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Yield, fruit quality and nutrients content of pomegranate leaves and fruit as influenced by iron, manganese and zinc foliar spray

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Abstract: This study was carried out in a private orchard at El-Tall El-Keppeer, Ismailia Governorate Egypt under sandy soil conditions, during 2011 and 2012 growing seasons. It was aimed to investigate the influence of foliar sprays of iron, manganese and zinc sulphates on the fruit yield and quality as well as nutrients content of fruit and leavesof pomegranate (Manfalouty cv.) with four years old. Foliar spraying treatments were applied three times at mid of March, April and June at the rate of 500, 1000 mg L^{-1} for Fe, 800, 1600 mg$L^{-1}$for Mn and 1000, 2000 mg L^{-1} for Zn. The obtained results showed that Fe, Mn or Zn sprays had positive significant effects on fruit fresh and dry weights, fruit dimensions and fruit yield as well as juice volume/fruit, and fruit juice quality i.e., total soluble solids (TSS), total acidity (TA), Total sugars, Anthocyanin and Vitamin C in both seasons as compared with the control treatment. The results also, showed that foliar spraying of Fe, Mn, or Zn led to positive increases of all macro (N, P, K, Ca and Mg) and micro (Fe, Mn, Zn and Cu) nutrients concentration in pomegranate leaves, fruit peel and arils. The highest fruit yield, fruit average weight (peel and grains), fruit dimensions, fruit chemical quality*i.e.*,TSS, Total sugars and Anthocyanin were recorded by Zn foliar spraying at 2000 ppm in both growing seasons. The distribution of nutrients in leaves and fruit parts was differed according to treatment and kind of mineral nutrient. The correlation coefficient between nutrients concentrations of pomegranate leaves, peel and grains and fruit yield and quality, as an average of the two seasons showed positively significant and highly significant relationship of most nutrients with most studied pomegranate fruit characteristics.
Key words: Pomegranate, iron, manganese, zinc foliar application, fruit physico –chemical properties, fruit quality, correlation coefficient.

Introduction

Pomegranate is a fruit shrub that succeeds cultivated in many parts of Asia, North Africa, the Mediterranean and the Middle East regions[1]**.** In Egypt,itscultivation area are concentrated in Assiut Governorate, Upper Egypt Region since a long time ago and the Manfalouty pomegranate cultivar is one of the most commonly cultivation grown in such area. Recently, because pomegranate in Egypt has become a promising crop in exportation, thus its cultivation has been expansion in the newly reclaimed sandy soils as well as introducing some new cultivars. In the same time such areas of soils which characterized with low fertility, high pH value and low organic matter content, consequently have low available of micronutrients content in the soil.

Foliar application of micronutrients was successfully used for correcting deficits in crops[2]**.** Micronutrients such as Fe, Mn and Zn play a great role in plant growth, yield and quality as a result of affecting many physiological processes in plant life. For example iron (Fe) have a role in the formation of chlorophyll molecule which leads to high growth of green parts and by then leads to high production of yield.The important role of manganese (Mn) in plant came from its involving in photosynthesis, membrane function, as well as activator of numerous enzymes in the cell[3,4].In addition, zinc activated large numbers of enzymes such as alcohol-dehydrogenase, Cu-Zn superoxide dismutase, carbonic anhydrase (CA) and RNA, and very important for photosynsetic CO_2 fixation in plant leaves[5].

In general suitable methods for the correction and /or prevention of micronutrients, i.e. Fe, Mn, and Zn deficiency in plants is the foliar spraying and the mostly two chemical forms used are inorganic (SO_4) or organic (chelated) solution forms of these nutrients[6]. According to the results of some experiments, [7]found that soil application of N, P and K (based on soil analysis) foliar application of 0.5% zinc sulfate increased pomegranate yield more than 1.3t ha^{-1} compared to control treatment. [8]reported that foliar spraying of 0.4% zinc sulfate improved marketable fruit yield and quality attributes (TSS% and Vitamin C) of pomegranate. Also,[9,10]found that sprayed pomegranate shrubs with Zn and Mn had increased fruit yield and number / shrub, as well as TSS, flesh thickness and weight of 100 arils. In concern of iron foliar spraying, [11]reported that foliar spraying of Fe-EDDHA at 2000mg L^{-1}significantly increased fruit yield and number, fruit size, total soluble solid (TSS) and total soluble solid to titratable acidity (TSS/TA) of pomegranate. The incompletely of fruit arils color was observed especially in the extremely hot seasons. This observation gave the ideal of fertilizer transactions due to that it's have a fundamental role in completion of arils color. Thus, reduce phenomenon of white arils in fruits (delayed pigment anthocyanin in fruits) and increasing fruit color, especially in the hot summer seasons.

Thus, the aim of this study was to investigate the possibility effect of the foliar spraying treatments with Fe, Mn, or Zn to reduces the phenomenon of white arils in fruits (delayed pigment anthocyanin in fruits) as well as fruit yield/ shrub, nutritional status of shrubs and fruits physical and chemical quality.

Material and Methods:

The shrubs were cultivated under drip irrigation systems and were uniform in growth and cultivated at 4x3 m (350 shrubs / fad.) or (830 shrubs/ ha.)

The common fertilizer applications: were used as following: Farmyard manure 15 $m^3 Fed^{-1}$during December – January, .NPK rates were 80 Kg N/ Fed^{-1}as ammonium nitrate (33.5 % N) and calcium nitrate (15.5 % N), 30 Kg $P_2O_5 Fed^{-1}$, as phosphoric acid (60 % P_2O_5) and 70 Kg K_2O Fed^{-1}as potassium sulfate (48-52%) $year^{-1}$) were using a fertigation with drip irrigation system application divided along the growing season. Other horticultural practices were done as follows in the region.

Treatments: In the two experimental seasons, six different treatments were used as foliar spraying, in addition to the untreated control as follows: Control, Ferrous sulphate at Fe (500 ppm and 1000 ppm), Manganese sulphate at Mn (800 and 1600 ppm) and Zinc sulphate at Zn (1000 and 2000 ppm) were sprayed alone. In each season, the foliar spraying treatments were applied at three times at mid of March, April and June. The foliar spraying were 6 L/ shrub.

Soil sampling: Soil samples were randomly collected from the root zone tips of the shrubs at the end of the canopy (0-60 cm depth) for physical and chemical analysis. The samples were air dried ground to pass through a 2 mm sieve using a wooden grinding and stored in plastic bottles.

Leaf sampling: The leaf samples were (taken in mid-September in all seasons) and collected randomly around the shrub from the fully mature leaves of spring flush (4 to 7 month old young shoots) to determine the nutrient contents. Samples were washed with tap water, 0.001 N HCl and distilled water respectively, then dried at 70 °C and ground in a stainless steel mill, then passed through and stored in plastic bottles.

Fruit sampling: At harvest, three fruits from four sides of each shrub were randomly picked and were used for determination of fruit physical, juice quantitative and qualitative characteristics in the laboratory. The mineral analysis was done in fruit peel and arils to estimate the total mineral nutrient contents in the harvested fruits. Commercially ripe fresh fruits were harvested in (mid-August 2011 for the first season and mid-September 2012 for the second season.

Chemical analysis:

Soil samples were analyzed (Table 1) for texture, pH and electric conductivity (EC) using water extract (1: 2.5) method, total calcium carbonate ($CaCO_3$ %) determined with Calcimeter method and for organic matter (O.M %) was determined with using potassium dichromate[12]. Phosphorus was extracted using sodium bicarbonate[13]. Potassium (K), calcium (Ca) and magnesium (Mg) and sodium (Na) were extracted using ammonium acetate[14]. Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted using DTPA[15].

Table (1): Soil physico-chemical properties of the experimental site

Mechanical analysis %			**Tex.**	**Physical properties**				**Macronutrients (mg/100 g)**					**Micronutrients (mg/Kg)**			
Sand	Silt	Clay	Sandy	pH	EC(mS/m)	CaCO3 (%)	O.M (%)	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
86.8	5.0	8.2		8.9	0.18	3.6	0.35	0.26	13.2	420	19.6	17.6	4.4	4.0	1.2	0.4

The results of soil analysis of the experimental field indicated that P, K, Mg, Fe, Mn, Zn, and Cu were deficiency according to[16].

Nutrient element analyses in leaves and fruit peels and arils:

Nutrient element compositions in the leaves and fruit peels and arils were analyzed for the macro-micro nutrient contents. Nitrogen was analyzed by using the Kjeldahl method and P spectrophotometerically[13], and K, Ca, Mg, Fe, Mn, Zn and Cu were analyzed by Perkin-Elmer (1100 B) atomic absorption spectrometer.

Fruit physical characteristics: Average weights (g) of fruit, fruit peel and fruit arils. Also, fruit peel thickness (cm) was measured.

The fruit length and diameter (cm): were measured by a Digital Electronic Calliper and the fruit shape index (length / diameter ratio) was calculated.

Juice Extraction Ripe of fruits were cut-up, the outer skin that encloses hundreds of fleshy sacs removed, juicelocalized in the sacs extracted by a domestic blender juice and the resulting juice filteredthrough chess cloth. Juice volume (cm3) was estimated and chemical properties determined.

Fruit chemical properties:

Total soluble solids (TSS %), titratable acidity (TA %), and pH: TSS is an index of soluble sugar content in fruit. TSS (°Brix) in juice samples was determined with a digital refract meter (MASTER-M 2313, Japan).**TA** was determined according to the method described in[17], 10 ml of the extracted juice was diluted to 100 ml and titrated against 0.1 N NaOH to pH 8.3. The pH was measured at room temperature by using pH meter (JENWAY – 3505).

Total sugars :(g/100g FW)**:** Total sugars was determined by the method given in[17] 25 ml of juice sample was naturalized to pH 7.5 to 8.0 with 1 N NaOH and 2 ml of lead acetate was added along with few drops potassium oxalate and diluted, 5 g of citric acid was added to the filtrateand neutralized using phenolphthalein as an indicator with 20 % NaOH until pink color is obtained. The end point of titration on was colorless.

Ascorbic acid content (Vitamin C) (mg/ 100 ml juice)**:** Juice was measured by titration with 2-6 dichlorophenol indophenols blue dye, as described by[17].

Total anthocyanin content ((mg/ 100 ml juice)**):** Anthocyanin pigments undergo reversible structural transformations with a change in pH manifested by strikingly different absorbance spectra[18]. The colored oxonium from predominates at pH 1.0 (25 mM with potassium chloride buffer) and the colorless from at pH 4.5 (0.4 m with sodium acetate buffer).The samples were diluted by potassium chloride buffer until the absorbance of the sample at a 510 nm wavelength was within the linear range of the spectrophotometer. This dilution factor was used later to dilute the sample with the sodium acetate buffer. At two wavelengths of 510 and 700 nm, readings were performed after 15 min of incubation, four times per sample diluted in the two different buffers. The absorbance was then calculated according to the following equation: A = (A510 - A700), pH 1.0 (510 - A 700 pH 4.5).

Statistical analysis: A complete randomized block design with three replicates was used in this study. The results were submitted to analysis of variance according to[19]**.** Differences among treatment means were determined as using the LSD test at a significance level of 0.05 according to[20].

Results and Discussion

1. Fruit physical properties and yield:

The data in Table (2) revealed that fruit fresh and dry weights, fruit diameter and its length as well as juice volume/fruit were significantly increased by foliar applications with Fe or Mn or Zn foliar spraying with both levels of concentrations in both seasons as compared with the control treatment. Also, there were significant increments in the studied fruit physical properties values with increasing level of micronutrient concentration in both seasons, except Zn in the second season. The highest value of all studied fruit physical properties were recorded by 2000ppm Zn treated trees, followed by 1000ppm Zn treated trees in both seasons.

Table (2): Effect of Fe, Mn and Zn foliar application on physical properties and yield fruits of Manfalouty pomegranate in 2011 and 2012 seasons

Treatments		Fresh weight (g)			Dry weight (g)		
		Fruit	**peel**	**grains**	**fruit**	**peel**	**grains**
First season (2011)							
Fe	(500 ppm)	206.10	72.90	133.20	43.40	19.30	24.10
Fe	(1000 ppm)	237.90	84.10	155.80	50.10	22.30	27.80
Mn	(800 ppm)	276.70	97.80	178.90	56.20	25.90	30.30
Mn	(1600 ppm)	288.10	101.92	186.20	60.90	26.96	33.93
Zn	(1000 ppm)	299.70	106.30	194.40	63.30	28.10	35.20
Zn	(2000 ppm)	312.40	110.40	201.92	65.70	29.20	36.50
	Control	190.46	67.34	123.12	40.10	17.82	22.28
	LSD (5%)	**11.1**	**3.75**	**6.49**	**1.71**	**0.98**	**1.04**
Second season (2012)							
Fe	(500 ppm)	227.37	80.39	146.98	47.87	21.27	27.84
Fe	(1000 ppm)	248.07	87.71	160.36	52.23	23.20	30.37
Mn	(800 ppm)	259.04	91.59	167.45	54.53	24.23	31.71
Mn	(1600 ppm)	309.33	109.37	199.96	65.12	28.93	37.87
Zn	(1000 ppm)	321.48	113.67	207.81	67.68	30.07	39.36
Zn	(2000 ppm)	323.10	114.24	208.86	68.02	30.22	39.56
	Control	211.60	74.82	136.78	44.55	19.79	25.91
	LSD (5%)	**11.69**	**4.13**	**7.56**	**2.46**	**1.11**	**1.43**

Fed.* = 4200m^2

Table (2) Cont.

Treatments	Dimensions		Juice volume /fruit(ml)	Yield	
	Diameter (D)	Length (L)		Per Shrub (kg)	Per Fed.* (ton)
First season (2011)					
Fe (500 ppm)	5.98	6.18	70.14	8.24	2.88
Fe (1000 ppm)	6.90	7.13	80.93	9.51	3.33
Mn (800 ppm)	8.02	8.29	94.15	11.07	3.84
Mn (1600 ppm)	8.36	8.64	98.08	11.53	4.04
Zn (1000 ppm)	8.72	9.01	102.32	12.03	4.21
Zn (2000 ppm)	9.06	9.36	106.29	12.50	4.38
Control	5.13	5.71	64.81	7.62	2.57
LSD (5%)	**0.31**	**0.32**	**3.62**	**0.42**	**0.17**
Second season (2012)					
Fe (500 ppm)	6.59	6.82	77.36	11.37	3.98
Fe (1000 ppm)	7.44	7.54	84.41	12.16	4.26
Mn (800 ppm)	7.52	7.78	88.25	12.97	4.54
Mn (1600 ppm)	8.97	9.27	105.25	15.47	5.41
Zn (1000 ppm)	9.32	9.64	109.39	16.07	5.62
Zn (2000 ppm)	9.37	9.69	109.94	16.16	5.66
Control	6.13	6.34	72.00	10.58	3.70
LSD (5%)	**0.53**	**0.35**	**3.98**	**0.65**	**0.23**

Regarding fruit yield as affected by micronutrients foliar spraying, data in Table (2) showed that Fe or Mn or Zn sprays at both levels of concentration caused significantly increased fruit yield of shrub and Feddan in the two growing seasons as compared with unsprayed trees. As well as there were significant increments in the fruit yield of shrub and Feddan with increasing level each of Fe or Mn or Zn nutrient in both seasons with the exception of Zn in the second season. Results also indicated that the highest fruit yield of 12.5 kg and 16.16 kg shrub^{-1} and 4.38 and 5.66 ton feddan^{-1} were obtained from shrubs receiving 2000ppm Zn foliar spray in both seasons, consecutively. Followed by 1000ppm Zn that recorded 12.03 kg and 16.07 kg shrub^{-1}, 4.21 ton and 5.62 ton feddan^{-1} in the first and second seasons, respectively.

The achieved results indicate superiority and preference of Zn in improving fruit physical properties and increase the productivity of pomegranate shrubs compared with Fe or Mn under the conditions of the experiment.

The positive action of micronutrients foliar application (Fe, Mn and Zn) on pomegranate fruit yield and studied fruit physical properties mainly attributed to these micronutrients play an important role in the multi-biological processes in plant such as the role of Fe in biosynthesis of chlorophyll and hemi proteins such as cytochrom and nonheme proteins such as ferredoxin, which participate in different functions in the plant metabolism[3]. Also, the particular role of Mn in photosynthesis through it is involved in the O_2 – evolution in PS II. As well as Mn acts as co-factor, activating about 35 different enzymes in plant[3]. In concern of Zn, there a large number of enzymes in which Zn are integral components of the enzyme structure or activate. Zn also involved in regulating the protein and carbohydrate metabolism[21].

The obtained results concerning the positive effects of foliar sprays with micronutrients on some fruits parameters and fruit yield of pomegranate go in line with the findingsof[9,10,11,22]they found that Fe or Mn foliar application significantly increased average fruit weight and fruit yield of pomegranate shrubs. Also, in this connection [23]mentioned that fruiting parameters and fruit yield of Canino apricot trees were greatly enhanced by the foliar application of micronutrients (Fe, MnandZn). On the contrary[24,8,9] found that Zn foliar spray had no significant effect on pomegranate fruit average weight and fruit yield. The variation in the results may be attributed to time of application of Zn and variable responses of different cultivars to Zn application or the environmental conditions and available micronutrients levels in soil.

2. Fruit quality:

Total soluble solid (TSS %):

Table (3) demonstrates that TSS % of Manfalouty pomegranate fruit juice was significantly increased by foliar spraying of Fe, Mn or Zn at two levels of concentration of each mineral nutrient as compared with unsprayed shrubs (control) in both growing seasons. Moreover, there were significant increases in the fruit juice with increasing level of Fe or Mn or Zn nutrient in both seasons. Results also showed that the highest TSS content of fruit juice was gained from shrubsreceiving the high level of Zn at2000ppm foliar spray followed by Mn at 1600ppm in the first and second seasons.

Total sugars (g/100g FW):

It is evident from the data in Table (3) that foliar spraying of Fe, Mn or Zn statistically increased total sugars (g/100g FW) of Manfalouty pomegranate fruit as compared with control treatment in both seasons. Furthermore, both levels of the three tested micronutrients (Fe, Mn or Zn) succeeded in increasing this parameter significantly and there were significant differences between Fe levels only in both seasons. However, the highest value of this parameter was registered by the foliar spraying of 2000ppm Zn followed by the same nutrient at the lower level (1000 ppm) in both seasons.

Table (3): Effect of Fe, Mn and Zn foliar application on chemical properties of Manfalouty pomegranate fruits in 2011 and 2012 seasons

Treatments	TSS (%)	Total sugars (g/100g FW)	Acidity (%)	TSS/ TA	Anthocyanin (mg/ 100 ml juice)	V.C (mg/100 ml juice)	pH
	First season (2011)						
Fe (500 ppm)	14.50	14.19	1.95	7.44	4.72	14.94	3.55
Fe (1000 ppm)	15.50	14.72	1.97	7.87	5.00	15.46	3.65
Mn (800 ppm)	16.00	15.09	1.92	8.33	5.15	15.78	3.65
Mn (1600 ppm)	17.00	15.11	1.93	8.81	5.39	15.87	3.65
Zn (1000 ppm)	16.50	15.11	1.88	8.78	5.06	15.86	3.45
Zn (2000 ppm)	17.00	15.22	1.96	8.67	5.72	15.39	3.45
Control	13.50	13.26	2.15	6.28	4.02	15.25	3.55
LSD (5%)	**0.48**	**0.39**	**0.03**	**0.48**	**0.61**	**0.34**	**0.10**
	Second season (2012)						
Fe (500 ppm)	15.00	14.23	1.97	7.61	4.72	14.92	3.50
Fe (1000 ppm)	16.00	14.94	1.99	8.04	5.00	15.22	3.64
Mn (800 ppm)	16.00	14.90	1.95	8.21	5.15	15.70	3.65
Mn (1600 ppm)	17.00	15.15	1.95	8.72	5.39	15.81	3.65
Zn (1000 ppm)	15.70	15.25	1.90	8.26	5.06	15.80	3.43
Zn (2000 ppm)	17.00	15.28	1.97	8.63	5.72	15.62	3.43
Control	13.00	13.32	2.10	6.19	4.02	15.40	3.55
LSD (5%)	**0.39**	**0.36**	**0.04**	**0.49**	**0.49**	**0.09**	**0.06**

Total acidity (%):

Table (3) indicated that total acidity (%)ofManfalouty pomegranate fruit was significantly decreased by foliar spraying of Fe, Mn or Zn at two levels of concentration compared with unsprayed treatment in both seasons. The lowest value of this parameter was attained from foliar spray of 1000ppm Zn and there were no significant differences between nutrient levels except Zn levels in both seasons.

Anthocyanin (mg/100ml juice):

Data in Table (3) revealed that all treatments of Fe, Mn and Zn foliar spraying at both levels had positive significant effect on anthocyanin content of Manfalouty pomegranate juice fruit in the two seasons as compared with the control treatment. Results also, showed no significant differences between lower and higher level of each nutrient except only in concern of Zn where 2000ppm Zn revealed significant increment in anthocyanin content as compared with 1000ppm Zn in both seasons. The highest anthocyanin content was obtained by using 2000ppm Zn foliar application in both seasons.

Ascorbic acid content (V.C) (mg/ 100ml juice):

It was notice from Table (3) that highest V.C content was resulted from shrubs which treated with 1600 ppm Mn while, the lowest one was attained from 500ppm Fe followed by control treatment in both seasons. This result was confirmed by [24] on Manfalouty pomegranate.

pH:

Generally, the results as shown in Table (3) indicate that pH of fruits juice was slightly affected by the treatment in both studied seasons; however Zn foliar spray clearly decreased pH of fruit juice. In this context[25,26]on pomegranate found that, the lowest pH of fruit juice was recorded by treatment of potassium and manganese

The improvements of pomegranate fruit quality and the cause for increasing the percentage of total soluble solids when spraying these elements, it may be due to the role of these elements in increasing the photosynthesis process efficiency, led to increase the sugar compounds and cause more soluble solids in fruit juice.

These results are in agreement with those reported by [9,10,11,22] they reported that pomegranate fruit quality were greatly enhanced by the foliar application of micronutrients (Fe, Mn and Zn). Also, in this connection[23] mentioned that foliar spray of micronutrients (Fe, Mn and Zn) had positive effect on fruit quality of Canino apricot**.**

3. Leaves macro and micronutrients content:

The effect of Fe, Mn or Zn as a foliar application on N, P, K, Ca, Mg, Fe, Mn, Zn and Cu concentration in pomegranate leaves are listed in Tables (4 & 5) as an average of the two seasons. Data clear that foliar application of Fe, Mn or Zn succeeded in significantly increasing of leaf macronutrient (N, P, K and Ca) and micronutrients (Fe, Mn, Zn and Cu) content. However, leaf Mg content was slightly or no affected by all treatment. Also 1000 ppm Fe had no positive effect on leaf Mg content as compared with unsprayed trees. Moreover, foliar spraying with 1600 ppm Mn gave the highest values of leaf content from N and Ca while, 1000 ppm Fe foliar spray gave the highest values of leaves K, Mn and Zn content. In addition, the highest leaf Fe and Cu content attained from 1000 ppm Zn foliar spraying. The obtained results of foliar spray with micronutrients (Fe, Mn or Zn) on leaf mineral content of pomegranate shrubs are in harmony with the finding of[9]on pomegranate and[23] on apricot trees, they mentioned that foliar spray of micronutrients (Fe, Mn and Zn) enhanced leaf mineral content**.** Also,[27]reported that spraying of micronutrients (Fe, Mn, and Zn) led to increase in the activities of the vegetative growth**,** consequently led to absorb more nutrients.

4. Fruits macro and micronutrients content:

The results in Tables (4 & 5) as an average of the two seasons showed that foliar spray of Fe, Mn and Zn significantly increased the concentration of all macro (N, P, K, Ca and Mg) and micro (Fe, Mn, Zn and Cu) nutrients in pomegranate fruit peel and arils. It is also; clear from the results that 500 ppm Fe treatment gave the highest values of N, P, Ca and Cu in peel and arils, as well as Mg in the arils. Moreover, the highest K, Mg, and Fe content in both peel and arils were obtained by using 1000 ppm Fe foliar spray.

Data also, clearly indicated that 1600 ppm Mn and 2000 ppm Zn foliar application led to the highest peel and arils content from Mn and Zn, respectively as compared with the other treatment. In this context, [27] mentioned that spraying of micronutrients (Fe, Mn and Zn) led to increase in the activities of the vegetative growth**,** consequently led to absorb more nutrients.

5. Correlation coefficient:

The correlation coefficient between nutrients concentrations of pomegranate leaves, peel and grains and fruit yield and quality, as an average of the two seasons are presented in (Tables 6, 7 and 8). Results indicated that the fruit yield and quality were positively significant correlated with macro- and micronutrients concentrations in pomegranate leaves, peel and grains, with the exception of magnesium and zinc in leaves, phosphorus, calcium and iron in peel, as well as phosphorus in grains. In addition, the highly significant positive correlation was found between the content of leaves from calcium and iron and fruit yield, juice volume, fruit diameter total sugars, anthocyanin and vitamin C, as well as highly significant positive correlation was found between the content of leaves from phosphorus and fruit yield, juice volume, fruit diameter total sugars and vitamin C. Also, highly significant positive correlation was found between the content of leaves from phosphorus and fruit yield, juice volume, fruit diameter total sugars and vitamin C.

Table (4): Effect of Fe, Mn and Zn foliar application on macronutrients content of pomegranate leaf, peel and arils (average of the two seasons)

Treatments	Leaf					Peel					Grains				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Fe (500 ppm)	2.22	0.49	0.81	3.75	0.39	2.38	0.36	1.43	0.90	0.86	2.81	0.64	1.33	0.63	0.95
Fe (1000 ppm)	2.70	0.81	1.19	3.38	0.32	2.40	0.35	1.53	0.78	0.90	2.87	0.64	1.38	0.63	0.95
Mn (800 ppm)	2.72	0.68	0.78	3.88	0.37	2.33	0.33	1.38	0.75	0.80	2.78	0.54	1.30	0.63	0.80
Mn (1600 ppm)	2.77	0.70	0.88	4.63	0.33	2.27	0.17	1.38	0.48	0.82	2.72	0.41	1.30	0.55	0.87
Zn (1000 ppm)	2.28	0.88	0.82	4.38	0.39	2.20	0.32	1.28	0.65	0.70	2.67	0.55	1.20	0.60	0.63
Zn (2000 ppm)	2.38	0.60	0.84	4.25	0.39	2.15	0.26	1.30	0.60	0.73	2.62	0.53	1.25	0.60	0.63
Control	1.90	0.48	0.63	3.38	0.37	1.76	0.17	0.90	0.43	0.53	1.90	0.37	1.03	0.45	0.31
LSD (5%)	**0.1**	**0.03**	**0.03**	**0.05**	**0.05**	**0.08**	**0.02**	**0.02**	**0.02**	**0.05**	**0.06**	**0.01**	**0.03**	**0.01**	**0.02**

Table (5): Effect of Fe, Mn and Zn foliar application on micronutrients content of pomegranate leaf, peel and arils (average of the two seasons)

Treatments	Leaf				Peel				Grains			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
Fe (500 ppm)	345	19	40	12	103	11	19	10.5	146	25	37	9.0
Fe (1000 ppm)	391	39	44	11	111	12	20	9.0	178	29	45	10.5
Mn (800 ppm)	389	35	41	12	78	27	18	10.5	119	33	34	9.0
Mn (1600 ppm)	464	21	25	8	51	19	14	9.0	103	35	27	4.5
Zn (1000 ppm)	543	30	25	14	59	11	23	10.5	116	24	45	9.0
Zn (2000 ppm)	456	35	30	12	70	12	25	9.0	116	29	50	10.5
Control	251	19	23	6	29	8	11	7.5	46	13	21	3.0
LSD (5%)	**8.7**	**1.6**	**2.3**	**1.0**	**1.7**	**1.0**	**1.4**	**0.5**	**1.2**	**1.2**	**1.5**	**0.8**

Table (6): Correlation coefficient between nutrients content in pomegranate leaves andfruit yield and quality (average of the two seasons)

	V.C	Anthocyanin	Total sugars	Diameter	Juice Volume	Yield / fed.
Nitrogen	0.23473	0.58884**	0.67727**	0.44769*	0.44845*	0.48113*
Phosphorus	-0.20243	0.24439	0.31547	0.02759	0.02819	0.06032
Potassium	0.06168	0.47907*	0.52155*	0.25454	0.25546	0.28850
Calcium	0.09533	0.51184*	0.62446**	0.37959	0.38041	0.40564
Magnesium	0.05708	0.39176	0.4519**	0.13151	0.13252	0.16664
Iron	-0.05021	0.36326*	0.42212	0.13642	0.13721	0.17324
Zinc	0.04648	0.54133*	0.5603**	0.53195*	0.53229*	0.55236**
Manganese	0.69678**	0.29861	0.5302*	0.46324*	0.46341*	0.46302*
Copper	0.02208	0.50465*	0.54861**	0.41495	0.41545*	0.43373*

$r_{0.05}$=0.433 , $_{0.01}$=0.549,* , ** = significant at the probability levels of 0.05 and 0.01, respectively

In the concern of macro and micronutrients concentration in pomegranate fruit parts (peel and grains) data in Tables (7 and 8) showed highly significant positive correlation was found between nitrogen and potassium content in peel and nitrogen content in grains and anthocyanin and vitamin C. Also, highly significant positive correlation was found between zinc concentration in peel and fruit yield, juice volume fruit diameter total sugars and anthocyanin.

Table (7): Correlation coefficient between nutrients content in pomegranate peel and fruit yield and quality (average of the two seasons)

	V.C	Anthocyanin	Total sugars	Diameter	Juice Volume	Yield / fed.
Nitrogen	0.25208	0.54839**	0.63140**	0.29584	0.29670	0.32727
Phosphorus	-0.11183	0.14458	0.29421	0.01095	0.01141	0.03426
Potassium	0.16202	0.55559**	0.62387**	0.33640	0.33729	0.36965
Calcium	-0.23933	0.12612	0.20304	-0.12884	-0.12819	-0.09908
Magnesium	0.03709	0.40769	0.47411*	0.14543	0.14588	0.18583
Iron	-0.24691	0.22461	0.25901	-0.07410	-0.07337	-0.03735
Zinc	0.09779	0.57790**	0.61140**	0.60416**	0.60452**	0.61791**
Manganese	0.27541	0.14042	0.31897	0.08138	0.08175	0.07904
Copper	0.25490	0.33402	0.50177*	0.24389	0.24403	0.26272

$r_{0.05}$=0.433 , $_{0.01}$=0.549,* , ** = significant at the probability levels of 0.05 and 0.01, respectively

Data also indicated that highly significant positive correlation between calcium, magnesium, zinc and copper concentration in grains and total sugars. In addition, highly significant positive correlation between fruit yield, vitamin C and total sugars and zinc, manganese and copper concentration in grains, respectively. The obtained results on relationship of fruit macro and micronutrients content with fruit yield and quality are in agreement with those reported on pear by [28, 29, 30].

Table (8): Correlation coefficient between nutrients content in pomegranate grains and fruit yield and quality (average of the two seasons)

	V.C	Anthocyanin	Total sugars	Diameter	Juice Volume	Yield / fed.
Nitrogen	0.49681*	0.53606*	0.65037**	0.51349*	0.51381*	0.53304*
Phosphorus	0.69841**	0.43244	0.65886**	0.60233**	0.60217**	0.61042**
Potassium	0.16068	0.39749	0.45386*	0.18911	0.18952	0.21909
Calcium	0.57079**	0.61828**	0.65580**	0.81564**	0.81580**	0.81606**
Magnesium	0.06628	0.26379	0.35473	0.20264	0.20163	0.20591
Iron	0.61923**	0.67501**	0.80689**	0.88893**	0.88904**	0.89976**
Zinc	-0.15740	0.18580	0.24716	-0.14910	-0.14856	-0.12934
Manganese	0.38486	0.26336	0.43705*	0.07934	0.07988	0.09945
Copper	0.25263	0.57092*	0.70131**	0.51668*	0.51686*	0.53139*

$r_{0.05}$=0.433 , $_{0.01}$=0.549,* , ** = significant at the probability levels of 0.05 and 0.01, respectively

Conclusion:

Foliar spraying of Fe, Mn and Zn had positive significant effects on fruits yield and improved fruit juice volume, total soluble solids content, total sugars, anthocyanin and vitamin C. Also, foliar treatments reduced the phenomenon of white grains in fruits which reflected by increasing anthocyanin in fruits and increase color, as well as enhanced nutritional status of pomegranate shrubs. Also, the obtained results indicate superiority and preference of Zn in improving fruit physical properties and increase the productivity of pomegranate shrubs compared with Fe or Mn under the conditions of the experiment.

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