International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)
Journal Home page: www.iscientific.org/Journal.html

Foliar spray of chemical substances to improve yield, physico-chemical fruit quality and reduce sunburned fruits of Murcott mandarin trees

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Abstract

This study carried out throughout two successive seasons 2020 and 2021, on 4 years-old on trees of Murcott mandarin (*Citrus reticulata*) budded on Volkamer lemon (*Citrus volkameriana* L.) grown in sandy soil at 3x6 m apart under drip irrigation system and received the same horticultural managements in in a private citrus orchard located at Wady El-Mollak region, Sharkia Governorate, Egypt. The experiment included 9 treatments as follow: T1 - Control (Water spray), T2 - Kaolin ($Al_4Si_4O_{10}$ $(OH)_8$) at 4%, T3 - Potassium silicate at (K_2SiO_3) 4%, T4 - Calcium carbonate (CaCO3) at 4%, T5 - Metalusite at 2 cm/l, T6 - Titanium oxide nano particles (Ti_2O_3 NPs) at 1%, T7 - Titanium oxide normal particles (Ti_2O_3) at 4%, T8 - Zinc oxide nano particles (ZnO NPs) at 1% and T9 - Zinc oxide normal particles (ZnO) at 4%. The results indicated that all treatments increased fruit weight (g) and total yield per feddan (ton) compared to control treatment. The trees sprayed with Metalusite or Titanium oxide nano particles gained least percentage of sunburned fruits/ tree (4.47 &7.22 and 3.82 & 7.82 %) in the first and second season, respectively, as well as Zinc oxide normal particles and trees sprayed with Titanium oxide normal particles. Trees sprayed by Metalusite or Titanium oxide normal particles recorded the highest pulp/ fruit ratio and also calcium carbonate or Titanium oxide nano particles or zinc oxide nano particles or normal gave higher values of pulp/fruit %, while the fruits from trees sprayed by potassium silicate or by zinc oxide normal particles or control or Kaolin recorded lower percentages. The longest fruits recorded for trees sprayed by Zinc oxide nano particles (56.44 and 57.00 mm) and Zinc oxide normal (58.41 and 58.01 mm) in the first and second season, respectively. The thickest peel fruit was for fruits from trees sprayed with Kaolin, Potassium silicate, Calcium carbonate, Titanium oxide, Metalusite and Control. The uppermost values of TSS% were in fruit juice for fruit trees sprayed with Calcium carbonate, Metalusite and Titanium oxide normal particles (13.15 & 13.60 %, 13.20 & 13.94 % and 13.76 & 13.37%) in the first and second seasons, respectively. The lowest TSS percentage was found in fruit juice of trees sprayed with Kaolin, Titanium oxide nano and also control in the two seasons. The total acidity percentage in the fruit juice was non-significantly affected by the studied treatments. The fruits of trees sprayed with potassium silicate recorded the lowest TSS/ acid ratio (7.83 and 7.88) in the two seasons, respectively, compared with other treatments exhibited higher TSS/ acid ratio except treatments Kaolin and Zinc oxide nano particles in the second season only.

Keywords: Murcott mandarin, Kaolin, Metalusite, Titanium oxide, Calcium carbonate, yield, Fruit quality, Sunburned.

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1. Introduction

Citrus is one of the most important fruit trees in the world and ranked first among fruit crops in Egypt. The cultivated area with citrus in Egypt has enormously increased through the last decades reaching about 469912 feddan with 429778.6 fed. fruiting area and producing about 4388325 tons with average of 10.21 tons/ fed. Statistics of the Ministry of Agriculture (2020) divided between the new reclaimed soil by 55.73% and the old soil by 44.27% [1]. Total fruiting areas of mandarin and tangerine varieties occupy 109609.5 fed. producing about 1038753 tons with average of 9.48 tons/fed., representing 25.5% of total citrus production [2]. Mandarin fruits stand as the second variety for exportation after orange fruits in Egypt. Murcott (*Citrus reticulate* L.) is one of common mandarin. The trees are vigorous, bushy in shape and have willowy branches, fruits are mainly borne terminally where they are vulnerable to wind, sunburn and frost damage [3]. Sunburn is an important problem in agricultural products grown in arid and semi-arid regions, causes economic losses of up to 40-60% in some years. Sunburn occurs as a result of overheating of the surfaces of fruits exposed to high air temperature and solar radiation from the sun.

Sunburn in mandarin fruits costs growers a lot of economic losses annually due to high temperatures and low relative humidity during the summer in Egypt especially in reclaiming new land. Ultraviolet (UV) radiation is greater at higher elevations and is the greatest contributor to damage. Excess absorbed energy is the greatest contributor to cell death and sunburn. The incidence and severity of sunburn depends upon climatic factor, cultivars, hormonal, nutritional and soil moisture [4]. The damage caused due to sun burning which occurs up to 0.9-19.13% in different varieties [5]. Severe sunburn alters the cuticle even more, and damages both the epidermal and sub epidermal tissues. Cell walls get thicker. Intercellular phenols increase, and the structures of plastids and thylakoids change [6-7]. The quality of the fruits is affected by sun burn [8-9]. Different applications of kaolin clay are made to reduce the sunburn in many kinds of fruits [10]. 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 [11]. Mango leaves sprayed with kaolin had higher average net photosynthesis (Pn), stomatal conductance (gs) and transpiration rate (E) than in bentonite and untreated leaves [12]. Several horticultural techniques such as spraying micronutrients during the fruit's development cycle like zinc are used to control fruit cracking, sunburn, and loss of color [13]. Zinc sulphate as a foliar spray led to decreasing fruit cracking and increasing yield, because of metabolic effects on transport and water uptake [14]. Zinc (Zn) is a vital micronutrient for plants**,** playing crucial roles in fruit development and retention, as well as in overall fruit yield and quality [15-16]. Zinc is essential for the activity of various enzymes, including dehydrogenases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases. Additionally, it aids in tryptophan synthesis, cell division, membrane structure maintenance, and photosynthesis. It functions as a regulatory cofactor in protein synthesis [17]. A more important characteristic of ZnO is their biocompatibility in providing a highly active surface area [18]. The UV protection efficiency of ZnO particles strongly depends on their particle size, method of application and concentration, Applications carried out by means of suspensions of the ZnO molecule show excellent UV protection properties [19]. Potassium silicate provides the plant a 100% available source of silicon and potassium that are essential for optimum plant growth and health. Potassium Silicate strengthens the plant’s internal processes and external defenses. Potassium silicate is the name for a family of inorganic compounds. The most common potassium silicate has the formula K2SiO3, samples of which contain varying amounts of water. These are white solids or colorless solutions [20]. Titanium (Ti) is considered a beneficial element for plant growth. Ti applied via roots or leaves at low concentrations has been documented to improve crop performance through stimulating the activity of certain enzymes, enhancing chlorophyll content and photosynthesis, promoting nutrient uptake, strengthening stress tolerance, and improving crop yield and quality [21]. The use of Ti appears to increase concentrations of some essential elements, both macro and micronutrients. Experiments have demonstrated that Ti chelates are able to promote the development of young plants and can increase the activity of some enzymes [22]. Also, the application of Ti in crop production has been reported to reduce the severity of disease, promote plant growth, and increase photosynthetic rate [23]. Titanium nano particles have photovoltaic properties and improve light absorption and conversion from photovoltaic to electrical and chemical energy, as well as pushing carbon dioxide to protect the green plastid from aging when exposed to long-lasting illumination [24]. Calcium plays significant role in sustaining fruits quality, preserving fruit firmness, proliferation of vitamin C, decreased breakdown of storage rotting. It also defends from membrane disorganization and protects tissue from senescence and sustains the protein manufacturing capability of cell. Calcium increases the mechanical power of cell wall because it is the main component of cell wall as calcium pectate in plants which play significant role in establishment of pedicel attachment to proximal of fruit thus resulted in reduced fruit drop [25]. Commercially preharvest spray of calcium delays senescence and increase consumer acceptance with less damaging effect during fruit storage [26]. Smaller amount of calcium carbonate has been effectively used to decrease softening in fresh fruit. High level of calcium contents in fruit may sustain membrane permeability and decrease the process of ripening during storage and it also increase fruit retention because it stimulates the development of lignin and cellulose and stimulate translocation and formation of carbohydrates [27]. There were no statistically significant differences in hazelnut yield and nut weights or grades for foliar spray multi mineral Metalosate compared to the untreated check in any of the three years of the study [28]. Subbarayappa et al., (2017) study the efficacy of different boron sources on quality and to maximize the yield of pomegranate (var. Bhagwa) [29]. There was significant increase in yield contributing parameters like number of fruits /plants, weight of fruit and fruit yield /plant in T12 (NPK + foliar spray 0.017% B metalosate) treatment followed by T11(NPK + foliar spray 0.0085% B metalosate) treatment. Significantly increased TSS, total sugars content and reduced titratable acidity were observed in T12 treatment followed by T11. Nelson et al., (2020) found that the citrus yield from trees treated with foliar Ca-Metalosate applications were approximately 20% higher on average than trees receiving no Ca supplementations [30]. The juice sugar content (as degree Brix ºBx) was the highest for Ca-Metalosate (10.95 ºBx) and the control had the lowest (10.05 ºBx). The objective of this study is to investigate the effect of some chemical substances (kaolin, potassium silicate, calcium carbonate, Metalusite, titanium and zinc oxide as nano and normal particles) to improve yield, fruit quality and reduce sunburned fruits of Murcott mandarin trees.

2. Materials and methods

This study carried out throughout two successive seasons 2020 and 2021, on 4 years-old on trees of Murcott mandarin *(Citrus reticulata*) budded on Volkamer lemon (*Citrus volkameriana* L.) grown in sandy soil at 3x6 m apart under drip irrigation system and received the same horticultural managements in in a private citrus orchard located at Wady El-Mollak region, Sharkia Governorate, Egypt.

The experiment included nine foliar spray treatments as follows:

- T1 - Control (water spray).
- T2 - Kaolin ($Al4Si_4O_{10}$ $(OH)_8$) at 4%.
- T3 - Potassium silicate at (K_2SiO_3) 4%.
- T4 - Calcium carbonate ($CaCO_3$) at 4%.
- T5 - Metalusite Mult at 2 cm/l.
- T6 - Titanium oxide nano particles (Ti_2O_3 NPs) at 1%.
- T7 - Titanium oxide normal particles (Ti_2O_3) at 4%.
- T8 - Zinc oxide nano particles (ZnO NPs) at 1%.
- T9 - Zinc oxide normal particles (ZnO) at 4%

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. The trees sprayed 4 times at the first of every month from May to August in both seasons. In both seasons, the harvested fruits transported immediately to the fruit laboratory of the Horticulture Department, College of Agriculture, Zagazig University to determine the fruit physical and chemical characteristics. The treatments will be evaluated through the following parameters:

1. Total yield per feddan (ton).
2. Percentage of sunburned fruits per tree (%).
3. Physical fruit quality

- Fruit weight (g).
- Fruit pulp and peel weights (gm).
- Percentage of pulp and peel per fruit (%).
- Peel thickness (mm).
- Seeds weight/ fruit (g).
- Fruit dimensions and fruit shape index

4. Chemical fruit quality

- Total soluble solids percentage (TSS%) in fruit juice measured using a hand Refractometer (A.S.T., Japan).
- Titratable acidity percentage in fruit juice was determined as citric acid by titration against 0.1 N sodium hydroxide solution in the presence of phenolphthalein index as indicator and the total acidity percentage was calculated [31].
- Maturity index (TSS/acid ratio).

2.1. Statistical Analysis

The obtained data tested by the one-way analysis of variance (ANOVA) technique, according to Snedecor et al., (1982) [32]. The treatments arranged in randomized complete block design with three replications. Treatments means separated and compared according to Duncan (1958) test at 0.05 level of significance [33].

3. Results

3.1. Total yield per feddan (ton)

It is clear from Table 1 that the tested treatments significantly affected fruit yield per per feddan (ton) of Murcott mandarin in the two seasons. However, the highest total yield was gained by trees sprayed by Metalusite (14.36 and 11.30 ton/ fed.), Titanium oxide nano (14.85 and 10.48 ton/ fed.), Titanium oxide normal particles (15.34 and 9.80 ton/ fed.), Zinc oxide nano (16.17 and 11.26 ton/ fed.) and Zinc oxide normal (14.59 and 9.27 ton/ fed.) in the first and second seasons, respectively without significant differences between them. The control trees (sprayed with water) produced the lowest yield/ fed. (ton) in the two studied seasons, respectively. The other tested treatments produced intermediate yields.

3.2. Number and percentage of sunburned fruits per tree

Data in Table 1 clearly show that number and percentage of sunburned fruits/tree were significantly affected by the treatments of foliar spraying in both seasons. The highest number of sunburned fruits / trees was recorded for Control trees and trees sprayed by Calcium carbonate at 4% or Zinc oxide nano particles at 1% (28.33 & 32.67, 33.33 & 32.00 and 37.33 & 30.00) in the first and second season, respectively, as well as Kaolin at 4% and Potassium silicate at 4% in the first season and also Zinc oxide normal at 4% in the second season. The lowermost number of sunburned fruits / trees was recorded for trees sprayed with Titanium oxide nano particles at 1% (14.33 and 20.33) in the first and second season, respectively. The trees sprayed with Metalusite at 2 cm/l or Titanium oxide nano particles at 1% gained least percentage of sunburned fruits/ tree (4.47 &7.22 and 3.82 & 7.82 %) in the first and second season, respectively, as well as Zinc oxide normal particles at 4% (4.43%) in the first season and followed trees sprayed with Titanium oxide normal particles at 4% (5.40 and 8.99 %) in the first and second season, respectively.

3.3. Physical fruit quality

3.3.1. Fruit weight

It is quite evident from Table 2 that weight of Murcott mandarin fruits were significantly affected by the studied treatments during the two seasons. All treatments of foliar spray nano or normal particles form increased fruit weight compared to the control in the two seasons. The treatment of Titanium oxide normal particles (Ti_2O_3) at 4% had non-significant increase (152.33gm) with control (151.00gm) in the first season only.

3.3.2. Pulp / fruit percentages

As shown in Table 2 cleared that pulp and peel / fruit percentages were significantly affected by the tested treatments in the two tested seasons. Trees sprayed by Metalusite at 2 cm/l or Titanium oxide normal particles at 4% recorded the highest pulp/ fruit ratio (86.95 & 83.29 and 83.15 & 82.90%) without significant differences between them in the first season and second season, respectively, moreover, the trees sprayed by calcium carbonate at 4% or Titanium oxide nano particles at 1% or zinc oxide nano particles at 1% or normal at 4% gave higher values of pulp/fruit % in the second season only without significant differences between them. The lowest pulp/ fruit ratio resulted from trees sprayed by potassium silicate at 4% (78.80 and 77.45%) in both seasons, also, trees sprayed by zinc oxide normal particles at 4% in the first season and control or Kaolin at 4% in the second season.

3.3.3. Fruit pulp and peel weights (gm)

Data in Table 3 show that the trees were sprayed with Metalusite at 2 cm/l or Zinc oxide nano particles (ZnO NPs) at 1% produced heaviest weights of fruit pulp (148.00 and 139.93gm) in the first season.

While in the second one the heaviest weights of fruit pulp were recorded for trees sprayed by Titanium oxide nano particles at 1% (139.67gm) or trees were sprayed by Zinc oxide nano at 1% (137.67gm) and Zinc oxide normal particles at 4% (138.33gm). The least weight of fruit pulp was gained by trees of control (122.32 and 120.77gm) in the first and second season, respectively, and non-significant differences with Kaolin at 4%, Potassium silicate at 4% and Titanium oxide normal at 4%. The other tested treatments produced intermediate weights of fruit pulp in both seasons. All foliar treatments spray recorded higher values of peel weight without significant differences between them compared with control treatment in the first season only. While in the second season, the treatments Metalusite at 2 cm/l, Titanium oxide nano particles at 1%, Zinc oxide nano at 1% and Zinc oxide normal particles at 4% recorded highest values of peel weight (32.89, 33.55, 31.11and 32.44 gm) respectively without significant differences between them. The lowest peel weight was for treatment of Kaolin at 4% in the second season.

3.3.4. Effect on peel thickness (mm)

It is clear from Table 4 peel thickness of Murcott mandarin fruits was significantly affected by the tested treatments in the two seasons. Peel thickness ranged between 2.50 to 3.06 mm in the two seasons. The thickest peel fruit was recorded for trees sprayed with Kaolin, Potassium silicate, Calcium carbonate, Titanium oxide nano at 1% and Control in both seasons without significant differences between these treatments, and also Metalusite and Titanium oxide nano at 4% in the second season. While, the thinner peel fruit was for trees sprayed with Zinc oxide nano and normal in the two seasons, as well as, Titanium oxide normal in the first season. The other tested treatments produced intermediate values of peel fruit thickness.

3.3.5. Seeds weight per fruit (gm)

It is clear from Table 4 that seeds weight per fruit was significantly affected by the studied treatments in the two seasons. Anyhow, trees sprayed by Zinc oxide nano at 1% gave the highest seeds weight per fruit (5.22 and 4.55 gm) in the first and second season, respectively, as well as the trees sprayed by Metalusite at 2 cm/l in the first season. The least seeds weight per fruit were for fruit sprayed with Calcium carbonate at 4%, Titanium oxide nano at 1% and Zinc oxide normal at 4% in both seasons. The other tested treatments produced intermediate values of seeds weight per fruit.

3.3.6. Fruit dimensions and fruit shape index

It is quite evident from Table 5 that fruit dimensions; i.e. length and width of Murcott mandarin were significantly affected by the tested treatments in the two seasons. However, the fruit length ranged between 49.74-58.41 mm and 51.01–58.01 mm while, the fruit width ranged between 61.19-72.13 mm and 63.53-73.21 mm in the first and second seasons, respectively. The longest fruits recorded for trees sprayed by Zinc oxide nano particles at 1% (56.44 and 57.00 mm) and Zinc oxide normal at 4% (58.41 and 58.01 mm) in the first and second season, respectively. The shortest fruits recorded for trees sprayed by Titanium oxide normal at 4% (49.74 and 50.53mm) in the two seasons, respectively. The other tested treatments produced intermediate values of seeds weight per fruit without significant differences between them for every season. All the tested treatments in the first season except the control showed that non-significant differences between them in fruit width. While, in the second season the treatments of Zinc oxide nano particles at 1% and Zinc oxide normal at 4% produced largest fruits (67.80 & 72.00mm and 72.13 & 73.21mm) in the first and second season, respectively. The trees sprayed by Titanium oxide normal at 4% gave smallest fruit width (63.53mm) in the second season. The other tested treatments produced intermediate values of fruit width. Regarding fruit shape index, the obtained data reveal that the highest fruit shape index values were recorded for fruits produced on trees sprayed by Potassium silicate at 4%, Titanium oxide nano at 1%, Zinc oxide nano particles at 1%, Zinc oxide normal at 4% and control in the first season. While, in second season fruit shape index values for all treatments were non- significant differences between them.

3.4. Chemical fruit quality

3.4.1. Total soluble solids percentage (TSS %)

Data in Table 6 show that the percentage of TSS in the fruit juice of Murcott mandarin ranged between 12.53-13.76 and 12.38-13.94% in the first and second seasons, respectively. The uppermost values of TSS percentage were in fruit juice for fruit trees sprayed with Calcium carbonate at 4%, Metalusite at 2 cm/l and Titanium oxide normal particles at 4% (13.15 & 13.60%, 13.20 & 13.94% and 13.76 & 13.37%) in the first and second seasons, respectively. The lowest TSS percentage was found in fruit juice of trees sprayed with Kaolin at 4%, Titanium oxide nano at 1% and also control in the two seasons. The other tested treatments produced intermediate values of TSS percentage.

3.4.2. Total acidity percentage (%)

As shown in Table 6 the total acidity percentage in the fruit juice was non-significantly affected by the studied treatments in the first season. The lowermost total acidity percentages were gained for Titanium oxide nano particles in the second season, however, the other treatments recorded higher non-significant values of total acidity percentages.

3.4.3. TSS/ acid ratio

Data in Table 6 show that values of TSS/ acid ratio were from 7.83 to 8.76 and from 7.88 to 8.60 in the first and second season, respectively. The fruits of trees sprayed with potassium silicate at 4% recorded the lowest TSS/ acid ratio (7.83 and 7.88) in the two seasons, respectively, compared with other treatments except treatments Kaolin at 4% and Zinc oxide nano particles at 1% in the second season only. The other treatments exhibited the highest TSS/ acid ratio in the both seasons without significant differences between them.

4. Discussion

The obtained results indicated that all treatments increased total yield per feddan (ton) and fruit weight (g) compared to control treatment agreeing with those stated by [34-36]. Abd El-wahed et al., (2024) indicate that the application of ZnONPs and B203NPs on fully bloomed wonderful pomegranate trees, six weeks after full bloom, and one month prior to harvest, resulted in enhanced growth and yield [36]. Mohsen and Ibrahim (2021) showed that the combined treatment of kaolin at 2% + potassium silicate at 0.3% (3 ml/l), was the best treatment and it reduced the sunburned fruits and improved yield, fruit weight, fruit dimensions, peel thickness, TSS% in comparison with other treatments [34]. Viorica et al., (2017) reported that application of foliar fertilizer based on amino acids on apple tree resulted significant increase in yield and fruit weight parameters compared to control but non-significant difference was observed on soluble solids and firmness [37]. Ilie et al., (2018) indicated that all foliar application of amino acids were very effective in increase yield and fruit quality of ‘Redix’ apple cultivar than control unfertilized [38]. Mohamed et al., (2020) found that spraying micronutrients and amino acids for obtaining the best fruit quality with reasonable yield and healthy fruits [39]. El-Badawy (2019) mentioned that sprayed amino acids plus (3 ml/L) micronutrients (150 ppm) induced the highest values of Canino apricot fruit T.S.S. %, fruit total sugars % and V.C (mg/ 100ml juice) [40]. Almutairi et al., (2022) stated that applied of amino acids improved fruit yield, fruit firmness, fruit content of total soluble solids (TSS %), as well as the leaf mineral content and leaf chlorophyll compared with untreated trees [35]. The obtained results for kaolin or calcium carbonates foliar spraying of Murcott mandarin did not affect fruits juice TSS, acidity and TSS/acidity ratio are in line with those reported by [41-42]. Zinc is essential for the activity of various enzymes, including dehydrogenases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases. Additionally, it aids in tryptophan synthesis, cell division, membrane structure maintenance, and photosynthesis. It functions as a regulatory cofactor in protein synthesis [17]. A more important characteristic of ZnO is their biocompatibility in providing a highly active surface area [18]. The UV protection efficiency of ZnO particles strongly depends on their particle size, method of application and concentration, Applications carried out by means of suspensions of the ZnO molecule show excellent UV protection properties [19]. The use of Titanium oxide (Ti) appears to increase concentrations of some essential elements, both macro and micronutrients. Experiments have demonstrated that Ti chelates are able to promote the development of young plants and can increase the activity of some enzymes [22]. Also, the application of Ti in crop production has been reported to reduce the severity of disease, promote plant growth, and increase photosynthetic rate [23]. Titanium nano particles have photovoltaic properties and improve light absorption and conversion from photovoltaic to electrical and chemical energy, as well as pushing carbon dioxide to protect the green plastid from aging when exposed to long-lasting illumination [24]. The highest significant activity level of catalase and superoxide dismutase enzyme activity was by using of nano-TiO_2 [43]. Commercially preharvest spray of calcium delays senescence and increase consumer acceptance with less damaging effect during fruit storage [26]. Smaller amount of calcium carbonate has been effectively used to decrease softening in fresh fruit. High level of calcium contents in fruit may sustain membrane permeability and decrease the process of ripening during storage and it also increase fruit retention because it stimulates the development of lignin and cellulose and stimulate translocation and formation of carbohydrates [27]. Subbarayappa et al., (2017) study the efficacy of different boron sources on quality and to maximize the yield of pomegranate (var. Bhagwa) [29]. There was significant increase in yield contributing parameters like number of fruits /plants, weight of fruit and fruit yield /plant in T12 (NPK + foliar spray 0.017% B metalosate) treatment followed by T11(NPK + foliar spray 0.0085% B metalosate) treatment. Significantly increased TSS, total sugars content and reduced titratable acidity were observed in T12 treatment followed by T11. Nelson et al., (2012) found that the citrus yield from trees treated with foliar Ca-Metalosate applications were approximately 20% higher on average than trees receiving no Ca supplementations [30]. The juice sugar content (as degree Brix ºBx) was the highest for Ca-Metalosate (10.95 ºBx) and the control had the lowest (10.05 ºBx).

5. Conclusions

It concluded that the foliar spray of of Murcott mandarin trees by kaolin at 4%, potassium silicate at 4%, calcium carbonate at 4%, Metalusite at 2 cm/l, titanium oxide nano particles at 1%, titanium oxide normal particles at 4%, Zinc oxide nano particles at 1% and Zinc oxide normal particles at 4% increased fruit weight (g) and total yield per feddan (ton) compared to control treatment. The fruits of trees sprayed with potassium silicate recorded the lowest TSS/ acid ratio (7.83 and 7.88) in the two seasons, respectively, compared with other treatments exhibited higher TSS/ acid ratio except treatments Kaolin and Zinc oxide nano particles in the second season only.

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