	2.2 d
T_4	2.4 d	2.5 d	0.61 e	0.74 cd	1.9 f	2.1 e
T_5	2.1 f	2.4 e	0.52 g	0.72 d	2.2 d	2.3 cd
T_6	2.3 e	2.7 c	0.56 f	0.76 cd	2.3 c	2.4 c
T_7	2.4 c	2.8 b	0.63 d	0.77 c	2.2 d	2.2 d
T_8	2.5 b	2.9 ab	0.77 b	0.82 ab	2.4 b	2.6 b
T_9	2.6 a	3.0 a	0.82 a	0.83 a	2.7 a	3.0 a
T_{10}	1.9 g	2.1 g	0.41 i	0.41 f	1.8 g	2.0 f

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

Table (12). Effect of foliar spraying with natural materials on some leaf micronutrients of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Fe (ppm)		Mn (ppm)		Cu (ppm)		Zn (ppm)	
	2023	2024	2023	2024	2023	2024	2023	2024
T_1	231.0 h	232.0 i	43.0 f	46.0 e	27.0 e	28.0 e	21.0 e	24.0 f
T_2	243.0 f	244.0 f	48.0 e	51.0 d	29.0 d	30.0 d	23.0 d	26.0 e
T_3	267.0 c	268.3 c	54.0 bc	55.0 b	33.0 c	34.0 c	28.0 c	31.0 c
T_4	236.0 g	238.0 g	47.0 e	50.0 d	30.0 d	31.7 d	34.0 b	35.0 b
T_5	256.0 e	258.0 e	51.0 d	53.0 c	32.0 c	34.0 c	21.0 e	22.6 f
T_6	261.0 d	263.0 d	53.0 c	55.0 b	33.0 c	35.7 c	23.0 d	24.0 f
T_7	242.0 f	244.3 f	48.0 e	50.0 d	27.0 e	30.0 d	27.0 c	28.0 d
T_8	271.3 b	274.3 b	56.0 b	56.0 b	35.0 b	38.0 b	34.0 b	36.0 b
T_9	280.0 a	283.0 a	58.0 a	60.0 a	38.0 a	41.0 a	36.0 a	38.0 a
T_{10}	231.0 h	234.0 h	41.0 g	43.0 f	21.0 f	24.0 f	18.0 f	20.0 g

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

These findings are consistent with those of Bacilieri et al. (2017), who discovered that TiO_2 form treatments applied topically have positive effects on the balance and absorption of important macro and micronutrients. This raises protein and chlorophyll levels, which in turn increases the growth, dry matter content and yield of capsicum.

Ti favors the absorption of nutrients like N, K, Ca and Mg and especially Fe in pepper and tomato plants (Carvajal et al., 1992; Hrubý et al., 2002 and Kleiber and Markiewicz, 2013). Similarly, the application of Ti at 500 and 1000 mg/L of tomato seedlings increased N, P, K, Ca and Mg concentrations in leaves (Víctor et al., 2022).

6. Number of Sunburned Fruits/Tree and Percentage of Sunburned Fruits / Tree

Data represented in Table (13) reveal that all natural treatments significantly decreased number of natural of fruits/tree as compared with control in both seasons. In this respect, T_{10} gave the highest number of sunburned fruits/tree and percentage of sunburned fruits/tree in the first and second season. In the contrast, the lowest number of sunburned fruits/tree and percentage of sunburned fruits/tree was recorded by T_8 and T_9 in both seasons without any significant difference between them.

Table (13). Effect of foliar spraying with natural materials on number of sunburned fruits/tree and percentage of sunburned fruits/tree of Keitt mango trees during 2023 and 2024 seasons.

Treatment	Number of sunburned (fruits/tree)		Percentage of sunburned (fruits/tree)	
	2023	2024	2023	2024
T_1	13.0 b	11.0 c	34.17 ef	28.20 e
T_2	11.0 cd	9.0 d	28.17 f	23.93 e
T_3	12.0 bc	12.0 b	38.67 de	38.53 d
T_4	11.0 cd	9.0 d	29.77 f	24.80 e
T_5	11.0 cd	10.0 c	50.13 c	47.23 c
T_6	10.0 de	10.0 cd	62.57 b	60.93 b
T_7	9.0 e	8.0 e	43.10 d	36.57 d
T_8	6.0 f	5.0 f	13.37 g	11.50 f
T_9	6.0 f	5.0 f	12.83 g	11.43 f
T_{10}	15.0 a	15.0 a	100.00 a	97.93 a

(T_1) Kaolin at 2%, (T_2) Kaolin at 4%, (T_3) Kaolin at 6%, (T_4) Calcium carbonate at 2%, (T_5) Calcium carbonate at 4%, (T_6) Calcium carbonate at 6%, (T_7) Titanium dioxide at 50 ppm, (T_8) Titanium dioxide at 100 ppm, (T_9) Titanium dioxide at 150 ppm, and (T_{10}) control (tab water). Mean values having the same letters in the same column in each season are not statistically different by Duncan's multiple range test at 5% level.

From the above-mentioned results, it could be concluded that spraying with 150 ppm of TiO_2 had a positive effect on reducing the number of sunburned fruits/tree and percentage of sunburned fruits/tree. Hamdy et al. (2022) and Abd-Allah et al. (2013) demonstrated that foliar application of sunblock materials significantly decreases sunburn incidence in on Keitt mango while enhancing photosynthetic pigments and antioxidant content and decrease fruit drop compared to unsprayed control.

CONCLUSIONS

Briefly, mango trees sprayed with 150 ppm of TiO_2 three times at the first week of June, July and August compared to other treatments and control treatment under desert conditions had superior values of vegetative growth, yield, fruit quality and nutritional status and gained least number of sunburned fruits/tree and percentage of sunburned fruits/tree.

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تأثير الرش الطبيعي على أشجار المانجو تحت ظروف الإجهاد الحراري الناتج عن تغير المناخ تحت ظروف الأراضى الصحراوية

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أُجريت تجربة حقلية خلال موسمي (٢٠٢٣ و٢٠٢٤) في بستان خاص يقع في طريق أبو غالب (طريق إسكندرية الصحراوي) بمحافظة الجيزة، مصر. رُشّت أشجار المانجو (صنف كيت) بعمر 18 عامًا بالرش الورقي. أُجريت التجربة باستخدام تصميم القطاعات العشوائية الكاملة، باستخدام ثلاث مواد بثلاثة تركيزات لكل منها: الكاولين (٢.٤ و٦٪)، وكربونات الكالسيوم (٢.٤ و٦٪)، وثاني أكسيد التيتانيوم (٥٠، ١٠٠، ١٥٠ ملجم/كجم) ، وذلك للتغلب على مشاكل تغير المناخ، وخاصةً ارتفاع درجات الحرارة وتأثيرها على النمو والإنتاجية والجودة، ومنع إصابة الثمار بلسعات الشمس التي تُسبب خسائر اقتصادية. تم رشّ هذه المعاملات في ثلاثة مواعيد مختلفة بالموسمين (فى الإسبوع الأول لكل من يونيو، يوليو، وأغسطس)، مقارنةً بالأشجار غير المعاملة (بالرش بالماء فقط) على النمو الخضري، والمحصول، وجودة الثمار، والحالة الغذائية. أظهرت النتائج أن رشّ ثاني أكسيد التيتانيوم بتركيز ١٥٠ ملجم/كجم حسّن خصائص نمو الأشجار، والحالة الغذائية، والمحصول، والخصائص الفيزيائية والكيميائية للثمار. بالإضافة إلى ذلك، كان له تأثير إيجابي في تقليل عدد ونسب الثمار/الأشجار المصابة باللسعات، وقد لوحظ هذا التأثير بوضوح في ظل ظروف هذه التجربة.