Horticulture Research Journal, 2 (4), 1-14, December 2024, ISSN 2974/4474

Effect of Foliar Application with Potassium Rates and Zinc Sources on Washington Navel Orange Trees

Hussein S. Ahmed and Wafaa A.M. Shehata

Citrus Research Department, Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

ABSTRACT

This investigation was carried out during two successive seasons (2020 and 2021) to study the effect of foliar application of potassium sulfate rates combined and different sources of zinc on Washington Navel orange (*Citrus sinensis*) trees grafted on sour orange rootstock (*Citrus aurantium*). Seven foliar spray treatments are conducted as follows: three different concentrations of potassium sulfate at 1, 2, and 3% combined with two sources of zinc: sugar alcohol zinc (SA-Zn) at 0.5% and chelated zinc (Zn-EDTA) at 0.5%, in addition to the control treatment. The best results were obtained by spraying potassium sulfate at 2% and sugar alcohol zinc (SA-Zn) at 0.5%, which was superior to improving tree nutritional status, fruit set percentage, yield efficiency, bio-chemical contents, mineral content of leaves and fruit quality.

Keywords: Navel orange- Sugar alcohol zinc- Zn-EDTA- Potassium sulfate and Fruit set percentage.

INTRODUCTION

One of the most significant citrus fruits cultivated in the Mediterranean basin is the Navel orange (*Citrus sinensis* L.). Navel oranges are the most widely consumed citrus fruit in Egypt. Washington navel oranges are the most popular in Egypt; their fruitful acreage reached over 166524 Fed., yielding approximately 12.944 tons/Fed. (Source: Ministry of Agriculture and Land Reclamation/Annual Report, 2021).

Potassium is one of the most significant macro elements that are highly mobile at all levels in plants, from individual cells to phloem and xylem tissue. Where it is mainly related to the flow of nutrients, water, and carbohydrates within plant tissue, potassium is involved in activation of enzymes that affect starch, protein, and adenosine triphosphate (ATP) production, which may regulate photosynthesis rate. Significant roles for this cation include photosynthesis, turgor-related activities, and stomatal function, also potassium enhances the size, color, juice content, and flavor of fruit. (Tiwari, 2005 and Ashraf et al., 2010).

Zinc is essential for plants' structural, regulatory, and catalytic processes, including photosynthesis, the metabolism of carbohydrates, and the synthesis of starch and sugar. (Hacisalihoglu and Leon, 2003). All crops, but especially major staple crops, are negatively impacted by zinc shortages in terms of yield and quality. Citrus cultivars are particularly vulnerable to zinc deficiency, and the symptoms of zinc insufficiency are well-established (Alloway, 2008 and Yan et al., 2010). Since zinc is not a mobile element in plants like other micronutrients, deficiencies are initially noticed in the youngest leaves (Fageria et al., 2003). One efficient, quick, and affordable way to treat zinc deficiency is to apply zinc to the aerial sections of plants (Swietlik, 2002a).

Sugar alcohols are natural alcohols produced from the enzymatic transformation of sugar and then artificially reacted with nutritional mineral elements to produce fertilizer. They can be quickly absorbed by the leaves, treating symptoms of nutrient deficiency and at the same time supplying the plant with sugar alcohols that enter directly into metabolic cycles within the tissue. On the other hand, it prevents the activity of most pathogenic bacteria that may infect agricultural crops, and this is a unique feature of fertilizers with alcoholic sugar elements. Also, the degree of stability of the association of alcoholic sugars with mineral elements varies according to the number of OH groups and their stereo position (axial - horizontal), and thus the number of coordination bonds. The greater the number of these bonds with the element, the greater the degree of stability of alcoholic fertilizer. A high degree of stability can be obtained if hydroxides of mineral elements used to react with alcoholic sugar, resulting in the release of H2O resulting from the reaction of the metal hydroxyl group and the sugar alcoholic hydroxyl group. Based on the degree of stability of the alcoholic fertilizer, the method of addition is determined. Foliar spraying does not require a high degree of stability, unlike ground addition. Alcoholic sugars bind with metal anions, unlike traditional chelating compounds (EDTA, ADA, and others). Sugar alcohol zinc (SA-Zn) liquid is one type of fertilizer chelated with zinc and contains sorbitol alcohol, which carries mineral nutrients for transport into the bark. It can also greatly improve the movement, absorption, transport and promotion of zinc utilization, quickly meet the needs of crops and promote plant growth (Halil and Ozgur, 2021).

The aim of the study was to determine the effects of foliar spraying for three different concentrations of potassium sulfate at 1, 2 and 3% combined with two sources of zinc: sugar alcohol zinc (SA-Zn) at 0.5% and chelated zinc (Zn-EDTA) at 0.5% on tree yield, fruit quality properties.

MATERIALS and METHODS

This investigation was carried out during two successive seasons (2020 and 2021) on 35-year-old Washington navel orange (*Citrus sinensis*) trees grafted on sour orange rootstock (*Citrus aurantium*) grown in a private orchard located in Qalyubia Governorate, Egypt. Navel orange trees were planted at (5 × 5) meters apart (168 trees/fed.) in clay loam soil with a surface irrigation system. The trees were carefully chosen to ensure that they were healthy, free of disease, and as uniform in size and vigorous as possible.

Seven treatments were conducted as follow: -

T_1- Control (spraying with water).

T_2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.

T_3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.

T_4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.

T_5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.

T_6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.

T_7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.

All treatments were foliar sprayed three times; the 1st date (after flowering), the 2nd date (70% leaf expansion) and the 3rd date (after stability of fruit set)**.** Triton B was used as a wetting ingredient in all foliar solutions at a rate of 0.1% and spraying continued until runoff. The proper horticultural practices used by the Ministry of Agriculture and Land Reclamation were routinely applied to all allocated trees.

Table (1). Analysis of the experimental orchard soil, both physically and chemically.

Analytical Physical	Relevance	Chemical Analysis			
		Meq/L of cations		Meq/L of anions	
Rough sand	10.5%	Ca^{2+}	7.8	CO_3^{2-}	Zero
Pristine sand	18.4%	Mg^{2+}	3.05	HCO_3^-	4.1
Stillness	17.0%	Na^+	2.90	Cl^-	3.95
Clay	46.9%	K^+	1.04	SO_4^{2-}	7.50
Class texture	**Loam with sandy texture**	N accessible at 22.50 mg/kg			
pH of the soil	6.8	P accessible at 10.94 mg/kg			
E.C., ds/m	1.60	K accessible at 165.10 mg/kg			
Plant material	3.1%				

Analysis and Research Section. Arid Land Agricultural Research and Services Center.

Measurements and analysis

1. Fruit set percentage.

For every tree, the proportion of fruit set and woody inflorescence at the flower balloon stage is calculated for each of the four main branches. The number of fruit set was determined around the middle of June.

Percentage of fruit set = (Total number of fruit set / Total number of flowers) × 100.

2. Yield efficiency.

Tree size, measured in canopy volume, and tree height were computed using the following formula: 0.5236 x height x diameter square (Turrell, 1946). Every year, the amount of fruit produced is documented. Yield efficiency was measured as yield in relation to tree volume (Yield efficiency = kg of fruits / m^3 canopy of tree).

3. Fruit quality attributes.

At harvest time, in the 1st week of January, a sample of ten fruits per replicate was chosen in order to assess the fruit quality as below:

a) Fruit physical attributes. Fruit peel thickness (mm), average fruit weight (g), size (ml) and juice percentage.

b) Fruit chemical attributes. Total soluble solids percentage, total acidity percentage and Vitamin C (mg/ 100 g. juice) were calculated as well. (A.O.A.C., 2000).

4. Bio-chemical contents

a) Leaf pigments contents

Chlorophyll (a), (b) and total chlorophylls as well as carotenoids were measured using the Beckman Du 7400 Spectrophotometer at wavelengths of 663, 647, and 470 MU. The results were computed using the equation given by (Nornai, 1982) and expressed as (mg/100g FW).

b) Leaf Indole and Phenol contents

Total phenols were calculated as mg/g dry weight as reported by (Daniel and George, 1972), and total indoles were calculated as mg/g dry weight in accordance with **(**Larsen et al., 1962), amended by (Selim et al., 1978).

5. Mineral content of leaves

In October, mature leaves from non-bearing spring flushes were gathered for the two seasons to determine leaf mineral content in leaves.

a) Total nitrogen using the semi-micro Kjeldahl technique, as ascribed by (Pregl, 1945).

b) Phosphorus spectrophotometer at 882 volts using the (Murphy and Riely, 1962) technique.

c) According to (Brown and Lilleland, 1946), a flame photometer was used to assess potassium.

d) Using an atomic absorption spectrophotometer, the amounts of zinc was measured. (Chapman and Part, 1961).

e) Total nitrogen and the hydrolysis of carbohydrates in mature leaves (Dubois et al., 1956) then the C/N ratio was calculated as total carbohydrates to total nitrogen ratio.

6. Statistical analysis

The experimental layout was a one-way ANOVA with seven treatments, each with three replications, where each replicate was represented by a single tree. Data were analyzed using ANOVA tests (p 0.05), according to the experiment design (Snedecor and Cochran, 1972). Differences between means were compared using the Duncan Multiple Range Test (DMRT) (Duncan, 1955). Statistical analyses were performed using Mstat-C software.

RESULTS and DISCUSSION

1. Fruit set percentage.

Concerning the combination between potassium sulfate rates applied foliar with different zinc sources, **Table (2)** displays statistics that demonstrated a noteworthy impact throughout the course of the two seasons. In contrast, potassium sulfate at 3% combine with (SA-Zn) at 0.5% (T_7) gave the highest fruit set percentage values whereas potassium sulfate treatment at 1% combined with (Zn-EDTA) at 0.5% (T_2) shows the lowest value. It can be concluded that fruit set percentage positively increased with more of potassium sulfate rate applications. Orange is a potassium and zinc-loving plant. Potassium affects cell division fruit, maintains the permeability and integrity of cells, and has a substantial impact on orange physiology and quality. It is a necessary nutrient component in the expansion and advancement of orange and a major regulator of orange tree metabolism and development (Thomas et al., 2018).

Table (2). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees fruit set percentage during the two successive seasons.

Parameter / Treatments	Fruit set percentage	
	1stSeason	2ndSeason
T1- Control (foliar spraying with water).	1.25C	1.38C
T2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	0.75E	0.69E
T3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	0.85D	0.90D
T4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	1.06CD	1.04CD
T5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	3.05BC	3.06BC
T6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	3.57B	3.71B
T7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	4.84A	4.89A

At the 5% level, there is no significant difference between the mean and the same letter.

2. Yield efficiency.

With regard to data in **Table (3),** it was determined that, for both analyzed seasons, foliar application of Potassium sulfate at 3% combine with (SA-Zn) at 0.5% (T_7) significantly increased navel orange tree yield efficiency (kg/m^3 canopy) during both seasons when compared to other treatments. In this regard we found that, (T_7) gave the highest yield efficiency values and (T_2) was the lowest. It was reported that potassium function in physiological processes including osmosis, cell division and growth, and protein synthesis can account for changes in fruit characteristics like size and color (Liu et al., 2000). Actually, though (Erdal and Onur 2018) reported that potassium foliar application increased fruit color and size in sweet cherry. Likewise, the influence of zinc on fruit quality characteristics in the study can be justified by the important role zinc plays as a cofactor in the structure and function of many enzymes (Andreini and Bertini, 2012), in various processes like photosynthesis, carbohydrate metabolism, and regulation of phytohormones (Gupta et al., 2011). In fact, according to (Zhang et al., 2013), applying zinc can greatly increase the quantity and quality of fruit produced by date palm, oranges, and apples. Research by (Kumari et al., 2020) found that there was a significant increase in production and orange fruit quality when (SA-Zn) was applied. Also, fruit quantity metrics such as productivity, weight of fruits per tree, and number of fruits per tree were modified by the usage of zinc and sugar. One possible explanation for the observed rise in the yield efficiency indicator, as presented in **Table (3),** following the application of sugar alcohols is that the sugar alcohols facilitate the transfer and migration of photosynthetic products from the leaves to the growth-active regions. The movement of nutrients from the source to the drain enhances physiological functions, speeds up photosynthesis, and increases the build-up of other elements and carbohydrates Abdullah et al. (2023).

Table (3). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees yield efficiency during the two successive seasons.

Parameter / Treatments	Yield efficiency (kg/m^3 canopy)	
	1stSeason	2ndSeason
T1- Control (foliar spraying with water).	1.01C	1.02C
T2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	0.75D	0.70DE
T3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	0.80D	0.83D
T4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	0.90CD	0.85D
T5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	1.83B	1.84B
T6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	2.90AB	2.92AB
T7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	3.04A	3.03A

At the 5% level, there is no significant difference between the mean and the same letter.

3. Fruit quality attributes

a) Fruit physical attributes

With regard to foliar application of potassium sulfate rates combined with different sources of zinc, data presented in

Table (4), Figures (1 and 2) showed significant effects during the two seasons. Foliar spray of potassium sulfate at all application rates combined with (SA-Zn) at 0.5% had the highest values for the fruit weight, fruit size, and fruit juice, while foliar application of potassium sulfate rates combined with (Zn-EDTA) at 0.5% recorded the least values for both studied seasons.

The presented results were consistent with the research conducted by (Kumari et al., 2020), which indicated that the foliar application of sugar alcohol zinc gave a higher sweet orange fruit weight led to a significant increase in production. Regarding the effect of potassium sulfate application rates bolstered by foliar spraying of various zinc sources on the navel orange fruit weight, fruit size and fruit juice displayed in **Table (4)** and **Figure (2),** are were confirmed that potassium sulfate at 3% (K_3) combined with (SA-Zn) at 0.5% (T_7) significantly increased the fruit weight (g), fruit size (ml.) and juice percentage in both research seasons. On the other hand, the foliar application of potassium sulfate at 1% (K_1) with (Zn-EDTA) at 0.5% (T_2) provided the minimum fruit weight (g), fruit size (ml.) and juice percentage. As for the effect of potassium sulfate rates supported by different zinc sources on the results of navel orange peel thickness (mm) shown in **Figure (1)** verified that the fruit peel thickness was dramatically raised in both study seasons by applying chelated zinc (Zn-EDTA) at 0.5%. However, this was notable variations in the peel thickness (mm) following foliar treatment with sugar alcohol zinc (SA-Zn) at 0.5%. In this regard, foliar application of potassium sulfate at 1% (K_1) plus (Zn-EDTA) at 0.5% (T_2) significantly increased peel thickness (mm). Whereas, foliar application of potassium sulfate at 3% (K_3) plus (SA-Zn) at 0.5% (T_7) gave the lowest significant value for peel thickness (mm) in both seasons. Previous research on Kinnow mandarin has shown that application on the leaves of sugar alcohol zinc at 0.6% improves fruit yield and quality because Zinc sprays may increase photosynthetic capability since sugar alcohol zinc is a necessary structural and regulatory cofactor for a variety of enzymes, including carbonic anhydrase (Razzaq et al., 2013). This study shows that foliar application of zinc sugar alcohols can increase the fruits size, weight, the amount of fruit produced by a plant and its yield navel orange. According to (Razzaq et al., 2013), foliar application of sugar alcohol zinc resulted in an increase in the size of the fruit, namely in sweet orange and mandarin. This study shows that foliar application of zinc sugar alcohols can increase the fruits size, weight, the amount of fruit produced by a plant and its yield navel orange. Therefore, potassium sulfate supplementation is an important measure to improve fruit quality (Montanaro et al., 2010).

Table (4). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees some physical attributes of the fruit during the two successive seasons.

Parameters / Treat.	Fruit weight (g)		Fruit size (ml.)	
	1st Season	**2nd Season**	**1st Season**	**2nd Season**
T_1- Control (foliar spraying with water).	214.75CD	217.11CD	241.25CD	240.55D
T_2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	167.25E	153.67E	225.70D	228.65E
T_3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	193.45D	200.00CD	239.18CD	238.00DE
T_4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	224.30C	229.10C	254.75C	258.25C
T_5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	261.40B	264.50B	276.85B	280.00AB
T_6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	275.15AB	287.70A	291.34A	289.50A
T_7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	288.75A	298.70A	307.28A	311.96A

At the 5% level, there is no significant difference between the mean and the same letter.

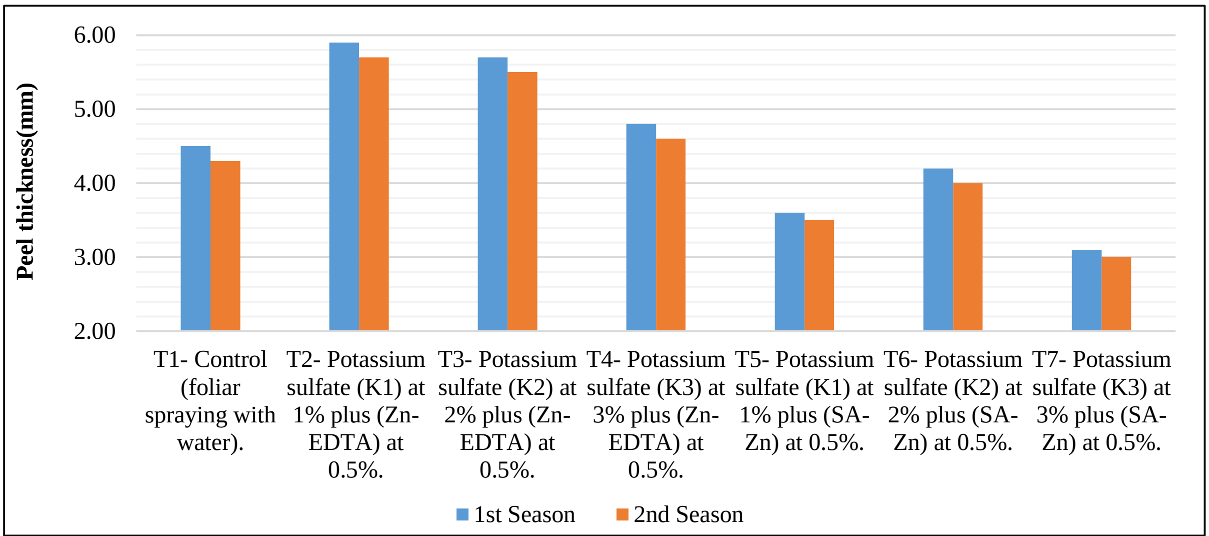


Fig. (1). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees Peel thickness (mm) of the fruit during the two **successive** seasons.

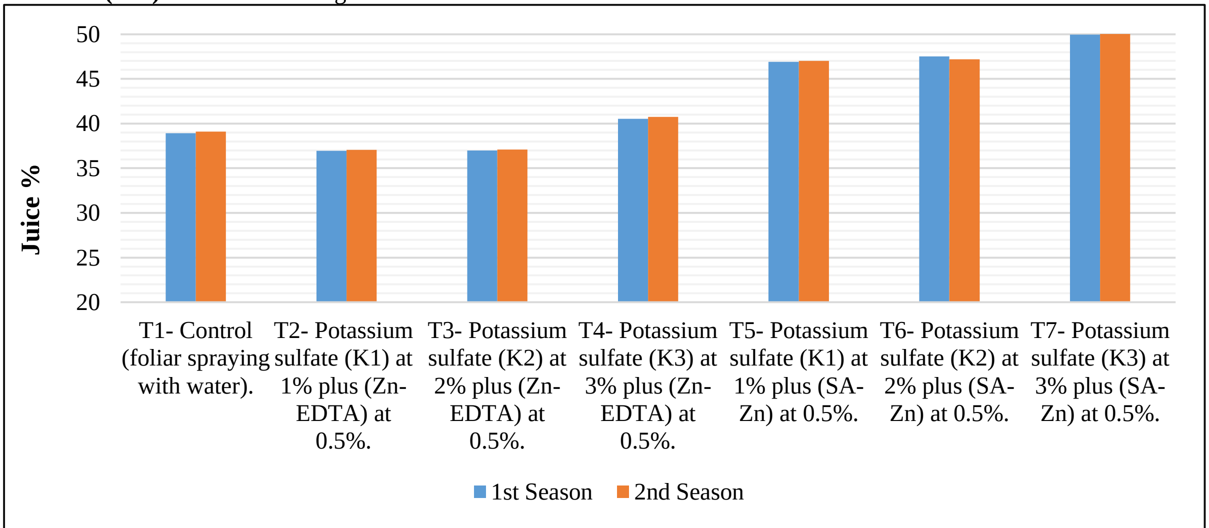
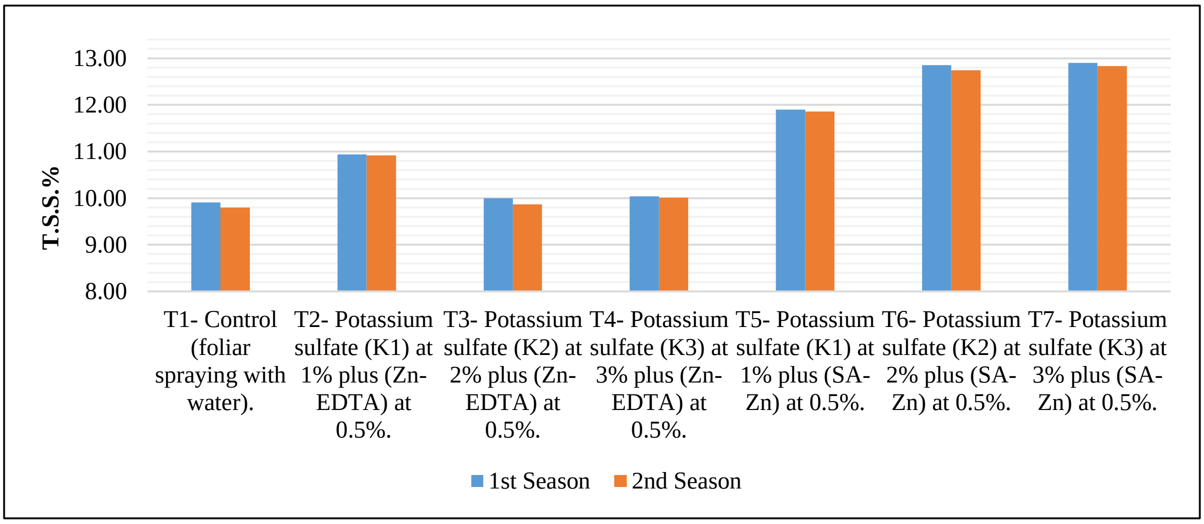


Fig. (2). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees Juice percentage of the fruit during the two **successive** seasons.

b) Fruit chemical attributes

Figs. (3, 4 and 5) showed that all treated trees produced a significantly high juice T.S.S. percentage, juice total acidity percentage and vitamin C content (mg/100 ml juice) compared with other trees. With regard to the foliar applications of different potassium sulfate rates combined with applied sources of zinc data showed significant effects during the two seasons. While, foliar application of potassium sulfate at 3% (K_3) with (SA-Zn) at 0.5% (T_7) had the highest values of the juice T.S.S. percentage and vitamin C content (mg/100 ml juice), the control (spraying with water) (T_1) was the least elevated. On the other hand, there are no significant differences between the treatments to which (SA-Zn) was added. The statistics that were provided aligned with the findings of (El-Mahdy et al., 2019), who found that applying potassium sulfate at varying rates improved the chemical properties of Balady mandarin. Previous research on Kinnow mandarin has shown that application on the leaves of sugar alcohol zinc at 0.6% improved vitamin C content in juice (Razzaq et al., 2013). In the present study, the effects of sugar alcohol zinc (SA-Zn) at 0.5% were greater than chelated zinc (Zn-EDTA) at 0.5% in results about juice T.S.S. percentage and vitamin C, potentially resulting from the Zn chelation of sugar alcohols to generate sugar alcohol zinc. In this regard, when compared to other trees, data in **Table (5)** demonstrated that all treated trees produced a noticeably higher juice T.S.S. percentage. In contrast, Juice total acidity percentage the control (spraying with water) (T_1) had the highest values. Because sugar alcohol fertilizers are rapidly absorbed by the shoots and address symptoms of nutrient deficiency while also providing the plant with sugar alcohols that immediately enter the metabolic cycles within the plant tissue, they are highly valuable in agriculture. The two forms of sugar that are carried to sink organs by photosynthesis are sucrose and sorbitol; in trees, sorbitol is the primary form that is carried to fruit. Also, several enzymes in fruit convert sucrose and sorbitol into reducing sugars like fructose and glucose (Yong Zhang et al., 2014). The current study found that the foliar application of sugar alcohol zinc (SA-Zn) at 0.5% significantly increased the T.S.S. and vitamin C content of fruit juice during the mature fruit stage, most likely as a result of fructose and glucose transformations. And in light of this, the concentration of reducing sugars in mature fruit increased significantly in all (SA-Zn) treatments. Sorbitol in the fruit is converted to glucose and fructose for storage or participation in other metabolic processes. Fruit sugar levels were increased due to the conversion of sucrose to fructose and glucose after foliar application with (SA-Zn).

Fig. (3). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees juice T.S.S percentage of the fruit during the two **successive** seasons.



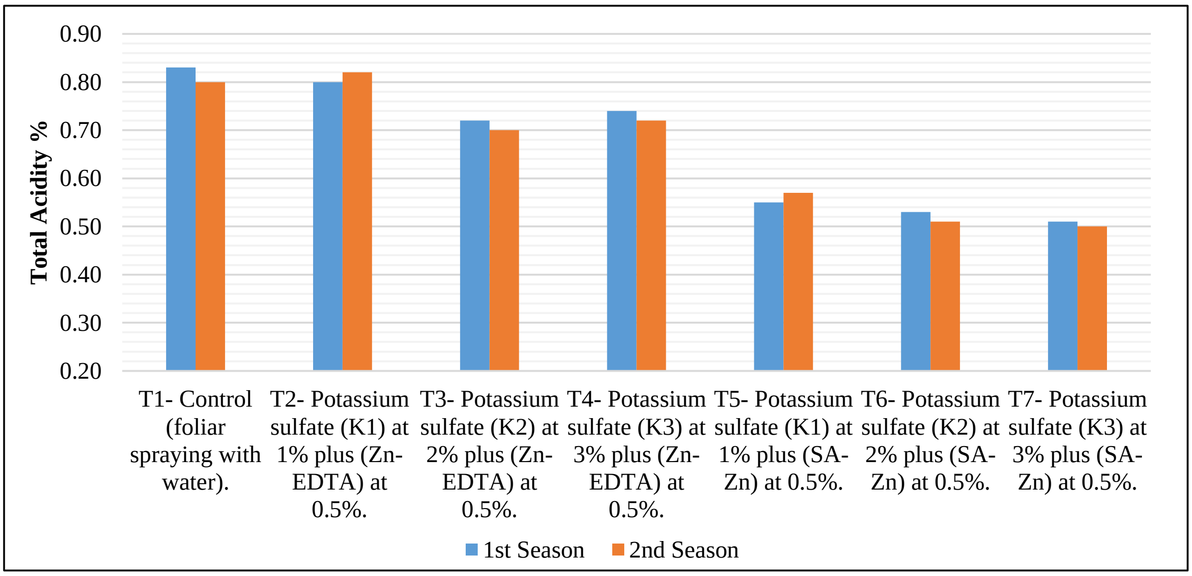


Fig. (4). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees juice total acidity percentage of the fruit during the two **successive** seasons.

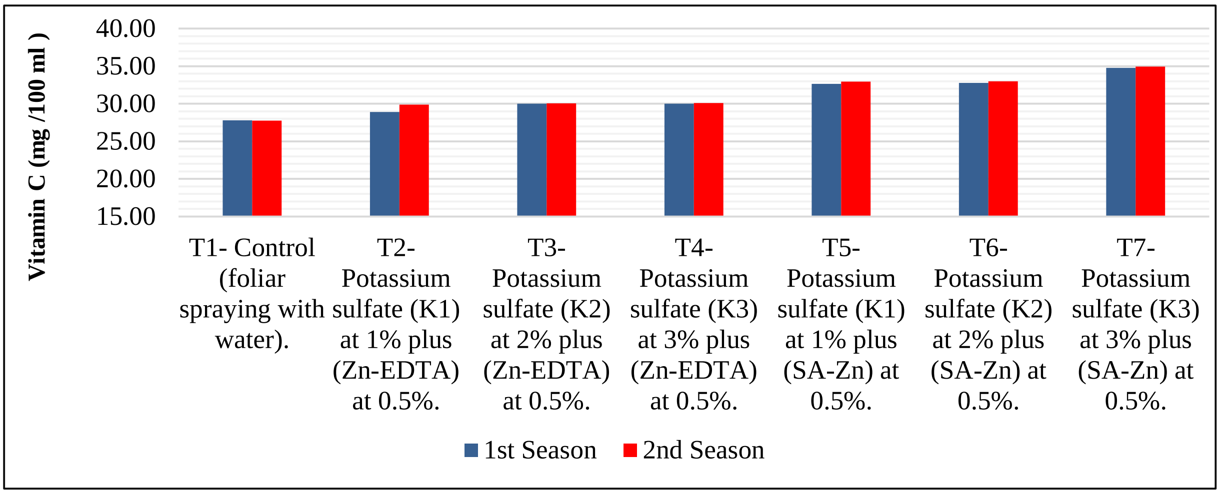


Fig. (5). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees juice Vitamin C (mg/100 ml) of the fruit during the two **successive** seasons.

a) Leaf pigments contents:

Data in **Table (5)** showed that maximum leaf chlorophyll a, chlorophyll b and total chlorophylls content (mg/g F.Wt.) were recorded by potassium sulfate at 3% (K_3) with (SA-Zn) at 0.5% (T_7), also, maximum Carotenoids (mg/g F.Wt.) content was obtained by potassium sulfate at 2% combined with (SA-Zn) at 0.5% (T_6). Lowest leaf pigments contents were recorded in the control (spraying with water) (T_1). According to research by (Kumart et al., 2020), applying sugar alcohol zinc topically on orange fruit improves its sugar content and stimulates the activity of metabolic enzymes. From the results it could be concluded that leaf pigments contents of Washington navel orange trees greatly respond to potassium sulfate concentrations as a foliar application supported with two sources of Zinc at (0.5%) to improve its nutritional status as compare control particular applying potassium sulfate at 3% (K_3) combined with foliar application of sugar alcohol zinc (SA-Zn) at 0.5%. Previous results had suggested that applied foliar zinc in March and repeated in May and July treatments could raise the leaf pigments contents of Balady mandarin trees grown under Egyptian Sandy soil condition (Sarrwy et al., 2012).

Table (5). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees pigments found in leaves (mg/g F.Wt.) during the two successive **seasons.**

Treatments \ Parameters	Chlorophyll a (mg/g F.Wt.)	Chlorophyll b (mg/g F. Wt.)	Total chloro. (mg/g F.Wt.)	Carotenoids (mg/g F.Wt.)
	1stSeason			
T1- Control (foliar spraying with water).	0.91E	0.43C	1.35C	0.86E
T2- Potassium sulfate (K1) at 1% plus (Zn-EDTA) at 0.5%.	1.01D	0.48C	1.58D	1.09D
T3- Potassium sulfate (K2) at 2% plus (Zn-EDTA) at 0.5%.	1.19C	0.62B	1.88D	1.21D
T4- Potassium sulfate (K3) at 3% plus (Zn-EDTA) at 0.5%.	1.17C	0.63B	1.86D	1.72C
T5- Potassium sulfate (K1) at 1% plus (SA-Zn) at 0.5%.	1.54B	0.96AB	3.02C	2.07B
T6- Potassium sulfate (K2) at 2% plus (SA-Zn) at 0.5%.	1.79AB	1.03A	4.03B	3.45A
T7- Potassium sulfate (K3) at 3% plus (SA-Zn) at 0.5%.	1.89A	1.11A	5.11A	2.26B
	2ndSeason			
T1- Control (foliar spraying with water).	0.86CD	0.38C	1.29C	0.82E
T2- Potassium sulfate (K1) at 1% plus (Zn-EDTA) at 0.5%.	0.90CD	0.45C	1.47D	1.13D
T3- Potassium sulfate (K2) at 2% plus (Zn-EDTA) at 0.5%.	1.16C	0.64B	1.89D	1.23D
T4- Potassium sulfate (K3) at 3% plus (Zn-EDTA) at 0.5%.	1.21C	0.65B	1.81D	1.91C
T5- Potassium sulfate (K1) at 1% plus (SA-Zn) at 0.5%.	1.63B	0.94AB	3.07C	2.25B
T6- Potassium sulfate (K2) at 2% plus (SA-Zn) at 0.5%.	1.81AB	1.09A	4.19B	3.50A
T7- Potassium sulfate (K3) at 3% plus (SA-Zn) at 0.5%.	1.93A	1.18A	5.37A	2.35B

At the 5% level, there is no significant difference between the mean and the same letter.

c) Leaf indol and phenolic contents

The findings displayed in **Table (6)** demonstrated that total indoles reached the highest significant values in response to potassium sulfate at 2% combined with (SA-Zn) at 0.5% (T_6). Moreover, most experimental foliar applications improved leaf growth promoters with sugar alcohol zinc (SA-Zn) at 0.5% foliar sprays significantly. While, control (spraying with water) (T_1) reduced leaf growth promoters in both seasons. As for, total leaf phenolic content the opposite can be traced, potassium sulfate at 2% (K_2) with (SA-Zn) at 0.5% (T_6) treated trees were significantly lower than values of the control (spraying with water) (T_1). Comparable results were documented by (Halil and Ozgur, 2021) fertilizers containing alcoholic sugar components have a unique property that inhibits the action of most pathogenic bacteria that could impact agricultural crops. This can lead to a decrease in total phenolics and an increase in total indoles. (Abdullah et al., 2023) reported similar results, indicating that the reason for the increase in the study's indicators could be related to the significant role sugar alcohols play in facilitating the transfer and movement of photosynthesis products from leaves to areas actively growing and in transporting macro- and micronutrients through the phloem. Through the action of the enzyme IAA-oxidase, the transfer of nutrients from the source to the drain is improved, leading to an increase in the auxin concentration. As a result, root growth is activated, which has a positive impact on the traits under investigation.

Table (6). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees leaf indol and phenolic contents during the two **successive** seasons.

Parameters / Treatments	Indol (mg/100g D.Wt)		Phenolic (mg/100g D.Wt)	
	1st Season	**2nd Season**	**1st Season**	**2nd Season**
T_1- Control (foliar spraying with water).	0.88EF	0.81E	1.48A	1.53A
T_2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	1.13E	1.17DE	1.38A	1.30B
T_3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	1.31D	1.27D	1.02B	1.13C
T_4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	1.39D	1.43C	1.16B	1.09C
T_5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	2.95C	2.86B	0.90C	0.96D
T_6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	4.78A	4.71A	0.55CD	0.58E
T_7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	3.28B	3.76AB	0.72C	0.62E

At the 5% level, there is no significant difference between the mean and the same letter.

5. Mineral content of leaves.

The results shown in **Table (7a)** show that after foliar application of potassium sulfate at 2% with sugar alcohol zinc (SA-Zn) at 0.5% (T_6), there was a significant increase in the percentage of potassium in the leaves; however, after foliar application of potassium sulfate at 3% with SA-Zn at 0.5% (T_7), there was an increase in the percentage of nitrogen in the leaves; and in all data, the control (spraying with water) (T_1) decreased in both seasons. Low potassium conditions have been shown to cause an accumulation of dissolved nitrogen compounds and a decrease in plant nitrogen content. This implies a relationship between potassium and protein metabolism. It was also shown that a potassium shortage causes slower photosynthesis and greater respiration (Kumari et al., 2020).Regarding the phosphorus percentage in the leaves, the current investigation revealed that, when applying two sources of zinc and varying quantities of potassium sulphate by foliar spraying, there were no appreciable variations between the treatments. According to (Nasir et al., 2016), fruit biochemical features were markedly improved by K and Zn treatments. The direct integration of potassium into the transportation of sugars and carbohydrates (Hassanein et al., 2021), zinc's participation in photosynthesis (Alloway, 2008), and zinc's encouragement of different enzymes required for biochemical reactions could all have contributed to these effects. Additionally, it was discovered that potassium sulfate at 2% (K_2) supported with (SA-Zn) at 0.5% (T_6) makes a good combination to enhance the macronutrients in leaves. While, The importance of using sugar alcohol fertilizers in agriculture is due to the fact that they are quickly absorbed by the shoots, treating symptoms of nutrient deficiency and at the same time supplying the plant with sugar alcohols that enter directly into the metabolic cycles within the plant tissue (Abdullah et al., 2023).

Table (7a). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees mineral content of leaves during the two successive seasons.

Parameters / Treat.	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
T_1- Control (foliar spraying with water).	2.12D	2.15D	011A	0.12A	0.91D	0.80D
T_2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	2.28C	2.29C	0.11A	0.11A	1.21C	1.26C
T_3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	2.39B	2.40B	0.12A	0.12A	1.24C	1.27C
T_4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	2.46AB	2.48AB	0.12A	0.12A	1.31BC	1.39C
T_5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	2.34BC	2.41BC	0.11A	0.12A	1.49B	1.51B
T_6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	2.51A	2.55A	0.12A	0.13A	1.70A	1.72A
T_7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	2.63A	2.67A	0.12A	0.12A	1.56AB	1.53B

At the 5% level, there is no significant difference between the mean and the same letter.

As for data presented in **Table (7b)** it is evident that foliar application of potassium sulfate at 2% (K_2) with (SA-Zn) at 0.5% (T_6) and Potassium sulfate at 3% (K_3) with (SA-Zn) at 0.5% (T_7) significantly increased the navel orange tree C / N ratio during the two seasons when compared to other treatments. In additions, spraying the two zinc sources gave a different trend, whereas, sugar alcohol zinc (Zn-SA) at 0.5% had a significant increase in the C/N ratio during the 1st and 2nd season. In contrast, foliar application of potassium sulfate at 2% (K_2) supported with (SA-Zn) at 0.5% (T_6) the greatest values for C/N ratio and the control (spraying with water) (T_1) was the lowest. We may conclude that in the presence of (SA-Zn) at 0.5%, which enhanced the protein in the cells, the C/N ratio positively increased with an increased potassium sulfate rate application. The obtained results regarding the carried out treatments on shoot Carbohydrates/ nitrogen contents goes partially with the earlier findings of (Abbas and Fares, 2008) who demonstrated how potassium is a necessary element for plants to carry out their usual biological functions, including cell division, growth, and respiration. It also allows plants to use solar energy to convert carbon dioxide and water into sugars. Gurjar and Rana (2014) suggested that the increased photosynthesis brought on by potassium sulfate application may have contributed to the rise in fruit weight by causing more carbohydrates to accumulate.

Two distinct sources of zinc and varying potassium sulfate levels applied had a significant and favorable effect on the uptake of Zn **Table (7b).** Foliar application of potassium sulfate at (2% or 3%) combined with (SA-Zn) at 0.5% (T_6) and (T_7) considerably showed the highest mean Zn uptake, for both season of study. The higher uptake of zinc could be attributed to sugar alcohol zinc (SA-Zn) at 0.5% application, which activated the enzymatic system and facilitated zinc translocation to other plant sections (Yadav et al., 1991). These results are consistent with those previously reports by (Tandon, 1992).The current study demonstrates how adding zinc can enhance plant development via a number of methods. Apart from their favorable impacts on micronutrient absorption, zinc also has a role in the uptake of other nutrients, promoting root and shoot development and enhancing the plant's ability to withstand various stressors (Quaggiotti et al., 2004). The results showed that applying sugar alcohol zinc (SA-Zn) spray to trees at various phases of growth enhanced the amount of Zn in the leaves. This may also account for the superior development and nutrient uptake of navel orange trees of plants treated with zinc. According to research, applying sugar alcohol zinc (SA-Zn) to the soil did not significantly raise the content of Zn in the plants. However, the fortification of this nutrient was achieved through foliar spray, which offers a productive way to accomplish bio fortification (Alwakel et al., 2021). The application of sugar alcohol zinc (SA-Zn) spray to citrus tree leaves at various growth stages was shown to increase the concentration of zinc in the leaves, according to the results. Previous research has suggested that applying foliar sugar alcohol zinc in May and repeated in July treatments could raise the Zn concentration in leaf elements (Neilsen and Neilsen, 2002). Sugar alcohol zinc foliar treatment was reported to have raised three times the Zn content in the leaves of three different pear cultivars (Erdem and Öztürk, 2012). Comparable results were also observed by applying (SA-Zn) to apples topically (Aglar et al., 2016; Zhang et al., 2016). In a similar trend, (Halil and Ozgur, 2021) found that applying (SA-Zn) topically to apple leaves enhanced the amount of leaf components. Our results demonstrated that foliar application of SA-Zn spray to branches and leaves of apples trees at different growth stages resulted in an increased concentration of Zn in leaves and fruit (Abdullah et al., 2023).

Table (7b). Effect of foliar application with potassium rates and sources zinc on "Washington" navel orange trees mineral content of leaves during the two **successive** seasons.

Parameters	Leaf zinc content (ppm)		C/N Ratio	
Treatments	**1st Season**	**2nd Season**	**1st Season**	**2nd Season**
T1- Control (foliar spraying with water).	39.78D	41.13D	6.11F	5.69E
T2- Potassium sulfate (K_1) at 1% + (Zn-EDTA) at 0.5%.	51.98C	51.90C	8.34E	9.05D
T3- Potassium sulfate (K_2) at 2% + (Zn-EDTA) at 0.5%.	53.74C	52.18C	10.55D	9.44D
T4- Potassium sulfate (K_3) at 3% + (Zn-EDTA) at 0.5%.	67.19B	66.70B	20.38C	19.65C
T5- Potassium sulfate (K_1) at 1% + (SA-Zn) at 0.5%.	73.19AB	75.67AB	20.38B	19.65B
T6- Potassium sulfate (K_2) at 2% + (SA-Zn) at 0.5%.	88.99A	89.23A	31.62A	32.74A
T7- Potassium sulfate (K_3) at 3% + (SA-Zn) at 0.5%.	90.00A	92.29A	26.28AB	28.68AB

At the 5% level, there is no significant difference between the mean and the same letter.

CONCLUSION

From the above mentioned results it could be concluded that potassium sulfate different concentration combined with different zinc source had an efficient role in production and increased fruit set as well as reducing the problem of flower and fruit drop of Washington navel oranges grown under Egyptian clay loam soil condition. As, sugar alcohol zinc had a positive role in improving yield indicators and fruit quality of Washington navel orange, indicating their importance in navel orange production. Sugar alcohol zinc is the most important factor limiting citrus crop production but negative effects of citrus deficiency can be minimized by the foliar application of Zn. Moreover, foliar application of sugar alcohol zinc significantly improves tree nutritional status, fruit set percentage, yield efficiency, leaf pigments contents, leaf indole and phenolic contents, mineral content of leaves, production and quality of citrus.Thus, it can be concluded that foliar application of Washington navel oranges with potassium sulfate at 2% concentration with sugar alcohol zinc (SA-Zn) at 0.5% was highly recommended for its effects on nutritional status, fruit set, yield, and fruit quality.

REFERENCES

Abdullah, H. K., Khalid A. S. and Adeeb J. A. (2023). The Effect of Spraying with Jasmonic Acid and Sugar Alcohols on some Chemical and Hormonal Properties of Lemon and Benzher Seedlings. Earth and Environmental Science. doi:10.1088/ 1755-1315/1259/1/012057.

Alwakel, E. Sh., Rizk, M.A., Fayed, M.H. and Darwish, N.E. (2021). Effect of nanometric nitrogen and micro elements fertilizers on yield and its component of

Canola (*Brassica napus*, L.) Egypt. J. of Appl. Sci., 36 (3).

Aglar, E., Yildiz, K. Ozkan, Y. Ozturk, B. and Erdem, H. (2016). The effects of aminoethoxyvinylglycine and foliar zinc treatments on pre-harvest drops and fruit quality attributes of Jersey Mac apples. Sci. Hortic., 213:173–178.

Andreini, C. and Bertini, I. (2012). A bioinformatics view of zinc enzymes. Journal of Inorganic Biochemistry, 111: 150–156.

Ashraf, M. Y., Gul, A., Ashraf, M. Hussain, F. and Ebert, G. (2010). Improvement in yield and quality of Kinnow (*Citrus deliciosa* x *Citrus nobilis*) by potassium sulfate fertilization. Journal of Plant Nutrition, 33: 1625-1637.

Alloway, B.J. (2008). Zinc in soils and crop nutrition. 2nd Ed. International Zinc Assn., Brussels, Belgium.

Abbas, F. and Fares, A. (2008). Best management practices in citrus production. Tree and Forestry Science and Biotechnology 3 (Special Issue1).

A.O.A.C. (2000). Official Methods of Analysis. 17th Edition, the Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Brown, J.D. and Lilliland, O. (1946). Rapid determination of Potassium sulfate and Sodium in plant material and soil extracts by flame photometer. Proc. Amer. Soc. Hort. Sci., 48:341-346.

Chapman, H.D. and Pratt, P.F. (1961). Methods of Analysis for Soil, Plant and Water. Div. Agric. Sci., Calif. Univ., Berkley.

Daniel, H.D. and George, C.M. (1972). Peach seed dormancy in relation to indogenous inhibitors and applied growth substances. J. Amer. Soc. Hort. Sci., 97(5): 651-654.

Dubois, M., Giller, K.A., Hamilton J.K., Rebers, P.A. and Smith, F. (1956). Colorometric method for determinations of sugars and related substance. Analytical Chemistry, 28:350-356.

Duncan, D. B. (1955). Multiple range and Multiple F test. Biometrics, 11: 1-42.

Erdal, A. and Onur S. (2018).Role of the foliar fertilization treatments on quality attributes of sweet cherry fruits. Akademik Ziraat Dergisi, 7(2):131-136.

Erdem, H. and Öztürk, B. (2012). Effect of foliar applied zinc on yield, mineral element contents and biochemical properties of pear varieties grafted to BA-29 rootstock. Süleyman Demirel University. J. Fac. Agric., 5:93–106.

Fageria, N.K., Slaton, N.A. and Baligar. V.C. (2003). Nutrient management for improving lowland rice productivity and sustainability. Adv. Agron., 80:63–152.

Gupta, B., Pathak, G.C. and Pandey, N. (2011). Induction of oxi-dative stress and antioxidant responses in *Vigna mungo* by zinc stress. Plant Physiology, 58 (1): 85–91.

Gurjar, P.S. and Rana, G.S. (2014). Influence of foliar application of nutrients and growth regulator on fruit drop, yield and fruit size and quality in Kinnow mandarin. Indian J. Hort., 71(1): 109-111.

Hacisalihoglu, G. and Leon, V. K. (2003). How do some plants tolerate low levels of soil zinc? Mechanisms of zinc efficiency in crop plants. New Phytologist, 159: 341–350.

Halil, E. and Ozgur, S. (2021). Foliar zinc sprays affected yield and bioactive compounds of granny smith apple. International journal of fruit science, 21(1): 670–680.

Hassanein, Y.Z., Abdel-Rahman, S.S.A., Soliman, W.S. and Salaheldin, S. (2021). Growth, yield, and quality of roselle plants as affected by zinc and bio-stimulant treatments. Hortic. Environ. Biotechnol., 62: 879–890.

Kumari, N., Manoj, K., Ruby, R., Farhana, K. and Deepak, K. (2020). Foliar Feeding of Micronutrients: An Essential Tool to Improve Growth, Yield and Fruit Quality of Sweet Orange (*Citrus sinensis* L.) Osbeck) cv. Mosambi under Non-traditional Citrus Growing Track.

Int. J. Curr. Microbiol App. Sci., 9(3): 473-483.

Larsen, P, Harbo, A, Klungsour, S. and Asheim, T. (1962). The biogenesis of some indol compounds in Acetobacter xylinum. Physiol. Plant, 15: 552-565.

Liu, B.Y., Nearing, M.A., Shi, P.J. and Jia, Z.W. (2000). Slope length effects on soil loss for steep slopes. Soil Sci. Soc. Am. J., 64 (5): 1759–1763.

Montanaro, G., Dichio, B. and Xiloyannis, C. (2010). Significance of fruit transpiration on calcium nutrition in developing apricot fruit. J. Plant Nutr. Soil Sci., 173: 618–622.

Murphy, J. and Riely, J. P. (1962). A modified single solution method for the determination phosphate in natural waters. Anal. Chem. Acta , 27:31-36.

Nasir, M., Khan, A.S., Basra, S.M.A. and Malik, A.U. (2016). Foliar application of Maringa leaf extract, potassium sulfate and zinc influence yield and fruit quality of 'Kinnow' mandarin. Sci. Hortic., 210:227–235.

Neilsen, G.H. and Neilsen, D. (2002). Effect of foliar Zn, form and timing of Ca sprays on fruit Ca concentration in new apple cultivars. Acta Hortic., 594:435–443.

Nornai, R. (1982). Formula for determination of chlorophylls Pigments extracted with N.N dimethyl formamid. Transplant physiol, 69:1371-1381.

Pregl, F. (1945). Quantitative inorganic microanalysis. 4th ed., J. &A Churcehill, Ltd., London.

Quaggiotti, S., Ruperti, B., Borsa, P., Destro, T. and Malagoli, M. (2004). Expression of a putative high-af®nity NO_3 ± transporter and of a H^+-ATPase in relation to whole plant nitrate transport physiology in two maize genotypes differently responsive to low nitrogen availability. Journal of Experimental Botany, 57: 1023-1031.

Razzaq , K. Khan, A. S., Malik, A. U., Shahid, M. and Ullah, S.(2013). Foliar application of zinc influences the leaf mineral status, vegetative and reproductive growth, yield and fruit quality of 'Kinnow' mandarin. Journal of Plant Nutrition, 36(10): 1479-1495.

Sarrwy, S.M.A, Mohamed, H., El-Sheikh, Sanaa K. and Abdelaal, S. (2012). Effect of Foliar Application of Different Potassium sulfate Forms Supported by Zinc on Leaf Mineral Contents, Yield and Fruit Quality of "Balady" Mandrine Trees. Middle-East Journal of Scientific Research, 12 (4): 490-498.

Selim, H.H.; M.A. Fayek and A.M. Sweedan, (1978). Reproduction of Bircher cultivar by layering. Annals Agric. Sci. Moshtohor , (9):157-166.

Snedecor, G.W. and Cochran, W.G. (1972). Statistical Methods, Oxford and J.B.H pup co. Publishing 6th Edition.

Swietlik, D. (2002a). Zinc nutrition of fruit trees by foliar sprays. Acta Hort., 594: 123–129.

Tandon, H.L.S. (1992). Fertilizer Guide. Fertilizer Development and consolation Organization, 204-204. A Bhanot Corner, 1-2 Pamosh Enclave New Delhi 110048 (India).

Thomas, M.S.C., Fedor, A., Davis, R., Yang, J., Alireza, H., Charman, T. and Best, W. (2018). Computational modelling of interventions for developmental disorders. Manu-script submitted for publication. Available from: http://www.bbk.ac.uk/psychology/dnl/personalpages/Thomas_computational_modelling_of_interventions_submitted.pdf

Tiwari, K. N. (2005). Diagnosing potassium deficiency and maximizing fruit crop production. Better Crop., 89: 29-31.

Turrell, F.M. (1946). Tables of surfaces and volumes of spheres and of prolate and oblate spheroids, and spheroidal coefficients. Univ. Calif. Press, Berkeley, CA, USA, 153 p.

Yadav, B. P. S. , Varma, A. and Gupta, J. J. (1991). Comparative studies on nutritional values of different pasture grasses for growing calves. Indian J. Anim. Sci., 61: 1242-1244.

Yan, Z.G., Zhang, Y.Z., Zhang, Y.H. Wang, Y.A., Zhang, F.S. and Shu, H.R. (2010). Effects of zinc fertilization on the dynamics accumulation and distribution of dry matter and zinc in apple trees. Plant Nutr. Fert. Sci., 16:1402–1409.

Yong, Z. , Chunxia, F. , Yujing, Y., Xiaodan, F., and Yan'an, W. (2014). Foliar Application of Sugar Alcohol Zinc Increases Sugar Content in Apple Fruit and Promotes Activity of Metabolic Enzymes. Hortscience, 49(8):1067–1070.

Zhang, Y., Yan, Y., Fu, C., Li, M. and Wang, Y.A. (2016). Zinc sulfate spray increases activity of carbohydrate metabolic enzymes and regulates endogenous hormone levels in apple fruit. Sci. Hortic., 211:363–368.

Zhang, Y., Fu, C., Yan, Y.J., Wang, Y.A., Li, M., Chen, M.X., Qian, J.P., Yang, X.T. and Cheng, S.H. (2013). Zinc sulfate and sugar alcohol zinc sprays at critical stages to improve apple fruit quality. Hort. Technology, 23(4): 490–497.

الملخص العربى

تأثير الرش الورقي بمعدلات البوتاسيوم ومصادر الزنك على أشجار البرتقال أبو سره واشنطجن

حسين سيد أحمد و وفاء عبد المنعم شحاتة

قسم بحوث الموالح، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر.

أجري هذا البحث خلال موسمين متتاليين (2020 و2021) لدراسة تأثير الرش الورقي بمعدلات سلفات البوتاسيوم مع مصادر مختلفة من الزنك على أشجار البرتقال أبو سره واشنطجن المطعومة على أصل النارنج. وتم إجراء سبع معاملات رش ورقي على النحو التالي: ثلاث تركيزات مختلفة من سلفات البوتاسيوم بنسبة 1، 2 و3٪ مع مصدرين من الزنك: سكر كحول الزنك بنسبة 0.5٪ والزنك المخلبي بنسبة 0.5٪، بالإضافة إلى معاملة الكنترول. تم الحصول على أفضل النتائج من خلال رش كبريتات البوتاسيوم بنسبة 2٪ مع سكر كحول الزنك بنسبة 0.5٪، والتي كانت متفوقة على تحسين الحالة الغذائية للأشجار ونسبة عقد الثمار وكفاءة الإنتاج والمحتوى الكيميائي الحيوي ومحتوى الأوراق المعدني وجودة الثمار.