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Influence of Foliar Applications with Microelements on Vegetative Growth and Productivity of Jojoba Shrubs

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Abstract: The present investigation was carried out on two genotypes (G1 and G2) of female Jojoba shrubs in a private orchard at Cairo/Alexandria desert road, Giza Governorate, Egypt, planted at 4×2 meter a part in sandy soil under drip irrigation system, to study the influence of foliar application with microelements on vegetative growth and productivity of jojoba shrubs during 2018 and 2019 seasons. Thirteen treatments were applied, control (tap water) and tow concentrations (100 and 200 ppm) of boron, copper, iron, manganese, zinc and combination of previous elements all together. All treatments were sprayed two times, the first was applied a month before start of flowering and the second at the time of fruit set. Results showed that, all foliar applications of the microelements improved all the studied characteristics compared with control. The best results in (shoot length, fruit density, seed yield and weight) were achieved from the foliar application of the high concentration of manganese (200 ppm) for both studied genotypes. Whereas, the foliar application of boron with the low concentration (100 ppm) affected positively on leaf area and seed oil content. So, we can recommend to use the manganese (200 ppm) and boron (100 ppm) to increase seed yield and oil content of jojoba shrubs under the same experiment conditions.

Key words: Jojoba · Microelements · Genotype · Seed yield · Seed oil content

INTRODUCTION

Jojoba *(Simmondsia chinensis* L.) belongs to family *Simmondsiaceae* is a woody, evergreen, dioecious, perennial shrub with extensive deep tap root system. It is considered a promising oil crop and is cultivated for diverse purposes in many countries. The jojoba seed produces unique high-quality liquid wax, which is very similar to sperm whale oil and has wide applications in cosmetics, lubricants and pharmaceutical industry. In addition, different extracts from jojoba plant are widely used in many folk medicinal uses [1, 2]. The plant also has potential value in combating desertification and land degradation in dry and semi-dry areas, although the plant is known for its high-temperature and high-salinity tolerance growth ability [3, 4].

All plants need an adequate supply of micro-elements in order to match their normal physiological and biochemical function, (iron, zinc, boron, etc.) are considered to be essential for metabolism, growth processes, fruit development and quality because they are cofactors and/or activators of many metabolic enzymes [5]. In addition, they are been required in small amount but play a great role in plant metabolism and essentially as important as macronutrients to have better growth, yield and quality in plants [6].

Micronutrients help in the uptake of major nutrients and play an active role in the plant metabolism process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity hormone synthesis, nitrogen fixation and reduction [7].

These are involved in the synthesis of many compounds essential for plant growth and productivity and are the activators for various enzymes. For instance, Zn is involved in the biosynthesis of tryptophan, a precursor of naturally occurring auxin, indole acetic acid [8]. Mn is required in the process of photosynthesis [9]. Fe plays a key role in several enzyme-systems [10]. Besides being involved in the functioning of the various plant enzymes, the foliar application of the micronutrients has also significant effect on the yield and quality of fruits in citrus [11, 12]. Boron plays an important role in plant

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growth and cell wall strength, cell division, seed development, sugar transport and hormone development, copper activates some enzymes in plants which are involved in lignin synthesis and it is essential in several enzyme systems [13-15].

Regarding to a deficient of studies on the role of all those elements on growth and productivity of Jojoba especially under the Egyptian conditions, this study was undertaken to find out the effects of five micronutrients boron (B), copper (Cu), Iron (Fe), manganese (Mn), zinc (Zn) and its combinations in two concentrations (100 and 200 ppm) on vegetative, fruiting characters, yield and extracted oil percentage of two jojoba genotypes.

MATERIALS AND METHODS

This experiment was conducted in 2018 and 2019 growing seasons on Jojoba shrubs, 4 years old planted in private farm at Cairo/Alexandria desert road. The shrubs were planted at 4×2 meter apart (525 shrubs/fed.), in sandy soil, under drip irrigation system. Seventy-eight shrubs were selected as uniform as possible. The experiment was subjected to the regularly recommended culture practices during the two years of the study. There were thirteen treatments, as follow:

- T1: Control (Tap water)
- T2:Boron (EDTA) 100 ppm, (15% B)
- T3: Boron (EDTA) 200 ppm, (15% B)
- T4: Copper (EDTA)100 ppm, (14% Cu)
- T5: Copper (EDTA) 200 ppm, (14% Cu)
- T6: Iron (EDTA) 100 ppm, (12% Fe)
- T7: Iron (EDTA)200 ppm, (12% Fe)
- T8: Manganese (EDTA) 100 ppm, (14% Mn)
- T9: Manganese (EDTA)200 ppm, (14% Mn)
- T10:Zinc (EDTA) 100 ppm, (14% Zn)
- T11:Zinc (EDTA)200 ppm, (14% Zn)
- T12: Combination (B + Cu + Fe + Mn + Zn), 100 ppm
- T13: Combination (B + Cu + Fe + Mn + Zn), 200 ppm

Soil and water samples were analyzed for various physic-chemical properties using standard methods using ICARDA manual according to Ryan *et al.* [16] and were summarized in Tables (1 and 2).

The experiment was designed as Complete Randomized Design (CRD) with three replicates per treatment and each replicate were presented by one shrub. Different concentrations of (Boron, Copper, Iron, Manganese and Zinc) were applied as foliar spray two times on two genotypes (G1 and G2) during the two seasons of the study. The first additional date of foliar application was applied a month before the start of flowering and the second was applied at the time of fruit set.

The control plants were sprayed with tap water. All foliar applications were made in early morning for better absorption and long-lasting effect.

Measurements: The plants were collected at 22nd June to determine the vegetative growth, yield characters, oil content and some minerals content.

Vegetative Growth: Twelve shoots were randomly selected at different sides on each female shrub labeled and used to study the following characteristics.

- Shoot length (cm): length of the growing shoots was measured for each shrub at the end of growing seasons.
- Leaf area (cm^2): was estimated from the following equation:

Leaf area = 0.717 X – 0.095, which X is the product of length by width [17].

- Leaves density: was estimated from the following equation

Leaves density= number of leaves X 100 /shoot length

- Fruits density: was estimated from the following equation

Fruits density= number of fruits X 100 /shoot length

- Seed yield and physical characteristics

- Yield/shrub (kg): was recorded at the harvesting date (22nd June) for every shrub.

Also, seed length (cm), seed width (cm) and seed weight (g) were determined.

Leaves Minerals Content: Five mature leaves were collected from each shrubs on May to determine the nutrient elements, the collected leaves samples were washed and dried at 70°C (leaf samples were randomly from the previously labeled shoots per each replicate/ shrubs and then grounded for determination of: Mn, Zn, Cu, B and Fe by atomic absorption according to Jackson, [18].

Table 1: Mechanical and chemical analysis of the experimental soil

Mechanical analyses (%)				
Coarse sand	Fine sand	Silt	Clay	Texture class
38.4	43.3	13.0	5.3	Sandy

Chemical analyses (Anions and Cations) mg/L

pH	ECds /m	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
7.99	0.56	1.8	0.87	2.5	1.25	--	1.51	4.51	0.43

Available nutrients (mq/ Kg Soil)

N	P	K
127.3	15.8	99.8

Table 2: Chemical characteristics of the tested water sample collected from the experimental area.

		Soluble cations(me/L)				Soluble anions (me/ L)				
pH 2.5:1	E.C. ds/M (1:5)	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3-	HCO_3^{-}	Cl^{-}	SO_4^{-}	S.A.R
7.12	6.10	22.69	16.54	16.54	0.17	-	1.52	18.75	47.91	6.25

Oil Content: Seed oil content (as a percentage of dry weight), was determined by extracting oil by means of the Soxhelt extraction apparatus as described in A.O.A.C. [19].

Statistical Analysis: All data were tested for treatments effects on analyzed parameters by the one-way analysis of variance (ANOVA). Difference between treatments were compared by Duncan's Multiple Range Test [20], according to Sendecor and Cochran [21].

RESULTS AND DISCUSSION

Vegetative Growth

Genotype 1 (G1): Table (3) noticed that, the application of manganese followed by boron treatment with their high level (200 ppm) gave the highest significant values in shoot length in both seasons of the study. However, the spraying with zinc (200 ppm) achieved the greatest values of leaves density in comparison with the other treatments in both seasons. Nevertheless, boron with its low level (100 ppm) followed by its high level (200 ppm) led to get the highest leaf area in both seasons of the study.

Genotype 2 (G2): Table (4) slowed that, application of manganese in its low concentration (100 ppm) in both seasons of the study and boron (100 ppm) in the first season gave the highest significant shoot length values. However, iron (100 ppm) and Manganese (100 ppm) conducted the greatest leaves density in 2018 and 2019 seasons, respectively. The highest values of leaf area had been showed by boron (100 ppm) in both seasons and control treatments in the second season, whilst there are no clear significant differences between other treatments in the first season.

The obtained results of vegetative growth are in accordance with the findings of Ahmed and Adam [22] on Jojoba plants, as well as, Ghatas and Abdallah [23] and Dawood *et al.* [24] found that, foliar spray with some micro-nutrients enhanced plant growth. Also, the current results are in agreement with those conducted on jojoba plant which reported that application of liquid fertilizer zinc, positively affected the physiological functions and growth plants compared with control [25].

Fruits Density, Seed Yield and Seed Oil Content:

Genotype 1 (G1): The obtained results in (Table 5) showed that, foliar application of manganese at 100 ppm in both seasons as well as, boron at 100 ppm and Copper at 200 ppm in the second season gave the highest significant values of the fruit density, flowed by Boron and Copper at 100 ppm in the first and second season respectively. As a while, the greatest yield had been achieved significantly by spraying of boron (100 ppm) followed by boron and manganese with their high concentration (200 ppm) in the first season and manganese (200 ppm) followed by boron with its two concentrations (100 and 200 ppm) in the second season of the study. Otherwise, the application of boron in its low concentration (100 ppm) followed by its high concentration (200 ppm) gave the greatest oil content percentages in both seasons of the study compared with other treatments.

Table 3: Influence of foliar applications with microelements on shoot length (cm), leaves density and leaf area (cm^2) of genotype 1 (G1) during 2018 and 2019 seasons

	Shoot length (cm)		Leaves density		Leaf area (cm^2)	
Treatments	2018	2019	2018	2019	2018	2019
Control	21.23 g	21.75 f	97.58 e	89.17 f	2.74 g	3.207 e
Boron at 100 ppm	24.96 bc	24.50 c	98.25 de	93.27 e	3.70 a	4.070 a
Boron at 200 ppm	25.46 b	25.33 b	99.51 cd	93.26 e	3.34 b	3.800 b
Copper at 100 ppm	22.46 e	21.83 f	97.24 ef	102.1 b	2.98 e-g	3.237 e
Copper at 200 ppm	22.58 e	21.92 f	97.03 ef	99.83 c	3.23 b-d	3.653 c
Iron at 100 ppm	23.54 d	22.50 e	95.59 f	93.73 e	3.31 bc	3.677 c
Iron at 200 ppm	23.33 d	23.75 d	101.8 ab	92.31 e	3.09 b-e	3.490 d
Manganese at 100 ppm	24.63 c	24.75 c	100.5 bc	97.71 d	2.81 fg	2.870 f
Manganese at 200 ppm	31.08 a	26.67 a	85.82 i	85.54 g	3.02 d-f	3.487 d
Zinc at 100 ppm	19.42 h	18.17 h	93.61 g	102.7 b	2.49 h	2.743g
Zinc at 200 ppm	22.29 e	21.75 f	102.5 a	107.1 a	2.94 e-g	3.240 e
Combination at 100 ppm	24.83 c	22.83 e	91.96 h	98.70 cd	3.07 c-e	3.277 e
Combination at 200 ppm	21.75 f	20.00 g	91.95 h	107.9 a	3.13 b-e	3.490 d

Values have the same letters are not significantly different at 5% using Duncan's Test.

Table 4: Influence of foliar applications with microelements on shoot length (cm), leaves density and leaf area (cm^2) of genotype 2 (G2) during 2018 and 2019 seasons

	Shoot length (cm)		Leaves density		Leaf area (cm^2)	
Treatments	2018	2019	2018	2019	2018	2019
Control	17.52 f	14.17 h	80.94 h	81.48 i	3.35 a-c	4.59 a
Boron at 100 ppm	25.00 a	19.83 b	79.36 h	91.45 f	3.98 a	4.69 a
Boron at 200 ppm	21.00 c	18.83 cd	89.64 b	99.19 c	3.85 a-c	4.33 b
Copper at 100 ppm	20.50 cd	18.33 de	89.76 b	89.71 g	3.31 a-c	3.68 f
Copper at 200 ppm	18.92 e	15.67 g	82.89 g	97.45 d	3.81 a-c	4.07 d
Iron at 100 ppm	15.75 g	14.33 h	92.52 a	92.61 f	3.62 a-c	3.88 e
Iron at 200 ppm	19.35 e	17.17 f	88.84 bc	95.66 e	3.00 c	3.39 h
Manganese at 100 ppm	25.67 a	21.67 a	84.42 fg	109.7 a	3.07 bc	3.51 g
Manganese at 200 ppm	22.35 b	19.33 bc	86.94 d	91.49 f	3.69 a-c	4.41 b
Zinc at 100 ppm	18.58 e	16.83 f	90.61 b	86.77 h	3.25 a-c	4.00 d
Zinc at 200 ppm	17.52 f	15.33 g	87.60 cd	96.10 de	3.87 ab	4.20 c
Combination at 100 ppm	20.08 d	17.33 f	86.31 de	104.0 b	3.00 c	3.31 h
Combination at 200 ppm	20.33 cd	18.00 e	85.00 ef	89.04 g	3.16 a-c	3.60 fg

Values have the same letters are not significantly different at 5% using Duncan's Test

Genotype 2 (G2): Data in Table (6), cleared that, copper (100 ppm) in both season and iron (100 ppm) in the first season gave the highest significant values of fruit density flowed by manganese (200 ppm) in both seasons and zinc (200 ppm) in the first season of the study. Nevertheless, spraying with manganese (200 ppm) achieved the highest significant yield in both seasons compared with other applications. Concerning oil content, the highest values had been achieved significant by boron (100 ppm) in both seasons, alongside iron 200 ppm and zinc (100 ppm) in the first season of the study.

These results are in agreement with those obtained by El-Khawaga [26] on mixture micronutrients; Perica, *et al.* [27] on micronutrients and Lovatt [28] who reported that if boron is sprayed on flowers in the pre-bloom stage on avocado trees increased yield, this increase in yield due to spraying of water soluble fertilizer plus emulsifier may be due to the increased absorb of nutrients and water resulting in more photosynthesis and increased nutrients accumulation in fleshy parts of fruits. Growth, yield and quality attributes influenced by different levels of micronutrients, significantly highest when the micronutrients were applied [29]. Foliar application of micronutrients directly affects the quality and yield of grapevines [30]. Also, Ganie *et al.* [31] and Khattab *et al.* [4] found that, foliar spraying with born improved yield and seed quality of jojoba.

Table 5: Influence of foliar applications with microelements on fruits density, yield (kg/shrub) and seed oil content (%) of genotype 1 (G1) during 2018 and 2019 seasons

	Fruits density		Yield (Kg/ shrub)		Seed oil content (%)	
Treatments	2018	2019	2018	2019	2018	2019
Control	11.38 bc	12.55 bc	0.632 d	0.961 e	42.3 e	43.6 e
Boron at 100 ppm	12.24 ab	15.98 a	1.290 a	1.490 b	51.3 a	53.1 a
Boron at 200 ppm	6.95 f-h	12.01 cd	1.070 b	1.400 b	49.1 b	50.3 b
Copper at 100 ppm	9.08 d-f	14.52 ab	0.610 e	1.070 d	40.6 f	41.9 fg
Copper at 200 ppm	8.73 e-g	15.97 a	0.600 e	0.965 e	41.6 ef	42.9 ef
Iron at 100 ppm	11.29 b-d	14.05 a-c	0.515 h	0.703 h	40.9 f	43.9 e
Iron at 200 ppm	6.54 gh	12.04 cd	0.555 f	0.843 f	47.7 c	48.7 c
Manganese at 100 ppm	13.72 a	16.14 a	0.655 c	1.260 c	42.3 e	43.6 e
Manganese at 200 ppm	8.65 e-g	14.26 a-c	1.090 b	2.020 a	44.9 d	45.8 d
Zinc at 100 ppm	8.79 e-g	12.89 bc	0.500 h	1.100 d	42.3 e	43.9 e
Zinc at 200 ppm	9.61 c-e	12.88 bc	0.560 f	1.050 d	44.9 d	46.0 d
Combination at 100 ppm	6.01 h	10.25 d	0.535 g	1.050 d	39.3 g	41.0 gh
Combination at 200 ppm	7.397 e-h	13.15 bc	0.510 h	0.784 g	37.7 h	40.1 h

Values have the same letters are not significantly different at 5% using Duncan's Test.

Table 6: Influence of foliar applications with microelements on fruits density, yield (kg/ shrub) and seed oil content (%) of genotype 2 (G2) during 2018 and 2019 seasons

	Fruits density		Yield (Kg/ shrub)		Seed oil content (%)	
Treatments	2018	2019	2018	2019	2018	2019
Control	9.11 b-d	12.01 cd	0.685 e	1.110 g	40.0 e	42.0 e
Boron at 100 ppm	8.95 b-d	11.86 cd	0.765 c	1.660 d	45.2 a	50.6 a
Boron at 200 ppm	7.60 c-e	12.98 bc	0.520 h	2.140 c	42.5 bc	46.3 b
Copper at 100 ppm	11.74 a	15.41 a	0.490 i	1.460 e	41.1 de	43.3 d
Copper at 200 ppm	9.03 b-d	12.10 cd	0.435 j	1.170 g	43.2 b	45.0 c
Iron at 100 ppm	11.73 a	10.53 de	0.515 h	1.160 g	40.9 de	42.1 de
Iron at 200 ppm	8.37 b-d	9.967 e	0.400 k	1.350 f	44.7 a	46.9 b
Manganese at 100 ppm	9.72 a-c	13.02 bc	0.700 d	1.610 d	40.9 de	42.1 de
Manganese at 200 ppm	10.15 ab	14.41 ab	1.160 a	2.600 a	40.0 e	42.6 de
Zinc at 100 ppm	5.92 e	12.46 c	0.550 g	1.230 g	44.3 a	45.1 c
Zinc at 200 ppm	10.40 ab	12.34 cd	0.590 f	1.370 f	41.7 cd	43.0 de
Combination at 100 ppm	7.47 de	13.32 bc	0.865 b	2.240 b	41.5 cd	42.3 de
Combination at 200 ppm	7.66 c-e	13.24 bc	0.590 f	1.670 d	42.5 bc	42.9 de

Values have the same letter are not significantly different at 5% using Duncan's Test.

Generally, foliar sprays of micronutrients might have affected the physiological processes resulting into higher fruit yield. This observation is in agreement with findings of Sanna and Abd El-Migeed [32]; Hamdy *et al.* [33]; Nehete *et al.* [34]; Singh and Varma [35] and Bhowmick *et al.* [36].

Concern the oil content, El-Khawaga [26] reported that spraying with micronutrients increasing the oil content in 'Manzanillo' olive trees. It is might be due to directly in various physiological processes and enzymatic activity for higher accumulation of food materials and thus, ultimately increased yield [37]. The balance of auxin in plant also regulates the fruits drop or retention in plants, which ultimately increased the total number of fruits per tree. The role of boron is also reported in fruit setting, which ultimately increase the number of fruits per tree [38].

Seed Physical Characteristics:

Genotype 1 (G1): Table (7) showed that, the foliar application of manganese with concentration of 200 ppm gave the highest values of seed weight and length in both seasons of the study, next to the application of copper and Iron at 100 ppm which gave also the highest significant values of seed length in the second season. On the other hand, the highest seed width had been noticed with the application of zinc (200 ppm) in both seasons followed by manganese (200) and zinc (100) in the first and second seasons respectively.

Table 7: Influence of foliar applications with microelements on average of seed weight (g), seed length and width (cm) of genotype 1 (G1) during 2018 and 2019 season

	Seed weight (g)		Seed length (cm)		Seed width (cm)	
Treatments	2018	2019	2018	2019	2018	2019
Control	0.697 f	1.027 e	1.463 ef	1.740 b-d	0.976 f	1.027 de
Boron at 100 ppm	0.829 e	0.972 g	1.503 cd	1.693 f	1.000 ef	0.983 f
Boron at 200 ppm	0.877 d	1.090 cd	1.520 a-c	1.687 f	1.017 de	1.070 bc
Copper at 100 ppm	0.872 d	1.042 e	1.497 cd	1.857 a	1.023 c-e	1.013 e
Copper at 200 ppm	0.877 d	1.029 e	1.443 f	1.743 bc	1.043 b-d	1.083 ab
Iron at 100 ppm	0.846 e	1.192 b	1.457 f	1.830 a	1.017 de	1.020 e
Iron at 200 ppm	0.938 b	1.103 c	1.503 cd	1.767 b	1.027 c-e	1.050 cd
Manganese at 100 ppm	0.825 e	0.967 g	1.490 de	1.713 d-f	1.017 de	1.040 de
Manganese at 200 ppm	0.999 a	1.215 a	1.547 a	1.840 a	1.070 b	1.030 de
Zinc at 100 ppm	0.945 b	1.074 d	1.523 a-c	1.730 c-e	1.030 cd	1.093 ab
Zinc at 200 ppm	0.942 b	1.038 e	1.510 b-d	1.703 ef	1.110 a	1.107 a
Combination at 100 ppm	0.903 c	1.090 cd	1.537 ab	1.727 c-e	1.033 cd	1.050 cd
Combination at 200 ppm	0.925 bc	1.045 e	1.490 de	1.753 bc	1.050 bc	1.020 e

Values have the same letters are not significantly different at 5% using Duncan's Test.

Table 8: Influence of foliar applications with microelements on average of seed weight (g), seed length and width (cm) of genotype 2 (G2) during 2018 and 2019 season

	Seed weight (g)		Seed length (cm)		Seed width (cm)	
Treatments	2018	2019	2018	2019	2018	2019
Control	0.852 e	0.843 de	1.50 bc	1.62 g	1.01 e	0.92 l
Boron at 100 ppm	0.810 f	0.837 de	1.44 e-g	1.44 h	0.98 f	1.00 ij
Boron at 200 ppm	0.835 ef	0.979 b-e	1.71 a	1.84 a	1.05 d	1.08 cd
Copper at 100 ppm	0.854 e	0.869 c-e	1.48 cd	1.73 de	1.10 b	1.02 hi
Copper at 200 ppm	0.949 b	0.929 b-e	1.45 ef	1.73 de	1.05 cd	1.05 ef
Iron at 100 ppm	0.841 e	0.781 e	1.46 de	1.78 bc	1.16 a	1.12 a
Iron at 200 ppm	0.931 bc	1.027 b-d	1.52 b	1.80 b	1.08 bc	1.07 cd
Manganese at 100 ppm	0.920 c	0.956 b-e	1.50 bc	1.75 cd	1.06 cd	1.06 de
Manganese at 200 ppm	1.147 a	1.305 a	1.50 fg	1.76 c	1.05 cd	1.07 d
Zinc at 100 ppm	0.934 bc	0.964 b-e	1.45 e-g	1.69 f	1.08 b-d	0.99 jk
Zinc at 200 ppm	0.941 bc	1.066 bc	1.50 bc	1.72 e	1.01 e	1.04 f
Combination at 100 ppm	0.880 d	0.887 c-e	1.44 e-g	1.69 f	1.05 cd	1.02 g-i
Combination at 200 ppm	0.851 e	1.127 b	1.42 g	1.73 de	1.01 e	1.04 fg

Values have the same letters are not significantly different at 5% using Duncan's Test.

Genotype 2 (G2): Table (8) showed that, manganese and boron treatments with their high concentration (200 ppm) achieved significantly the highest values of seed weight and length respectively in both seasons of the study. Whereas, sprayed of iron with low concentration (100 ppm) gave the highest significant seed width in both seasons of the study.

The obtained results of seed physical characteristics are in accordance with the findings of Singh *at el.* [37] who mentioned the reason for increase in fruit weight by the micronutrients might be due to faster loading and mobilization of photo assimilates to fruits and involvement in cell division and cell expansion which ultimately reflected into higher weight of fruit in treated plants. Also, the increase in size of fruit as a result of foliar application of micronutrients in present investigation might be because it improved the internal physiology of developing fruit in terms of better supply of water, nutrients and other compounds vital for their proper growth and development [39]. Similar results were found by Dutta [40]; Nehete *et al.* [34]; Singh and Varma [35] and Bhatt *et al.* [41]. Zinc responsible for auxin synthesis and boron involved in translocation of starch to fruit resulted into better photosynthesis and accumulation of starch in fruits. The role of zinc and boron increased the fruit length and diameter of peach [42].

Leaves Minerals Content

Genotype 1 (G1): Table (9) detected that, the application of iron (200 ppm) in the both seasons and iron (100 ppm) in the second season of the study gave the highest leaves content of boron. Also, the spraying with zinc at 100 and 200 ppm in the first and second seasons respectively achieved the greatest content of zinc in leaves. However, manganese (200 ppm) followed by its low concentration

Table 9: Influence of foliar applications with microelements on content of leaves microelements of genotype 1 (G1) during 2018 and 2019 seasons

	Fe (ppm)		Zn (ppm)		Mn (ppm)		Cu (ppm)		B (ppm)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	41.80 f	44.91 e	5.00 d	5.11 d-f	6.30 h	6.91 g	3.56 b-d	3.49 c-f	3.10 k	4.10 h
Boron100 ppm	46.20 e	48.70 d	6.60 bc	5.72 c-f	9.80 d	11.60 cd	3.35 c-e	3.62 b-e	8.20 b	8.60 b
Boron 200 ppm	46.00 e	43.44 f	6.80 a-c	6.14 cd	9.00 e	9.34 e	3.82 bc	3.84 b-d	10.0 a	10.5 a
Copper 100 ppm	32.65 i	42.55 fg	5.32 d	7.30 ab	6.00 hi	6.11 gh	4.00 b	4.26 b	5.00 gh	5.10fg
Copper 200 ppm	28.18 j	31.98 h	3.00 f	3.92 g	7.00 g	8.16 f	5.35 a	5.56 a	5.20 g	5.50 f
Iron 100 ppm	64.20 b	70.81 a	3.50 ef	6.35 bc	7.40 fg	8.99 ef	2.84 ef	3.36 d-f	4.50 j	5.00 g
Iron 200 ppm	69.30 a	71.62 a	3.80 e	5.53 c-f	7.50 f	12.33 c	2.90 ef	3.96 b-d	4.80 hi	4.20 h
Manganese 100 ppm	42.90 f	43.75 ef	6.10 c	5.41 c-f	12.20 b	14.71 b	3.16 de	2.88 fg	6.00 f	6.30 e
Manganese 200 ppm	46.30 e	55.13 b	6.50 bc	6.02 c-e	15.30 a	18.21 a	3.88 bc	3.95 b-d	6.50 e	6.60de
Zinc 100 ppm	38.18 g	55.04 b	7.18 ab	7.89 a	5.20 j	5.54 h	3.60 b-d	2.63 gh	4.90 hi	5.00 g
Zinc 200 ppm	36.20 h	42.78 fg	7.40 a	7.36 ab	5.70 i	6.04 gh	3.65 b-d	4.09 bc	4.70 ij	4.90 g
Combination 100 ppm	54.20 d	41.90 g	5.00 d	4.54 fg	10.00 d	10.81 d	2.50 f	2.12 h	6.90 d	7.00cd
Combination 200 ppm	58.60 c	53.60 c	5.40 d	4.87 e-g	10.50 c	10.80 d	3.12 de	3.02 e-g	7.20 c	7.30 c

Values have the same letters are not significantly different at 5% using Duncan's Test.

Table 10: Influence of foliar applications with microelements on content of leaves microelements of genotype 2 (G2) during 2018 and 2019 seasons

	Fe (ppm)		Zn (ppm)		Mn (ppm)		Cu (ppm)		B (ppm)	
Treatments	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	40.70 f	38.41i	5.22 cd	5.86 c	6.80 de	6.94ef	3.15 ef	3.02 fg	4.00 j	4.25 f
Boron100 ppm	41.90 f	46.95 f	4.00 e	4.23 e	6.32ef	6.77ef	3.10 ef	2.73 g	7.50 b	8.25 a
Boron 200 ppm	44.30 e	50.60 d	4.60 de	5.72 cd	6.95 d	7.88 de	3.70 cd	3.99 c-e	8.00 a	8.00 b
Copper 100 ppm	30.14 i	45.08 g	6.10 b	7.35 b	7.25 d	7.66 d-f	4.30 ab	4.80 ab	3.90 jk	4.00 g
Copper 200 ppm	33.28 h	37.23i	6.33 b	8.30ab	7.35 d	8.24 cd	4.75 a	5.02 a	3.80 k	4.35 f
Iron 100 ppm	63.30 b	74.47 b	3.98 e	5.09 c-e	5.95 f	6.56 f	2.85 f	4.40 a-c	4.15 i	4.70 e
Iron 200 ppm	70.38 a	82.16 a	4.16 e	4.80 c-e	6.12 f	9.17bc	2.90 f	3.61 d-f	4.20 i	4.70 e
Manganese 100 ppm	38.22 g	44.32 g	5.15 cd	5.93 c	9.85 b	12.01 a	3.00 ef	3.44 ef	6.10 f	5.40 d
Manganese 200 ppm	41.15 f	49.01 e	5.36 c	4.93 c-e	10.78 a	13.05 a	3.10 ef	2.72 g	6.25 e	5.50 d
Zinc 100 ppm	31.20 i	58.25 c	7.60 a	8.86 a	7.32 d	6.82ef	3.20 ef	3.63 d-f	5.40 h	5.50 d
Zinc 200 ppm	34.66 h	40.56 h	8.10 a	8.99 a	8.42 c	9.92 b	3.50 de	4.28 b-d	5.75 g	5.60 d
Combination 100 ppm	47.16 d	49.01 e	5.68bc	5.63 cd	8.55 c	9.68 b	3.90 b-d	3.59 d-f	6.50 d	7.00 c
Combination 200 ppm	50.18 c	51.58 d	5.33 c	4.61 de	6.13 f	5.26 g	4.05 bc	3.27 fg	6.90 c	7.20 c

Values have the same letters are not significantly different at 5% using Duncan's Test.

(100 ppm) gave the highest values of manganese in leaves content in both seasons of the study. Otherwise, the highest copper content in leaves was showed by foliar application of copper (200 ppm) in both seasons. Also boron treatment with (200 ppm) followed by (100 ppm) achieved the greatest boron leaves content in both seasons of the study.

Genotype 2 (G2): Table (10) noticed that, the same trend was generally achieved in leaves mineral content, where the highest boron content was found with iron (200 and 100 ppm) in both seasons of the study. However, the spraying with zinc (100 and 200 ppm) achieved the highest values of zinc leaves content in both seasons. Whereas, manganese (200 ppm) in both seasons and (100 ppm) in the second season of the study gave the greatest values of manganese in leaves content. Also the highest copper content in leaves was obtained from copper foliar application (200 and 100 ppm) in 2018 and 2019 seasons. On the other hand, boron treatment with (200 ppm followed by 100 ppm) in 2018 season and boron (100 ppm followed by 200 ppm) in 2019 seasons achieved the greatest boron leaves content.

These results are in agreement with those obtained by Samra [43] and Marschner [44] who mentioned the effect on plant nutrient status resulted from spraying different solutions might be attributed to quick absorption via leaves and the limited loss of the nutrients when they were sprayed. Foliar application with H_3BO_3 and (Fe + Zn + Mn) either singly or in combination were significantly very effective on the leaf Fe, Zn, Mn and B concentrations in leaves of olive [45].

CONCLUSION

Generally, all foliar applications of the micro elements improved all the studied characteristics compared with control. The best results in (shoot length, fruit density, seed yield and weight) with achieved from the foliar application of the high concentration of manganese (200 ppm) in both studied genotypes of jojoba shrubs. Whereas, the foliar application of boron with the low concentration (100 ppm) affected positively on leaf area and seed oil content. So, we can recommend using the manganese (200 ppm) and boron (100 ppm) to increase seed yield and oil content of jojoba shrubs under the same experiment condition.

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