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(Original Article)

Zinc and Selenium Spray Effects on Yield and Quality of Manfalouty Pomegranate Cultivar

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Abstract

The experiment was conducted at the research orchard and the laboratories of Pomology Department, Faculty of Agriculture, Assiut University during 2021 and 2022 seasons. The study included one pomegranate cultivar named Manfalouty to study the effect of conventional and nano selenium (N-Se) and nano zinc (N Zinc) both at 5 and 10 ppm on productivity and fruit quality under Assiut conditions.

The experiment suggested that N zinc application at 5 and 10 ppm significantly exceeded the rest of treatment concerning leaf area, however, the differences between the two concentrations were significant. N-Se at 10 and 5 ppm recorded the highest yield weight while N-Se at 10 ppm recorded the highest number of fruits/tree. N Zinc at 10 ppm followed by N-Se at 10 ppm and Se at 10 ppm significantly exceed the other treatments in average fruit weight. Generally, Se (conventional or Nano) recorded the highest value of fruit height and diameter, Aril weight, juice volume, and other fruit quality properties.

***Keywords**: Nano, Pomegranate, Selenium, Zinc.*

Introduction

The fruit shrub known as pomegranate (*Punica granatum* L.) is successfully grown throughout much of Asia, North Africa, the Mediterranean, and the Middle East (Sarkhosh *et al*., 2006). It is a common horticultural crop in many tropical and subtropical nations. It is one of the most tolerant fruit crops, growing well in semi-arid and desert climates. Arils, or the pulp bearing seeds, are the edible portion of the fruit that makes up roughly 52% of the fruit (weight/weight), with seeds making up 22% and juice forming the remaining 78%.

The pomegranate tree possesses numerous desirable traits, such as disease resistance, tolerance to salt stress and alkalinity of the soil, longevity. It is a non-climacteric fruit that grows well in desert, interior, and coastal regions. Its parts can be used for a variety of purposes, including ornamental, therapeutic, and pharmacological ones. Its fruits also have a long shelf life.

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In Egypt, pomegranates are grown in warm climates like the Assiut governorate (375 km south of Cairo), where long, hot summers and low air humidity provide the perfect conditions for the growth and fruiting of the crop. Manfalouty is the most important cultivar, valued for its appealing color and good acidic taste.

The Ministry of Agriculture's 2021 figures show that 79,893 feddans (1 feddan = 4200m^2) was the total area planted with pomegranates, while 78,429 feddans were the area used for fruiting. These areas together produced approximately 672,827 tons, with an average of 8.579 tons per feddan.

Micronutrients foliar applications have been successfully employed to restore crop deficiencies (Alexander, 1986). Micronutrients like iron, magnesium, and zinc are important for plant development, yield, and quality because they impact numerous physiological processes in plants.

Zinc activated a great deal of enzymes, including RNA, carbonic anhydrase (CA), Cu-Zn superoxide dismutase, and alcohol-dehydrogenase. These enzymes are crucial for photosynthetic CO_2 fixation in plant leaves (Romheld and Marschner 1991).

For modern crop production, fertilizer addition to enhance natural soil fertility is necessary, and careful nutrient element management is necessary for sustainable agricultural production (Barker and Pilbeam, 2006). Microelements in particular play significant roles in fruit yield and quality, as well as in fruit set and retention (Khan *et al* 1993).

According to Pérez-de-Luque (2017), nanoparticles are atomic or molecular aggregates that range in size from 1 to 100 nm and have the ability to alter a substance's physicochemical properties in comparison to its bulk form. Due to their low toxicity and high bioavailability, nanoparticles like nano-Se (N-Se), which is soluble and very stable (Sharma *et al*., 2014), have drawn a lot of interest (Abdulsalam *et al*., 2018). N-Se can scavenge free radicals in a size-dependent manner because N-Se nanoparticle size affects their biological activity, particularly in the 5–200 nm range (Peng *et al*., 2007). According to Zhang *et al*. (2001), N-Se exhibits great absorption, high biological activity, and minimal toxicity in plants.

Furthermore, foliar fertilizing prevents toxicity symptoms that could arise from applying the same microelements to the soil (Obreza *et al*., 2010). Conversely, nanotechnologies have proven useful in solving numerous scientific and industrial challenges (Scott and Chen, 2003). These technologies are now employed in the synthesis, manipulation, and utilization of nano-scale compounds.

Generally speaking, materials that are smaller than 100 nm, at least in one dimension, are categorized as nanomaterials. Nanotechnologies are already being used in agriculture for the production, processing, storage, packing, and transportation of agricultural goods (Scott and Chen, 2003; Wiesner *et al*., 2006). Applications for this new technology have been identified in agriculture.

The field of nano-fertilizers, which can feed plants gradually and under control in contrast to conventional fertilizers, is the most significant application of nanotechnology in agricultural crop production. By reducing soil contamination and other environmental concerns associated with the use of chemical fertilizers, these more efficient nano-fertilizers can be used (Naderi *et al*., 2011).

Compared to conventional fertilizers, nano-fertilizers allow for smaller application amounts, which is one of its benefits (Selivanov and Zorin, 2001; Reynolds, 2002; Batsmanova *et al*., 2013; The properties of nano-particulate zinc (size, specific surface area, and reactivity) influence the solubility, diffusion, and availability of zinc to plants. This makes nanomaterials useful for creating novel zinc fertilizers (Mosanna and Khalilvand, 2015).

One of the elements that plants need most is zinc (Zn), and deficiencies in Zn are widespread in various crops (Marschner, 2012; Ojeda-Barrios *et al*., 2014).

Numerous enzymes, such as RNA and DNA polymerases, aldolases, isomerases, transphosphorylases, dehydrogenases, and cell division, depend on zinc for their activity. Zinc also plays a regulatory role in protein synthesis and is necessary for the synthesis of tryptophan and the maintenance of membrane structure and photosynthesis (Marschner, 2012).

Selenium (Se) is a helpful element and a micronutrient that is almost necessary for higher plants. As selenium (Se) is an essential component of the enzyme glutathione peroxidase (Peng *et al*., 2007) and stimulates the expression of sulphur assimilation genes (Djanaguiraman *et al*., 2010; Hasanuzzaman *et al*., 2014), plants require Se for antioxidant defense. Glutathione peroxidase (GPx) and the activity of other Se-based proteins can be increased by supplementing with selenium (Oraghi-Ardebili *et al*., 2015).

Se is employed to combat a variety of abiotic challenges, including heavy metals (Mroczek Zdyrska and Wójcik, 2012), and salt stress (Djanaguiraman *et al*., 2005; Hawrylak-Nowak, 2009). It is still unclear if selenium (Se) is a necessary element for plants, despite the fact that numerous studies on the impact of Se on some plants, including favourable features, have been done (Haghighi *et al*., 2014; Bystrická *et al*., 2015).

By stimulating the synthesis of polyphenols (Bystrická *et al*., 2015) or a higher expression of S-assimilation genes (Djanaguiraman *et al*., 2010), Se may be able to counteract oxidative damage. These investigations showed that the application of Se improved a number of growth indicators, the nutritional state of trees, yield, and the physical and chemical properties of fruits.

Due to Se deficiency in some crop production areas worldwide, various forms of this element have been applied—either foliar or soil—or used iN-Seed priming to boost crop growth, quality, or edible parts (Djanaguiraman *et al*., 2010; Haghighi *et al*., 2014; Ibrahim and Al-Wasfy, 2014).

Thus, the goal of this study was to determine how zinc and selenium affect pomegranate trees and paving the path for more research on the effects of nano-fertilizers on fruit trees.

Materials and Methods

The experiment was executed at the experimental orchard and the laboratories of the Pomology Department at Faculty of Agriculture, Assiut University throughout two successive seasons of 2021 and 2022. The study included one pomegranate cultivar named Manfalouty. The treatments were:

1- Spraying with zinc at 5 ppm.
2- Spraying with zinc at 10 ppm.
3- Spraying with nano zinc at 5ppm.
4- Spraying with nano zinc at 10 ppm.
5- Spraying with selenium at 5 ppm.
6- Spraying with selenium at 10 ppm.
7- Spraying with nano selenium at 5 ppm.
8- Spraying with nano selenium at 10 ppm.
9- Control (water only).

The spraying solutions were added twice: at full bloom and a month after full bloom. Samples were picked and transferred directly to the laboratory of Pomology Department, Faculty of Agriculture, Assiut University to determine the following traits:

1-Vegetative traits

- Leaf area (cm^2)

2-Physical properties

- Fruit dimensions (Height and Diameter) (cm.)
- Fruit weight (g).
- Fruit peel and arils weight (g).

3-Chemical properties

- Total soluble solids (T.S.S.) were estimated by using the hand refractometer (ATAGO N-IE).
- Total acidity was determined by titration of NaOH at 0.1N using phenolphthalein as an indicator. The NaOH was adjusted by using a known volume of oxalic acid 0.1M according to A.O.A.C. (1984).

The total acidity was expressed as citric acid according to the following equation:

$$\text{Acidity}(\%) = \frac{\text{NaOH volume used in titration} \times \text{NaOH molarity} \times \text{equivalent weight of citric acid}}{1000 \times \text{sample volume}} \times 100$$

Where:

Equivalent weight of citric acid = 64, NaOH molarity = 0.1M and Sample Vol. = 5 ml.

- TSS/acid ratio was calculated.
- Sugars: reducing sugars were determined according to Lane and Eynon method as outlined in A.O.A.C (1984).
- Total anthocyanin content (T.A.C.) of peel and juice

Extracts were prepared by the method described by Rababah *et al*., (2005). Five gm of arils were extracted with 50 ml of aqueous ethanol (70%). Extraction was carried out under stirring for 60 min. Each extract was filtered into a 50 ml volumetric flask; then brought to a 50 ml final volume and allowed to set in the dark at refrigerated temperature (at about 5°C) until the time of analysis.

The absorbance of the extracts was read using the previous kind of spectrophotometer at 530 and 657 nm. Using the formula:

A= (A530 – 0.25 A 657) was employed to compensate the contribution of chlorophyll and its degraded products to the absorption at 530 nm. Total anthocyanin content was expressed as Cyanidin-3-glucoside equivalents (mg /g of dry peel weight basis and mg/L. of juice).

Total anthocyanin content was calculated according to the following equation (Rabino and Mancinelli, 1986):

$$\text{T.A.C.} = \frac{\text{Absorbance} \times 449.2 \times \text{Dilution factor}}{29600 \times \text{sample weight}}$$

Where:

29600 = molar extinction coefficient, 449.2 = molecular weight of C.3.g., and Dilution factor = final volume / initial volume.

Statistical analysis

The experiment was up in a three-replications randomized complete block design (RCBD). All obtained data was conducted for analyzed of variance (ANOVA) using SAS program version 9.2, and means were compared using revised least significant Difference (RLSD) at a 5% level of the probability (Steel and Torrie, 1980).

Results and Discussion

Tables 1-6 show the effect of various treatments on leaf area, yield parameters and physical and chemical fruit properties of Manfalouty pomegranate cultivar during 2021 and 2022 seasons.

1-Leaf area

Data presented in Table 1 shows the effect of zinc and selenium applications on leaf area of Manfalouty pomegranate cultivar. During the 1st season of study zinc application at 5 and 10 ppm significantly exceeded the other treatments. They recorded 8.79 and 7.75 cm^2, respectively. During the 2nd season of study, only zinc at 5 ppm significantly surpassed the other treatments. Such treatment gave 8.07 cm^2 of leaf area.

Two seasons' average data (Table 1) revealed that zinc application at 5 and 10 ppm recorded the highest leaf area (8.43 and 6.89 cm^2). They significantly exceeded the rest of treatments, however, the differences between the two concentrations were significant.

Table 1. Effect of zinc and selenium on Leaf area of Manfalouty pomegranate cultivar during 2021 and 2022 seasons

Treatments	Leaf area (cm^2)		Mean
	2021	2022	
Zn 5 ppm	8.79	8.07	8.43 a
Zn 10 ppm	7.75	6.03	6.89 b
N-Zn 5 ppm	5.38	4.49	4.94 c
N-Zn 10 ppm	5.97	5.36	5.67 c
Se 5 ppm	5.18	4.95	5.07 c
Se 10 ppm	5.34	5.47	5.41 c
N-Se 5 ppm	5.05	5.13	5.09 c
N-Se10 ppm	5.90	5.56	5.73 c
Control	5.29	5.28	5.29 c
RLSD			0.97

Means with the same letters are not significantly different based on LSD of 5%.

A-Yield components

The results concerning yield weight (kg/tree), number of fruits/tree and fruit weight (g) are found in Table 2.

Yield weight (kg/tree):

The effect of Zn and Se applications on yield weight (kg/tree) of Manfalouty pomegranate cultivar is shown in Table 2.

The presented data revealed that, during the 1st season of study N-Se at 5 and 10 ppm, Se at 5 ppm and Zn at 5 ppm exhibited the highest yield weight (kg/tree). The recorded yield weight of such treatments was 66.67, 63.00, 62.00, and 56.33 kg/tree, for N-Se at 10 ppm, N-Se at 5 ppm, Se at 5 ppm and Zn at 5 ppm. The differences between these treatments were not significant. Se at 10 ppm also produced a higher yield (52.33 kg/tree). The rest of treatments did not significantly differ compared with the control. The increment percentages of the prevalent treatments recorded 88.71, 78.32, and 75.49% for the treatments SN at 10 ppm, N-Se at 5 ppm and Se at 5 ppm, respectively.

During the 2nd season of study, similar trend could be observed where N-Se at 10 ppm represented the highest yield weight (118.33 kg/tree) followed by N-Se at 5 ppm, N-Zn at 10 ppm and N-Se at 5 ppm. The rest of the treatments did not have a significant effect as compared with the control trees. The corresponding increment percentages due to the abovementioned treatments were 65.10, 32.55, 19.53, and 13.95%, respectively.

Table 2. Effect of zinc and selenium on Yield weight (Kg), Number of fruits/tree and Fruit weight (g) of Manfalouty pomegranate cultivar during 2021 and 2022 seasons

Treatments	Yield weight (Kg)		Mean	Number of fruits/tree		Mean	Fruit weight (g)		Mean
	2021	2022		2021	2022		2021	2022	
Zn 5 ppm	56.33	45.00	50.66 d	219.00	153.33	186.16 abc	355.22	356.78	356.00 c
Zn 10 ppm	42.67	66.67	54.67 cd	173.33	188.33	180.83 abc	371.56	369.44	370.50 c
N-Z 5 ppm	37.33	68.33	52.83 cd	130.00	143.33	136.66 c	376.00	361.56	368.78 c
N-Z 10 ppm	33.67	85.67	59.67 bcd	108.67	213.33	161.00 bc	427.89	392.11	410.00 a
Se 5 ppm	62.00	81.67	71.83 bc	203.33	215.00	209.16 ab	369.89	342.67	356.28 c
Se 10 ppm	52.33	66.67	59.50 bcd	110.00	235.00	172.50 abc	409.33	387.33	398.33 ab
N-Se 5 ppm	63.00	95.00	79.00 ab	187.33	206.67	197.00 abc	407.33	343.78	375.56 bc
N-Se 10 ppm	66.67	118.33	92.55 a	191.67	263.33	227.50 a	431.89	369.11	400.50 ab
Control	35.33	71.67	53.50 cd	111.33	155.00	133.16 c	333.44	375.33	354.39 c
RLSD			20.65			63.47			27.72

Means with the same letters are not significantly different based on LSD of 5%.

Two season's average data suggested that N-Se at 10 and 5 ppm recorded the highest yield weight (92.55 and 79.00 kg/tree, respectively), while the other treatments did not have a significant effect. The yield weight for N-Se at 10 and 5 ppm increased by 72.99 and -47.66 over the control, respectively.

Number of fruits/tree

The presented data (Table 2) showed that during the 1st season of study most of the treatments significantly exceeded the control. Zinc at 5 ppm and Se at 5 ppm recorded the highest number of fruits/tree (219.00 and 203.33 fruits/tree, respectively). During the second season of study, most of the treatments significantly surpassed the control, however, N-Se at 10 ppm and Se at 10 ppm gave the highest fruit number/tree (263.33 and 235.00, respectively). The two seasons' average data revealed that N-Se at 10 ppm recorded the highest number of fruits/tree (227.5 fruit/tree) followed by Se at 5 ppm (209.16 fruits).

Fruit weight (g)

Data presented in Table 2 showed the effect of various treatments on fruit weight (g) of Manfalouty pomegranate cultivar during 2021 and 2022 seasons. The obtained results revealed that N-Se at 10 ppm exhibited the best results followed by N-Z at 10 ppm and N-Se at 10 ppm and N-Se at 5 ppm. The weight of fruits associated with the abovementioned treatments were 431.89, 427.89, 409.33, and 407.33 fruit/ tree. The rest of the treatments did not significantly differ from the control. During the second season N-Z at 10 ppm and Se at 10 ppm gave the best results, however, the differences of all the treatments and control were not significant.

The effect of treatments on the fruit weight as an average of the two seasons of study revealed that N-Z at 10 ppm followed by N-Se at 10 ppm and Se at 10 ppm significantly exceed the other treatments in this respect (Table 2). The average fruit weight of such treatments was 410.00, 400.50, and 398.33 (g), respectively.

3- Fruit attributes

Fruit dimensions

Data presented in Table 3 shows the effect of various treatments on fruit height (cm), diameter (cm) and its ratio of Manfalouty pomegranate cultivar during 2021 and 2022 seasons.

Fruit height (H) (cm)

The obtained results revealed that there were no distinguishing differences between the treatments on this trait. However, during the 1st season of study N-Se at 10 ppm represented the highest fruit length (8.42 cm) followed by Se at 10 ppm (8.34 cm). As an average of the two seasons of study, the illustrated data suggested that N-Se at 10 ppm and Se at 10 ppm gave the highest value (8.12 cm) followed by N-Se at 5 ppm (8.04 cm).

Table 3. Effect of zinc and selenium on Fruit height (cm), Fruit diameter (cm) and H/D of Manfalouty pomegranate cultivar during 2021 and 2022 seasons

Treatments	Fruit height (cm)		Mean	Fruit diameter (cm)		Mean	H/D		Mean
	2021	2022		2021	2022		2021	2022	
Zn 5 ppm	7.77	7.73	7.75 b	8.72	8.69	8.71 abc	0.89	0.89	0.89 b
Zn 10 ppm	7.97	7.68	7.82 ab	8.49	8.37	8.43 c	0.94	0.92	0.93 a
N-Z 5 ppm	7.80	7.66	7.73 b	8.67	8.47	8.57 bc	0.90	0.90	0.90 ab
N-Z 10 ppm	8.12	7.87	7.99 ab	9.02	8.86	8.94 ab	0.90	0.89	0.89 b
Se 5 ppm	8.19	7.41	7.80 ab	9.12	8.43	8.78 abc	0.90	0.88	0.89 b
Se 10 ppm	8.34	7.90	8.12 a	9.12	8.74	8.93 ab	0.92	0.90	0.91 ab
N-Se 5 ppm	8.11	7.97	8.04 ab	9.06	8.83	8.94 ab	0.90	0.90	0.90 b
N-Se 10 ppm	8.42	7.82	8.12 a	9.38	8.82	9.10 a	0.90	0.89	0.89 b
Control	7.92	7.70	7.81 ab	8.82	8.81	8.82 abc	0.90	0.87	0.89 b
RLSD			0.33			0.48			0.03

Means with the same letters are not significantly different based on LSD of 5%.

Fruit diameter (D) (cm)

The presented data (Table 3) suggested that during the 1st season, N-Se at 10 ppm represented the highest value of fruit diameter (9.38 cm). During the 2nd season of study there were no distinguished differences between the treatments. The average of two studied seasons showed that N-Se at 10 ppm produced the highest value of fruit diameter (9.10 cm).

Fruit H/D ratio

Data presented in Table 3 revealed that there were no significant differences between the treatments during the two seasons of study. However, Zn at 10 ppm showed the highest ratio (0.94 and 0.92 in the 1st and 2nd season, respectively). Two season's average data suggested that Zn at 10 ppm represented the highest ratio (0.93).

4- Aril, peel weight (g) and their ratio

Data concerning Aril, peel weight and their ratio are found in Table 4.

Aril weight (g)

The obtained results showed that during the 1st season, the treatments N-Se at 10 ppm recorded the highest weight of Aril (361.67 g) followed by Se at 10 ppm (327.56 g) and N-Zn at 10 ppm (326.56 g). The abovementioned treatments significantly exceeded the other treatments.

During the 2nd season of study, N-Zn at 10 ppm and Se at 10 ppm represented the highest aril weight. However, the differences between the treatments were not significant.

The average of two seasons suggested that at N-Zn at 10 ppm, Se at 10 ppm and N-Se at 10 ppm significantly surpassed the rest of treatments. They recorded 305.44, 303.50, and 303.06 g, respectively.

Peel weight (g)

The results obtained suggested that during the 1st season the highest peel weight was obtained from the fruits treated with Zn at 10 ppm and Se at 5 ppm. However, the differences between the treatments were not significant. During the 2nd year of study, N-Zn at 5 ppm and Zn at 10 ppm represented the highest peel weight (142.67 and 131.89 g, respectively).

Two season's average data revealed that N-Zn at 10 ppm and N-Zn at 5 ppm produced the highest peel weight (133.67 and 123.17 g, respectively).

Aril/peel ratio

The results obtained (Table 4) revealed that during the 1st season of study, N-Se at 10 ppm recorded the highest ratio with significant differences between it and the other treatments. During the 2nd season there were no significant differences between the treatments, however, N-Se at 5 ppm produced the highest ratio. Two season's average data suggested that N-Se at 10 ppm recorded the highest ratio, while the rest of treatments exhibited no significant differences between them.

Juice volume

During the 1st season of study, the highest juice volume was obtained from the fruits treated with Se at 10 ppm while the other treatments had insignificant differences. During the 2nd season there were no significant differences between the treatments. Two season's average data suggested that Se at 10 ppm recorded the highest volume (108.38 cm^3).

Table 4. Effect of zinc and selenium on aril weight (kg), peel weight (kg) and juice volume/150 arils of Manfalouty pomegranate cultivar during 2021 and 2022 seasons

Treatments	Aril weight (g)		Mean	Peel weight (g)		Mean	Aril/peel		Mean	Juice volume/ 150 arils		Mean
	2021	2022		2021	2022		2021	2022		2021	2022	
Zn 5 ppm	232.22	252.22	242.22 c	123.00	104.56	113.78 b	1.93	2.41	2.17 bc	97.09	99.44	98.27 ab
Zn 10 ppm	236.11	237.56	236.83 c	135.44	131.89	133.67 a	1.83	1.81	1.82 c	92.41	91.89	92.15 b
N-Z 5 ppm	272.33	218.89	245.61 c	103.67	142.67	123.17 ab	2.68	1.60	2.14 bc	92.86	89.56	91.21 b
N-Z 10 ppm	326.56	284.33	305.44 a	101.33	107.78	104.56 b	3.23	2.64	2.93 abc	100.61	86.11	93.36 b
Se 5 ppm	235.78	253.78	244.78 c	134.11	88.89	111.50 b	1.77	2.94	2.35 bc	91.98	92.78	92.38 b
Se 10 ppm	327.56	279.44	303.50 a	101.56	107.89	104.72 b	3.46	2.79	3.12 ab	124.87	91.89	108.38 a
N-Se 5 ppm	281.33	245.56	263.44 bc	126.00	98.22	112.11 b	2.40	3.05	2.73 bc	96.36	104.44	100.40 ab
N-Se 10 ppm	361.67	244.44	303.06 ab	70.22	124.67	97.44 c	5.37	2.57	3.97 a	97.83	94.56	96.19 ab
Control	254.89	222.78	238.83 c	78.56	119.22	98.89 c	3.45	1.46	2.46 bc	87.32	100.00	93.66 b
RLSD			39.86			N.S			1.19			13.05

Means with the same letters are not significantly different based on LSD of 5%.

Table 5. Effect of zinc and selenium on TSS, Acidity and TSS/Acid ratio of Manfalouty pomegranate cultivar during 2021 and 2022 seasons

Treatments	TSS		Mean	Acidity		Mean	TSS/Acid ratio		Mean
	2021	2022		2021	2022		2021	2022	
Zn 5 ppm	16.50	17.16	16.83 ab	0.643	0.648	0.65 b	26.03	27.03	26.53 b
Zn 10 ppm	16.83	16.67	16.75 ab	0.645	0.484	0.56 b	27.87	34.62	31.25 ab
N-Z 5 ppm	17.00	16.96	16.98 a	0.524	0.553	0.54 b	33.16	30.79	31.97 a
N-Z 10 ppm	16.97	16.67	16.82 ab	0.586	0.564	0.58 b	29.36	29.96	29.66 ab
Se 5 ppm	16.78	16.62	16.70 ab	0.597	0.556	0.58 b	29.23	30.15	29.69 ab
Se 10 ppm	16.47	16.31	16.39 ab	0.553	0.527	0.54 b	29.83	31.10	30.46 ab
N-Se 5 ppm	16.71	16.42	16.57 ab	0.616	0.569	0.59 b	27.95	29.74	28.84 ab
N-Se 10 ppm	16.43	16.58	16.51 b	0.648	0.632	0.64 b	26.22	26.53	26.37 b
Control	17.07	16.20	16.63 b	0.902	0.885	0.89a	19.23	18.48	18.86 c
RLSD			0.45			0.11			5.19

Means with the same letters are not significantly different based on LSD of 5%.

Chemical constituents of fruits

The effect of various treatments on TSS%, acidity %, TSS/acid ratio, reducing sugars % and anthocyanin content in Manfalouty pomegranate fruits is found in Tables 5 and 6.

Total soluble solids % (TSS%)

Table 5 showed that during the two seasons of study, the only treatment that significantly exceeded the control was Zn at 5 ppm during the second season of study. However, two season's average data revealed that N-Zn at 5 ppm significantly surpassed the control in this respect.

Acidity %

Data presented in Table 5 suggested that all the treatments significantly reduced the total acidity compared with the control. These results were identical during the two studied seasons as well as the average of both seasons of study.

TSS/acid ratio

The obtained results (Table 5) revealed that during both seasons of study all the treatments significantly exceeded the control, however, the differences between them were not significant.

During the 1st season of study, the most prevalent treatments in this respect were spraying with N-Zn at 5 ppm, Se at 10 ppm, N-Zn at 100 ppm and Se at 5 ppm. The values associated with these treatments were 33.16, 29.83, 29.36, and 29.23, respectively while the control produced the lowest ratio.

During the second season of study spraying with Zn at 10 ppm, Se at 10 ppm, N-Zn at 5 ppm, Se at 5 ppm, N-Zn at 10 ppm and N-Se at 5 ppm exhibited the highest treatments of their effect on TSS/acid ratio.

Two seasons' average data suggested that all the treatments surpassed the control. The best treatments were N-Zn at 5 ppm followed by Zn at 10 ppm, and N-Se at 10 ppm. The ratio of TSS/acid ratio for such treatments was 31.97, 31.25, and 30.46, respectively.

Reducing sugars

The obtained results for the 1st season (Table 6) demonstrated that the best treatment that gave the highest percentage of reducing sugars was N-Se at 5 ppm followed by N-Se at 10 ppm, and Zn at 10 ppm. The percentage of reducing sugars for the abovementioned treatments was 12.94, 12.57, and 12.56%, respectively. During the 2nd season of study, spraying with Se at 10 ppm, Se at 5 ppm and N-Se at 5 ppm exhibited the best results. The percentage of reduced sugars for these treatments was 13.0, 12.34, and 12.33, respectively. The two seasons' average data revealed that Se at 10 ppm, N-Se at 5 ppm and Se at 5 ppm recorded the highest percentage of reducing sugars. Such treatments gave 12.79, 12.64, and 12.02%, respectively.

Anthocyanin content

The presented data (Table 6) revealed that most of the treatments significantly enhanced the content of anthocyanin of pomegranate compared with the control. The best treatment during the 1st season in the respect was N-Zn at 10 ppm followed by Se at 5 ppm. Such treatments produced 26.89 and 25.61 mg/g, respectively. During the second season of study, N-Se at 10 ppm recorded 30.92 mg/g and significantly exceeded all the other treatments. Two season's average data suggested that all the treatments significantly surpassed the control.

Table 6. Effect of zinc and selenium on Reducing sugar and Anthocyanin content of Manfalouty pomegranate cultivar during 2021 and 2022 seasons.

Treatments	Reducing sugars (%)		Mean	Anthocyanin		Mean
	2021	2022		2021	2022	
Zn 5 ppm	10.44	11.14	10.79 de	21.06	15.24	18.15 b
Zn 10 ppm	12.56	10.92	11.74 abcd	23.67	14.21	18.94 b
N-Zn 5 ppm	11.93	11.16	11.55 bcde	26.89	25.27	26.08 a
N-Zn 10 ppm	10.54	11.14	10.84 cde	24.09	25.51	24.8 a
Se 5 ppm	11.70	12.34	12.02 ab	25.61	26.35	25.98 a
Se 10 ppm	12.57	13.00	12.79 a	23.31	26.41	24.86 a
N-Se 5 ppm	12.94	12.33	12.64 ab	17.35	18.33	17.84 b
N-Se 10 ppm	12.11	11.75	11.93 abc	20.65	30.92	25.78 a
Control	10.21	10.65	10.43 e	17.86	12.66	15.26 c
RLSD		1.14			1.34	

Means with the same letters are not significantly different based on LSD of 5%.

Discussion

Zinc plays a great role in plant growth and fruiting. It activated many enzymes and plays an important role in photosynthetic CO_2 fixation in plant leaves (Romheld and Marschner, 1991). A zinc deficit drastically lowers the capacity for growth and output. Low zinc levels diminish the number of fruits on a tree, which lowers output. On the other hand, Se is needed for antioxidant defense against various abiotic stresses. It also had a beneficial effect on plant growth.

Nano-fertilizers are used in smaller amount than the common fertilizers. The current study dealing with effects of Zn and Se and their nanoparticles on yield and quality of Manfalouty pomegranate cultivar.

Results of the present study revealed that zinc applications exceeded the other treatments on leaf area of pomegranate trees.

Impact of zinc on leaf area of pomegranate was supported by Hasani *et al.,* (2012). Obaid and Al-Hadethi (2013) found that spraying pomegranate trees with zinc gave the highest leaf area. Some findings were found by Abdelghany (2023) and Abd El-Wahed *et al.* (2024) that zinc or nano zinc spraying had a positive effect on all vegetative growth including leaf area.

The current study also suggested that, either common zinc fertilizer or N-Z had a significant effect on yield components. Zinc application increased yield weight (kg/tree), number of fruits/tree and fruit weight. Investigators found a significant increase in yield of pomegranate due to zinc application. For instance, Jumaa and Ali (2016) found a significant increase of pomegranate yield as a result of zinc spraying. Also, Hamouda *et al*., (2016), working on Manfalouty pomegranate, found that zinc spraying gave the highest yield. Same results on the positive effects of zinc on pomegranate yield were reported by Amer *et al*. (2020), Davarpanah *et al*., (2016), Chater and Garner (2018) and Moradinezhad and Ranjbar (2024).

The positive effect of zinc application on fruit quality was clear in the present study.

The previous studies also revealed that zinc application improved fruit quality parameters of pomegranate (Hasani *et al*. (2012); Hamouda *et al*. (2016); Kumar *et al*. (2016); Davarpanah *et al*. (2016); Abdel-Aal *et al*. (2022); Hussein *et al*. (2024) and Maradinezhad and Ranjbar (2024)). They found that zinc or nano-zinc improved fruit quality of pomegranate in terms of TSS%, TSS/acid ratio, juice volume, and sugars in addition to reducing total acidity percentage of pomegranate fruits.

Conversely, a trace amount of selenium (Se), an important micronutrient, promotes the growth and development of plants. Additionally, it shields plants against several abiotic stressors (Khan *et al*., 2023). It has been discovered that Se promotes growth. Its application has the ability to trigger several plan growth cascades. Selenium controls the manufacture of ethylene, which in turn controls fruit ripening, quality, and flavor as well as plant senescence (Ryant *et al*., 2020).

Investigators agreed upon the effectiveness of Se or N-Se on improving vegetative growth of pomegranate and other fruit trees. Selenium alone or combined with other materials improve the leaf area of pomegranate (Radwan (2017), Mosa *et al*. (2022), and Zahedi *et al*. (2019)). Selenium also was found to be effective for enhancing productivity and quality of pomegranate (Radwan (2017), Zahedi *et al*. (2019) and Zerak *et al*. (2023)). Their results came online with the results of present study.

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تأثيرات الرش بالزنك والسيلينيوم على محصول وجودة صنف الرمان المنفلوطى

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الملخص

نفذت التجربة بالمزرعة البحثية ومعامل قسم الفاكهة بكلية الزراعة جامعة أسيوط خلال موسمين متتاليين عامي 2021، 2022. وشملت الدراسة صنف رمان واحد هو المنفلوطي.

أشارت التجربة إلى أن إضافة الزنك بتركيز 5، 10 جزء في المليون تفوق بشكل ملحوظ على بقية المعاملات فيما يتعلق بمساحة الورقة، إلا أن الاختلافات بين التركيزين كانت كبيرة.

سجل نانو سيلينيوم عند 10، 5 جزء في المليون أعلى وزن محصول بينما سجل نانوسيلينيوم عند 10 جزء في المليون أعلى عدد من الثمار/الشجرة. أوضحت النتائج أيضا ان نانو زنك عند 10 جزء في المليون يليه نانوسيلينيوم عند 10 جزء في المليون والسيلينيوم عند 10 جزء في المليون تفوق بشكل كبير على المعاملات الأخرى في متوسط وزن الثمرة. بشكل عام سجلت معاملات السيلينيوم (التقليدية أو النانو) أعلى قيمة لقطر وارتفاع الثمرة ووزن الحبوب وحجم العصير وغيرها من خصائص جودة الثمار.

الكلمات المفتاحية: *نانو، الرمان، سيلينيوم، زنك*