SVU-International Journal of Agricultural Sciences
Volume 5 Issue (2) pp.: 75-84, 2023
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2023.215697.1290

RESEARCH ARTICLE

Response of Manfalouty and Hejazy pomegranate cultivars to conventional and Nano Zinc oxide foliar application

Abdelghany, A.M.M. *

Pomology Department, Faculty of Agriculture, Assiut University, 71526 Assiut, Egypt.

Abstract

Recently, there has been interest in substituting ordinary mineral equivalents with nanoparticles (NPs), notably those derived from micronutrients. This experiment was carried out during two progressive seasons of 2021 and 2022 on 45 years-old Manfalouty and Hejazy pomegranate cultivars grown in the research orchard and laboratories of Pomology department, faculty of agriculture, Assiut university, Egypt. The aim of this study was to evaluate the effect of Nano & conventional Zinc oxide and their comparative efficacy on fruit quality and marketable yield. Zinc Oxide conventional and nanoparticle (ZnO NPs) with two concentrations of each other (15 and 25 ppm), two sources of Zinc Oxide were sprayed twice (first: at full bloom and the second after a month from the first one). Results showed that Nano Zinc at 15 and 25 ppm led to a significant improvement in almost studied characters (leaf area, fruit, arils and rind weight, juice volume, TSS, TSS/ acid, reducing sugars and total acidity percentage in fruit juice).

Keywords : Nano fertilizers; micronutriens; *Punica granatum*.

1. Introduction

One of the edible fruit crops and one of the most important in terms of commerce is the pomegranate (*Punica granatum* L.). It is a Punicaceae fruit tree that is primarily grown in subtropical and tropical climates (Adsule and Patil, 1995; Naik and Chand, 2011). Consumed either processed or fresh, pomegranate fruits offer a good amount of antioxidant components and a balanced cuisine for jams, jellies, syrups, and juices (Legua et al., 2012). Pomegranate could also be ingested in its refined state (Alighourchi *et al*., 2008). Fruit quality and production can be impacted by minerals both directly and indirectly (Al-hadrawi and Al-janabi, 2020).
According to Dong *et al*. (2005), the most crucial objective in agricultural systems is to use fertilizers effectively to increase crop output. Nevertheless, it can be difficult to match fertilizer supply to crop needs. Due to the ability of plant leaf canopy to absorb nutrients, foliar spraying of fertilizers has become a widespread practise for feeding plants with nutrients (Weinbaum, 1988).
Several crops experience deficits of zinc (Zn), one of the crucial and fundamental minerals for plants (Swietlik, 1999; Marschner, 2012; Ojeda-Barrios *et al*., 2014). Cell division, photosynthesis, tryptophan synthesis, and membrane structure preservation are all aided by it. Moreover, it serves as a cofactor regulator for a certain protein's synthesis. It is required for a number of enzymatic processes, including those involving aldolases, transphosphorylases, dehydrogenases, and polymerases of RNA and DNA (Marschner, 2012).
Commercial chemical fertilizers have been connected to a number of problems, such as loss of biodiversity, eutrophication, soil acidification, and groundwater and air pollution (Kourgialas *et*

.***Corresponding author:** **Ahmed M. M. Abdelghany**
Email: Ahmed.Abd_Elgany@agr.aun.edu.eg
Received: June 5, 2023; Accepted: June 22, 2023;
Published online: June 26, 2023.
©Published by South Valley University.

al., 2017). Hence, several initiatives to substitute chemical fertilizers with biosynthesized and environmentally friendly nano-fertilizers have been made recently (Liu and Lal, 2015). Pomegranate fruit output rose following a single foliar spray of relatively tiny dosages of B or Zn nano-fertilizers, according to Davarpanah *et al*. (2016).

The main reason for this was that each tree produced more fruits. The impact was not as great with Zn as it was with B. The higher of the two doses of fertilization produced fruit with significantly better quality while other physical characteristics of the fruit unaffected. These improvements included 4.4–7.6% increases in TSS, 9.5–29.1% decreases in TA, 20.6-46.1% and increases in maturity index. Changes in total sugars were comparatively minor.

Using biosynthesized nano-fertilizers is the most cutting-edge and technologically sophisticated method of providing crops with mineral nutrients. Biosynthesized nano fertilizers may contribute to sustainable development in agriculture. By utilizing fewer resources, creating fewer wastes, reducing nutrient losses, and releasing nutrients at a rate that is appropriate for plant requirement, this encourages sustainable agriculture as opposed to conventional orchards.

Nano fertilizers and biosynthetic nano-fertilizers differ slightly from one another in terms of their application methods, mechanisms in the plant and soil, recommended addition rates, and environmental consequences (El-Ghamry *et al.*, 2018).

A single foliar spray with relatively low amounts of Zn nano-fertilizers (636 mg Znso4/ tree) was ineffective on pomegranate physical fruit characteristics, where there was an increases in fruit yield, and this was mainly due to increases in the number of fruits per tree. (Davarpanah *et al*., 2016).

Also, the same researchers issued a significant improvement in fruit quality, including 4.4–7.6% increases in TSS, 9.5–29.1% decreases in TA, 20.6–46.1% increases in maturity index and 0.28–0.62 pH unit increases in juice pH, where changes in total sugars was only minor. Also, they found minor changes in total phenolic compounds, whereas the antioxidant activity and total anthocyanins were unaffected.

Alalaf *et al.* (2020) issued that foliar spraying with chelated zinc fertilizer recorded a significant increase in the seedling diameter and the zinc content of the leaves, while there were no significant differences between all the fertilizer treatments, including the comparison treatment with the leaves content of phosphorous and potassium of seedlings of Citrus grandis grafted onto the rootstock of Sour orange.

El-Hak *et al.* (2019) found that spraying grape vines with 0.4 ppm nano-zinc increased significantly leaf area and fresh weight compared with the control, while1.2 ppm nano-zinc increased significantly total carbohydrate, leaf concentration of Fe, No. of clusters, cluster weight and yield. Also results showed that 0.4, 0.8 and 1.2 ppm of nano-zinc had a significant increase on yield of flame seedless grapevine cultivar compared with conventional fertilizer.

The aim of this study was to evaluate and compare the effects of foliar spraying two pomegranate cultivars with traditional and Nano zinc oxide.

2. Materials and methods

2.1. Experiment site

The current experiment was conducted during two progressive seasons of 2021 and 2022 on Manfalouty and Hejazy pomegranate cultivars grown in the research orchard and laboratories of Pomology department, faculty of agriculture, Assiut, Egypt.

2.2. Plant Materials

Thirty healthy 45 years-old pomegranate trees of the two studied cultivars (15 trees for each cultivar, 3 trees/treatment) were chosen in a complete randomized block design to execute the following treatments:

1- Zinc oxide (conventional) at 15 ppm
2- Zinc oxide (conventional) at 25 ppm

3- Zinc oxide (Nano) at 15 ppm
4- Zinc oxide (Nano) at 25 ppm
5- Control (water only)

Trees were sprayed using a Knapsack sprayer (20 L). A total volume of 5 lit. was sufficient for each tree at maximum growth. A surfactant "liquid soap" at 0.5 ml/L. was added to the spraying solutions. The spraying compounds were added two times: at full bloom (mid-May) and one month later. Each treatment consisted of 3 trees (experimental units or replicates). common horticultural practices on orchard such as (irrigation and fertilization) were done except those dealt with zinc oxide.

2.3. Vegetative measurement

Leaf area (cm^2): was measured by using the following equation as mentioned by Ahmed and Morsy (1999)

Leaf area (cm^2) = 0.41 (Length of leaf x Width of leaf) +1.83

2.4. Physical characteristics

1- Fruit, arils and rind weight (g): by using sensitivity balance with 0.01g accuracy
2- Juice volume (ml): by using a measuring cylinder

2.5. Chemical characters

1- Total soluble solids (TSS %): By using a hand refractometer (ATAGO N-IE).
2- Total acidity (T.A) (expressed as % Citric acid): according to A.O.A.C. (1984).

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

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

Where:

Equivalent weight of Citric acid = 64

NaOH molarity = 0.1M

Sample Vol. = 5 ml.

3- TSS / acid ratio was then calculated.
4- Reducing sugars (%): According to Lane and Eynon procedure outlined in A.O.A.C. (1985).

2.6. Statistical analysis

The study was designed as a randomized complete block design (RCBD) (5 treatments x 2 cultivars) with three replications for each treatment. The treatments were placed in a subplot, whereas the cultivars were placed in the whole plot. ANOVA was performed using Proc Mixed of the SAS software version 9.2 (SAS, 2008), and means were compared using the revised L.S.D. test at the 5% level of probability (Steel and Torrie, 1980).

3. Results

3.1. Leaf area (cm^2), fruit and arils weight (g):

Leaf area increased significantly compared to the control (Table 1). Zinc oxide (Nano) at 25 ppm recorded the highest values of leaf area (cm^2) of Manfalouty and Hejazy Pomegranate cultivars (11.36, 12.25 and 12.22, 12.11 cm^2) compared to the check treatment which recorded the lowest values (10.38, 10.41 and 9.79, 10.17 cm^2) during 2021 and 2022 seasons, respectively.

Fruit weight take the same trend of leaf area and increased significantly compared to the control where Zinc oxide (Nano) at 25 ppm recorded the highest values of leaf area (cm^2) of Manfalouty and Hejazy Pomegranate cultivars (403.1, 404.9 and 433.0, 408.0 g) compared to the check treatment which recorded the lowest values (315.9, 314.1 and 307.2, 313.3 g) during the two seasons, respectively.

These results were concomitant with those found by El-Hak El., *et al.*, (2019) on Flame seedless grapevine cultivar.

Table 1. Effect of foliar application with conventional and Nano Zinc oxide on leaf area, fruit weight and arils weight of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

Treatments	leaf area (cm2)*				Fruit weight (g)**				Arils weight (g)**			
	Manfalouty		Hejazy		Manfalouty		Hejazy		Manfalouty		Hejazy	
cultivars	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Zinc oxide (conventional) at 15 ppm	10.98	10.85	11.71	10.51	369.8	382.6	412.1	364.7	247.9	247.0	257.7	224.8
Zinc oxide (conventional) at 25 ppm	11.14	10.49	10.95	10.46	381.4	370.2	401.9	382.5	254.7	253.1	271.2	261.8
Zinc oxide (Nano) at 15 ppm	11.26	11.31	10.45	11.21	344.7	373.6	372.2	370.8	217.8	239.7	231.3	246.7
Zinc oxide (Nano) at 25 ppm	11.36	12.25	12.22	12.11	403.1	404.9	433	408	231	256.8	288.8	264.7
Control (water only)	10.38	10.41	9.79	10.17	315.9	314.1	307.2	313.3	205.7	214.7	201.9	208.2
L.S.D 0.05	0.51	0.03	0.61	0.23	23.1	44.4	53.2	50.8	12.08	23.8	29.2	15.9

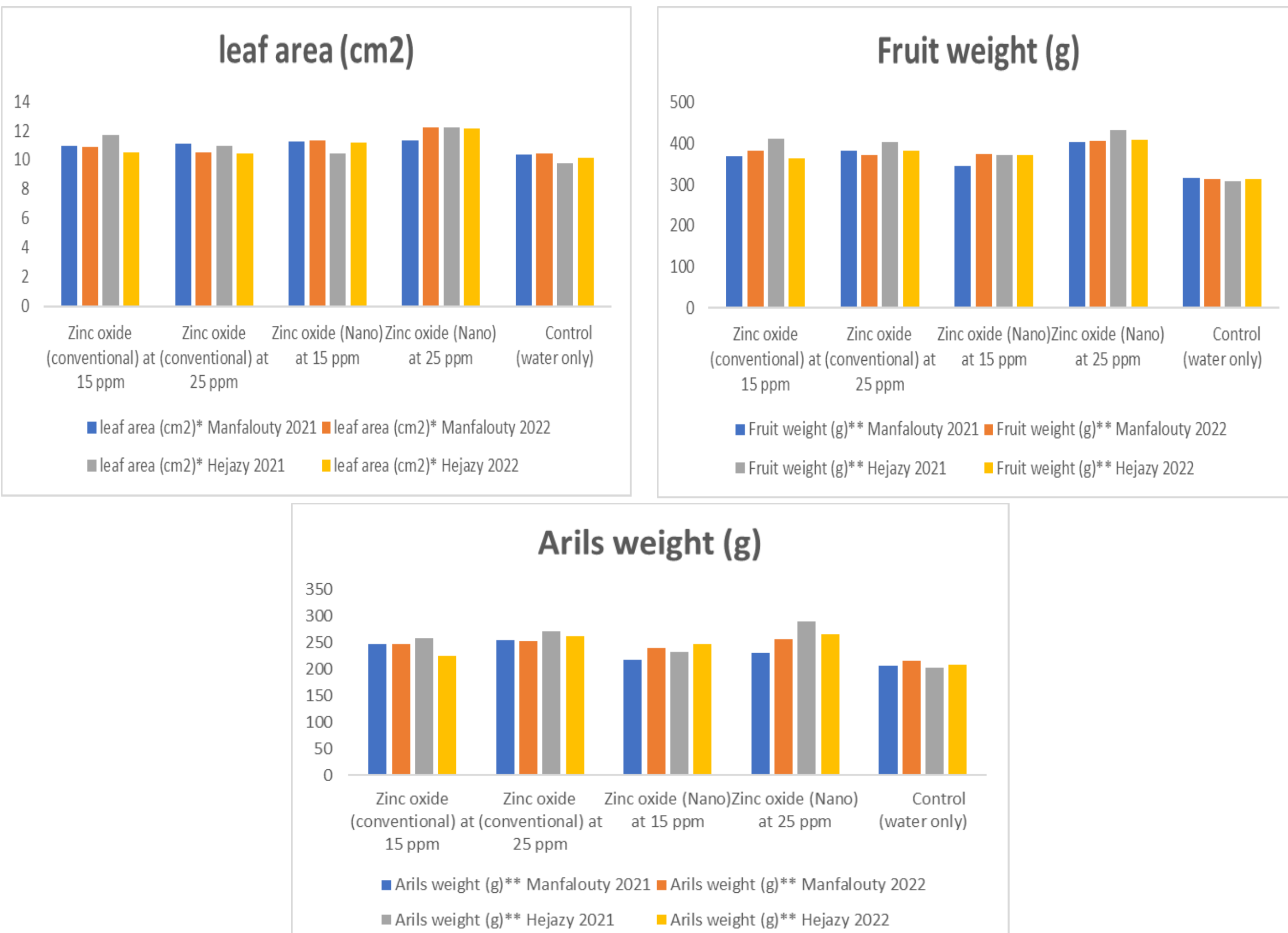

Figure 1. Effect of foliar application with conventional and Nano Zinc oxide on leaf area, fruit weight and arils weight of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

Arils weight also increased significantly compared to the control. Zinc oxide (conventional) at 25 ppm and Zinc oxide (Nano) at 25 ppm recorded the highest values of arils weight (g) of Manfalouty Pomegranate cultivar (254.7 and 256.8 g) compared to the check treatment which recorded the lowest values (205.7 and 214.7 g) during the two seasons, respectively.For the same respect, spraying Zinc oxide (Nano) at 25 ppm recorded the highest value for Hejazy cultivar (288.8, 264.7 g) compared to the check treatment which gave the lowest values (201.9, 208.2 g) during the two seasons, respectively. Otherwise, Davarpanah *et al*. (2016) found non-significant impact on fruit physical properties.

3.2. Rind weight (g), juice volume (ml) and TSS (%)

Data in table (2) indicated that rind weight increased significantly compared to the control. Zinc oxide (Nano) at 25 ppm and Zinc oxide (Nano) at 15 ppm recorded the highest values of rind weight (g) of Manfalouty Pomegranate cultivar (172.1 and 148.1 g) compared to the check treatment which recorded the lowest values (110.2 and 148.1 g) during the two seasons, respectively.

For the same respect, spraying Zinc oxide (conventional) at 15 ppm and Zinc oxide (Nano) at 25 ppm recorded the highest values for Hejazy cultivar (154.4, 143.3 g) compared to the check treatment which gave the lowest values (105.3, 105.1 g) during the two seasons, respectively. Juice volume take the same trend of arils weight, as it increased significantly compared to the control. Zinc oxide (conventional) at 25 ppm and Zinc oxide (Nano) at 25 ppm recorded the highest values of juice volume (ml) of Manfalouty Pomegranate cultivar (213.6 and 215.0 ml) compared to the check treatment which recorded the lowest values (154.5 and 158.3 ml) during the two seasons, respectively.

For the same respect, spraying Zinc oxide (Nano) at 25 ppm recorded the highest values for Hejazy cultivar (236.9 and 217.4 ml) compared to the check treatment which gave the lowest values (155.5 and 107.6 ml) during the two seasons, respectively.

Table 2. Effect of foliar application with conventional and Nano Zinc oxide on rind weight, juice volume and TSS of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

Treatments	Rind weight (g)				Juice volume (ml)				TSS (%)			
	Manfalouty		Hejazy		Manfalouty		Hejazy		Manfalouty		Hejazy	
cultivars	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Zinc oxide (conventional) at 15 ppm	121.9	135.6	154.4	139.9	196.8	190.7	212.7	188.5	17.16	17.13	17.00	17.11
Zinc oxide (conventional) at 25 ppm	126.7	117.1	130.7	120.7	213.6	197.6	220.6	197.6	17.02	17.12	17.11	17.13
Zinc oxide (Nano) at 15 ppm	126.9	133.9	140.9	124.1	161.3	188.0	189.5	191.5	16.98	17.09	17.13	17.12
Zinc oxide (Nano) at 25 ppm	172.1	148.1	144.2	143.3	187.7	215.0	236.9	217.4	17.11	17.11	17.10	17.09
Control (water only)	110.2	99.4	105.3	105.1	154.5	158.3	155.5	107.6	16.73	16.71	16.73	17.00
L.S.D 0.05	10.3	15.2	24.6	14.3	5.7	19.8	31.7	61.3	0.23	0.37	0.23	0.06

Likewise, TSS increased significantly compared to the control. spraying Zinc oxide (conventional) at 15 ppm recorded the highest values for Manfalouty cultivar (17.16 and 17.13 %) compared to the check treatment which gave the lowest values (16.73 and 16.71 %) during the two seasons, respectively. Where spraying Zinc oxide (Nano) at 15 ppm and Zinc oxide (conventional) at 25 ppm recorded the highest values for Hejazy cultivar (17.13 % for each treatment) compared to the check treatment which gave the lowest values (16.73 and 17.00 %) during the two seasons, respectively. This finding matches the result reported by Davarpanah *et al.* (2016),

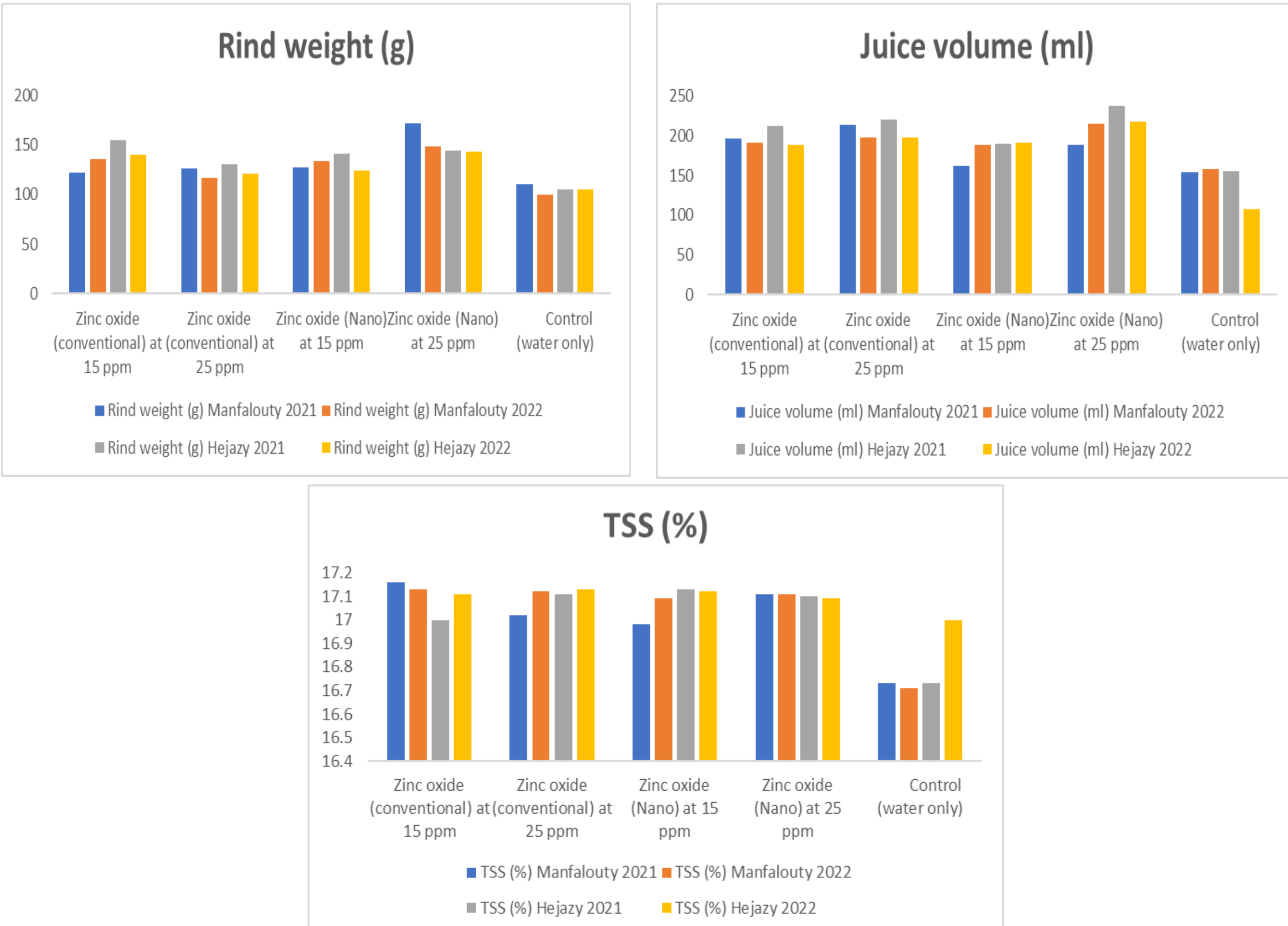

Figure 2. Effect of foliar application with conventional and Nano Zinc oxide on rind weight, juice volume and TSS of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

3.3. Acidity (%), TSS/acid and reducing sugars (%)

Data in (Table 3) showed that acidity decreased significantly compared to the control. Zinc oxide (Nano) at 15 ppm recorded the lowest values of Manfalouty and Hejazy Pomegranate cultivars (0.36, 0.42 and 0.43, 0.46 %) compared to the check treatment which recorded the highest values (0.53, 0.56 and 0.56, 0.59 %) during 2021 and 2022 seasons, respectively. This finding matches the result reported by Davarpanah *et al.* (2016),

TSS/acid take the same trend of acidity, whereas it increased significantly compared to the control, where Zinc oxide (Nano) at 15 ppm recorded the highest values of Manfalouty and Hejazy Pomegranate cultivars (47.17, 40.69 and 39.84, 37.22) compared to the check treatment which recorded the lowest values (31.57, 29.84 and 29.88, 28.81) during 2021 and 2022 seasons, respectively.

Table 3. Effect of foliar application with conventional and Nano Zinc oxide on acidity, TSS/ acid and reducing sugars of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

Treatments	Acidity (%)				TSS/ acid				Reducing sugars (%)			
	Manfalouty		Hejazy		Manfalouty		Hejazy		Manfalouty		Hejazy	
cultivars	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Zinc oxide (conventional) at 15 ppm	0.40	0.45	0.44	0.47	42.90	38.07	38.64	36.40	10.13	10.11	10.04	10.10
Zinc oxide (conventional) at 25 ppm	0.39	0.44	0.45	0.48	43.64	38.91	38.02	35.69	10.05	10.10	10.10	10.11
Zinc oxide (Nano) at 15 ppm	0.36	0.42	0.43	0.46	47.17	40.69	39.84	37.22	10.03	10.09	10.11	10.13
Zinc oxide (Nano) at 25 ppm	0.38	0.43	0.44	0.49	45.03	39.79	38.86	34.88	10.10	10.10	10.12	10.09
Control (water only)	0.53	0.56	0.56	0.59	31.57	29.84	29.88	28.81	9.56	9.55	9.56	9.70
L.S.D 0.05	0.21	0.12	0.10	0.11	11.21	8.27	8.71	7.24	0.42	0.57	0.42	0.33

The values shown are means of Three replicates (3 samples/ each replicate).

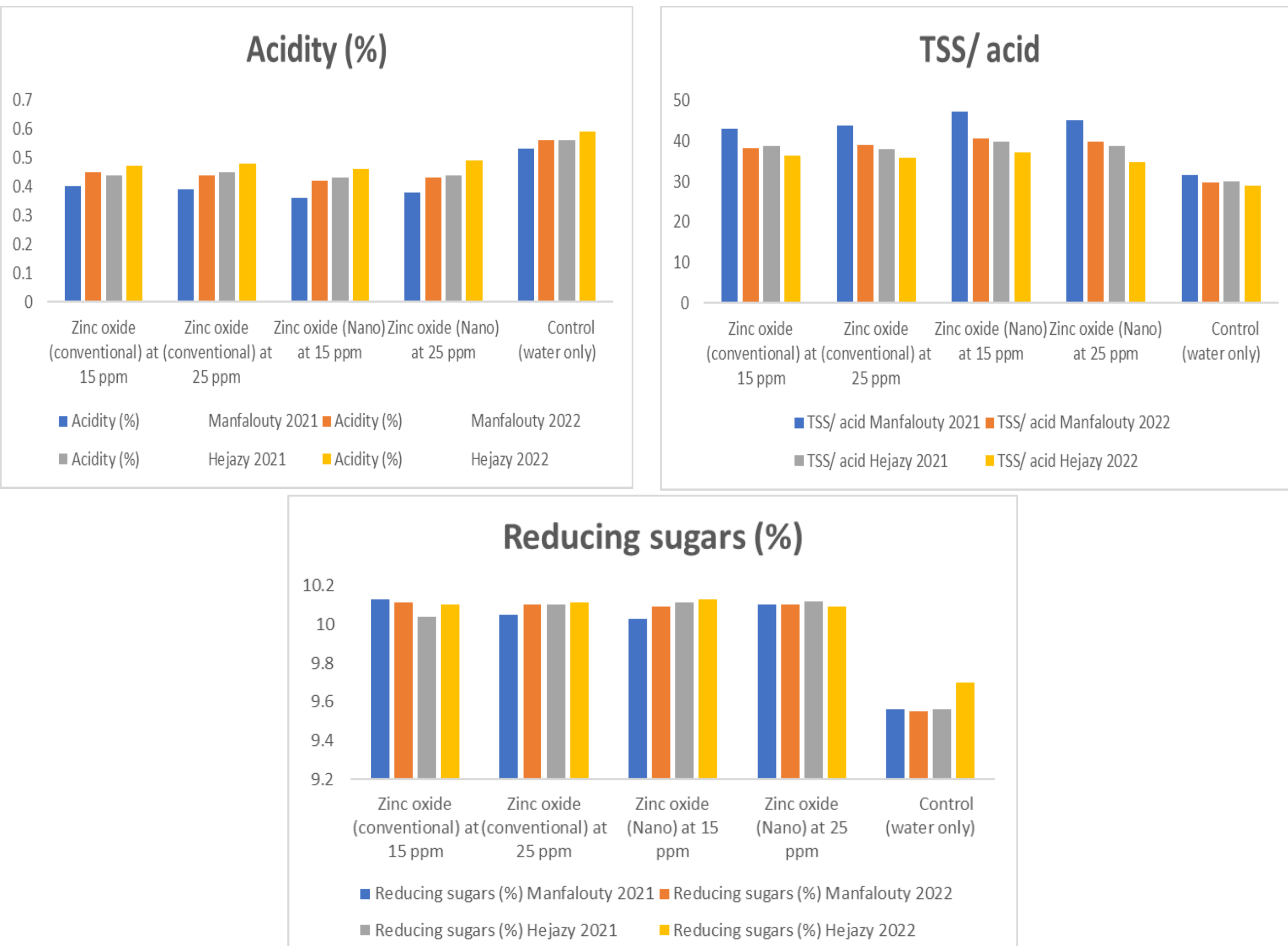

Figure 3. Effect of foliar application with conventional and Nano Zinc oxide on acidity, TSS/ acid and reducing sugars of Manfalouty and Hejazy Pomegranate trees during 2021 and 2022 seasons.

This finding matches the result reported by Davarpanah et al. (2016),

Reducing sugars, also, increased significantly compared to the control. Zinc oxide (conventional) at 15 ppm recorded the highest values for Manfalouty Pomegranate cultivar (10.13 and 10.11 %) compared to the check treatment which recorded the lowest values (9.56 and 9.55 %) during the two seasons, respectively. For the same respect, spraying Zinc oxide (Nano) at 25 ppm and Zinc oxide (Nano) at 15 ppm recorded the highest values for Hejazy cultivar (10.12 and 10.13 %) compared to the check treatment which gave the lowest values (9.56 and 9.70 %) during the two seasons, respectively.

4. Discussion

Reactivity, uncommon surface area, and size of zinc nanoparticulate particles promote zinc solubility, diffusion, and accessibility to plants, making zinc fertilizers new nanomaterials that can be employed to construct plant components (Subramanian *et al*., 2015; Mosanna and Behrozyar, 2015). Zinc is one of the important nutrients for plants, and many crops frequently lack it (Swietlik, 1999; Marschner, 2012; Ojeda-Barrios *et al*., 2014). In addition, several enzymes, including transphosphorylases, dehydrogenases, isomerases, and aldolases, often need a specific quantity of Zn in the cellular environment to work. The manufacture of tryptophan, DNA and RNA polymerases, membrane structure maintenance, cell division, and photosynthesis are all processes that tryptophan is engaged in. Zn is also a regulatory co-factor in protein biosynthesis (Marschner, 2012). According to past observations, zinc foliar sprays have increased the productivity and number of fruits on pomegranate trees.

During the creation and blossoming of fruit buds, zinc functions in the synthesis of tryptophan, an auxin precursor, and the transfer of metabolites to the site of bud growth or to the bud itself (Swietlik, 1999; Usenik and Stampar, 2002), (Day, 1994; Ryugo, 1988).

Increases in TSS in apple fruits fertilized with Zn have previously been connected to Zn's effects on carbohydrate synthesis and translocation (Yogeratnam and Greenham, 1982). Whereas Zn's effects on total sugars can be linked to its function in starch and nucleic acid metabolism as well as the activity of numerous enzymes engaged in these biochemical steps, B's effects on total sugars can be related to B's roles in sugar transport and carbohydrate metabolism (Alloway, 2008), (Hansch and Mendel, 2009).

5. Conclusion

It could be concluded that Nano Zinc at 15 and 25 ppm led to a significant improvement in almost studied characters (leaf area, fruit, arils and rind weight, juice volume, TSS, TSS/ acid, reducing sugars and total acidity percentage in fruit juice).

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The author disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

6. References

A.O.A.C. (1984). *'Official Methods of Analysis'*, 14th ed. Association of Official Analytical Chemists, Washington DC, U.S.A.

A.O.A.C. (1985). *'Official Methods of Analysis'*, A. O. A. C. 14th Ed. Published by A. O. A. C., Washington, D. C., U S A.

Adsule, R.N., Patil, N.B. (1995). *'Handbook of fruit science and technology'*, In: Salunkhe, D.K., Kadam, S.S. (Eds.), Pomegranate.

Marcel Dekker Publishers, New York, pp. 455–464.

Ahmed, F. F., Morsy, M.H. (1999). 'A new method for measuring leaf area in different fruit species', *Minia. J. Agric. Res. & Develop.*, 19, pp. 97 – 105.

Alalaf, A. H., Alalam, A. T. S., Fekry, W. M. (2020). 'The effect of spraying with nano-iron and zinc on improving growth and mineral content of pomelo (Citrus grandis) seedlings', *Int. J. Agricult. Stat. Sci. Vol*, *16*(1), pp. 1645-1650.

AL-hadrawi, D.A.K., Al-janabi, A.S.A. (2020). 'Analysis FCPOXS Gene Expression Responsibility on Peroxidase Synthesis for Two Fig Cultivars Growing Under Salt Stress and Treated with Proline and Neutra-Sol.', *Plant Archives*, 20(2), pp. 1411-1420.

Alighourchi, H., Barzegar, M., Abbasi, S. (2008). 'Effect of gamma irradiation on the stability of anthocyanins and shelf-life of various pomegranate juices', *Food chemistry*, 110(4), pp. 1036-1040.

Alloway, B. J. (2008). *'Zinc in soils and crop nutrition',*

Davarpanah, S., Tehranifar, A., Davarynejad, G., Abadía, J., & Khorasani, R. (2016). 'Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (*Punica granatum* cv. Ardestani) fruit yield and quality', *Scientia horticulturae*, 210, pp. 57-64.

Day, K., (1994). 'Correcting zinc deficiency in stone fruit orchard', *Calif. Grower*, 18, pp. 14–15.

Dong, S., Cheng, L., Scagel, C., Fuchigami, L. (2005). 'Timing of urea application affects leaf and root N uptake in young Fuji/M. 9 apple trees', *The Journal of Horticultural Science and Biotechnology*, 80(1), pp. 116-120.

El-Ghamry A.M., Mosa A.A., Alshaal T.A. and ElRamady H.R. (2018). 'Nanofertilizers vs. Biofertilizers: New Insights', *Env. Biodiv. Soil Security*, 2, pp. 51-72

El-Hak El, R. E. S. A., El-Aty El, S. A., El-Gazzar, A. A. E. F., Shaaban, E. A. E. A., Saleh, M. M. S. (2019). 'Efficiency of nano-zinc foliar spray on growth, yield and fruit quality of flame seedless grape', *Journal of Applied Sciences*, 19(6), pp. 612-617.

Hänsch, R., Mendel, R. R. (2009). 'Physiological functions of mineral micronutrients (cu, Zn, Mn, Fe, Ni, Mo, B, cl)', *Current opinion in plant biology*, 12(3), pp. 259-266.

Kourgialas, N.N., Karatzas, G.P., Koubouris, G.C. (2017). 'A GIS policy approach for assessing the effect of fertilizers on the quality of drinking and irrigation water and wellhead protection zones (Crete, Greece)', *J. of Environmental Management*, 189, pp. 150-159.

Legua, P., Melgarejo, P., Abdelmajid, H., Martinez, J.J., Martinez, R., Ilham, H., Hernández, F. (2012). 'Total phenols and antioxidant capacity in 10 Moroccan pomegranate varieties', *Journal of food science*, 77(1), pp. C115-C120.

Liu, R., Lal, R. (2015). 'Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions', *Sci. Total Environ.*, 514, pp. 131-139.

Marschner, H. (2012). *'Mineral Nutrition of Higher Plants',* Academic Press Limited Harcourt Brace and Company, Publishers, London, pp. 347–364.

Mosanna, R., Behrozyar, E.K. (2015). 'Morpho-physiological response of maize (*Zea mays* L.) to zinc nano-chelate foliar and soil application at different growth stages', *Journal on New Biological Reports*, 4(1), pp. 46-50.

Naik, S.K., Chand, P.K. (2011). 'Tissue culture-mediated biotechnological intervention in pomegranate: a review.', *Plant cell reports*, 30(5), pp. 707-721.

Ojeda-Barrios, D.L., Perea-Portillo, E., Hernández-Rodríguez, O.A., Avila-Quezada, G., Abadía, J., Lombardini, L. (2014). 'Foliar fertilization with zinc in pecan trees', *Hort. Science,* 49(5), pp. 562-566.

Ryugo, K. (1988). *'Fruit Culture',* John Wiley and Sons, New York, pp. 259–261.

SAS institute, (2008). *'The SAS system for windows',* release 9.2 Cary NC: SAS institute.

Steel, R.G., Torrie, J. (1980) '*Principles and procedures of statistics, A biological approach',* 2nd Ed., Mc. Graw-Hill Book Co. Inc., New York, USA.

Subramanian, K.S., Manikandan, A., Thirunavukkarasu, M., Rahale, C.S. (2015). 'Nano-fertilizers for balanced crop nutrition', *In Nanotechnologies in food and agriculture, Springer, Cham.,* pp. 69-80.

Swietlik, D. (1999). 'Zinc nutrition in horticultural crops', *Horticultural reviews,* 23, pp. 109-180.

Usenik, V., Stampar, F., (2002). 'Effect of foliar application of zinc plus boron on sweetcherry fruit set and yield', *Acta Hortic.,* 594, pp. 245–249.

Weinbaum, S.A. (1988). 'Foliar nutrition of fruit trees', *Plant growth and leaf applied chemicals,* pp. 81-100.

Yogaratnam, N., Greenham, D. W. P. (1982). 'The application of foliar sprays containing nitrogen, magnesium, zinc and boron to apple trees. I. Effects on fruit set and cropping', *Journal of Horticultural Science, 57*(2), pp. 151-158.