Saadati et al., Vegetos 2016, 29:2
http://dx.doi.org/10.5958/2229-4473.2016.00021.5

Vegetos- An International Journal of Plant Research

Research Article

A SCITECHNOL JOURNAL

Foliar Applications of Zinc and Boron on Fruit Set and Some Fruit Quality of Olive

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Abstract

The impact of foliar application of zinc and boron solutions on fruit set percentage, fruit physical properties and intake rate of the elements by leaf and fruit of three olive cultivars ('Keylet', 'Coronaiki' and 'Mission') were assessed. The spraying carried out twice at full bloom and 15 days later with zinc sulphate (2.5 kgm^{-3}), boric acid (2.5 kgm^{-3}) and the combination of these chemicals. The result indicated that the boric acid spray increased the initial fruit set (76.9%) while spraying with zinc sulphate + boric acid caused significant increase of final fruit set and number of fruit during the harvest (8.2% and 8%, respectively). The highest fruit length (2.08×10^{-2} m) was resulted from zinc sulphate application. No significant difference was observed between treatments on the fruit and pit length/diameter, length, diameter and weight of pit. Nutrient solution spraying significantly increased B and Zn concentration in leaf and fruit.

Keywords

Olive; Nutrient status; Fruit set; Fruit quality

Introduction

Olive tree (*Olea europaea* L.) of the Oleaceae family has a high economic value and many countries such as Iran and Mediterranean countries use its oil and conserved fruits [1]. A mature olive tree produces almost 500,000 flowers, 10% to 15% of which set fruit. This is followed by a rapid fruit drop that continues at a declining rate until 6-7 weeks after full bloom. In a year with normal flowering, 1% to 2% final fruit set will result in a good commercial yield [2]. Olive is very well adapted to high temperature; high soil salinity levels and poor soil fertility [3]. The production of olive under infertile soil condition is generally low. Accordingly, it seems that trees are in need to mineral nutrition for growth, flowering and fruiting. Micronutrients greatly affect plant growth and development. Among micronutrient, zinc and boron have important role on pollination, fruit set and total yield [4]. Zinc is closely involved in the metabolism of RNA and ribosomal content in plant cells which lead to stimulation of carbohydrates, proteins and the DNA formation. It is also, induces pollen tube growth resulted from its role on tryptophan synthesis as an auxin precursor biosynthesis [5]. The main function of boron relate to cell wall strength and development, cell division, sugar transport and hormones development, RNA metabolism, respiration, indole acetic acid (IAA) metabolism and as part of the cell membranes [6]. Lewis [7] speculated that B may be required in stigma and styles to physiologically inactivate callus present in pollen tube walls that would otherwise elicit phytoalexin production to inhibit pollen tube growth. The boron requirement is much higher for reproductive growth period than for vegetative growth and increases flower production and retention, pollen tube elongation and germination, and seed and fruit development [8].

Several investigators studied the effect of zinc and/or boron on fruit set, productivity and fruit quality in many plant species. Ramezani and Shekafandeh [9] reported that zinc sulphate had positive effects on fruit characteristics in terms of fruit weight and fruit dimensions of 'Shengeh' olive cultivar. Talaie et al. [10] showed that foliar spray of B and Zn decreased fruit drop and increased fruit quality in the 'Zard' olive. Hassan [11] found that boric acid treatments increased pollen germination than control and increased percentage of retained fruits in 'Picual' olive. Abd El-Migeed et al. [12] on 'picual' olive reported that boric acid spray at 300 mgl^{-1} increased fruit length. Osman [13] on olive found that boron treatments either as foliar or soil applications increased percentage of retained fruits. Khayyat et al. [14] reported that boric acid at 1500 mgl^{-1} on 'Shahany' date palm increased pulp weight, pulp/seed ratio; fruit length and diameter.

The objective of this experiment was to investigate the effect of foliar application of zinc sulphate and boric acid and the combination on fruit set, fruit characteristics and intake of the elements by leaf and fruit of three olive cultivars.

Materials and Methods

Plant selection and treatment

The present experiment was conducted at the research orchard, Department of Horticulture, Agriculture Faculty of the Shahid Chamran University of Ahvaz on three olive cultivars: i.e., 'Keylet', Coroneiki and 'Mission' in 2010-2011 years. Twelve olive tree of each cultivar were selected according to their similarity in vigor, free from any visible pathogenic symptoms and at the same bearing phase. The trees were eight years old, grown in a loam soil at planting distance of 5×6 meters apart under basin irrigation system. Two composite samples of orchard soil were taken from the successive depth of two profiles: 0-30 and 30-60 and analyzed by the methods of Klute [15], one week prior to commencing the experiment. Physical and chemical characteristics of the soil are shown in Table 1.

The experiment was carried out as a complete randomized block design arranged in a factorial whit three replicates for each treatment. Trees were sprayed twice at full bloom and 15 days later, with control (distilled water), zinc sulphate (2.5 Kgm^{-3}), boric acid (2.5 Kgm^{-3}), and zinc sulphate (2.5 Kgm^{-3}) + boric acid (2.5 Kgm^{-3}). Sprays were applied by small spraying motor until run-off stage. Wetting agent Tween 20 (0.5 %) was applied with spraying solution.

Measurements and determination

Fruit set (%): At full bloom, four branches of each tree in different directions were randomly selected and tagged. Then the number of flowers on the labeled branches was counted. The following were

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Received: November 25, 2015 **Accepted:** February 08, 2016 **Published:** February 13, 2016 *doi:http://dx.doi.org/10.5958/2229-4473.2016.00021.5*

determined: Initial fruit set, final fruit set and harvest fruit set, respectively, by counting fruits on days 15, 42 and 126 days after full bloom. The percentage of fruit set was calculated:

$$\text{Fruit set \%} = \frac{\text{Number of fruit set}}{\text{ˇˇ?ˇˇˇˇˇˇˇˇˇˇ}} \times 100$$

Fruit physical properties: Mature fruits as samples were collected at the last of September from examined trees and subjected to the following measurements: fruit weight (kg), pulp and pit weight (kg), pulp/pit ratio, fruit and pit length and diameter (m), and fruit shape index (length/diameter).

Leaf and fruit mineral contents: Hundred mature leaves from each tree were collected in July. At the end of the experiment, fruits were randomly harvested and analyzed as follows. Samples washed with tap water then with distilled water, dried at 70°C until constant weight, ground and finally digested. The digested solution was used to determine zinc and boron in leaves and fruits. Boron was determined by the curcumin method [16] and zinc was analyzed by Atomic Absorption Spectrometer.

Statistical analysis

The data were statistically tested for analysis of variance using MSTAT-C and Means were compared with using Duncan's multiple range tests at 5% level. SPSS (version 13) was used to determine correlation among treats.

Results and Discussion

Fruit set (%)

Data in Table 2 demonstrate that boric acid treatment significantly increased initial fruit set percentage compared with control and other treatment, whereas percentage of the final and harvest fruit set was increased by using zinc sulphate + boric acid treatment. There were positive correlations between initial fruit set with boron content of leaves and fruits, also positive correlation were shown between percentage of the final and harvest fruit set with zinc content of leaves (Table 3). 'Coronaiki' cultivar attained the highest percentage of the initial, final and harvest fruit set 65.7, 10.5 and 10.2% respectively, compared to both 'Keylet' and 'Mission' cultivars. The 'Mission' cultivar attained the lowest percentage of initial fruit set Compared to other cultivars. There were no significant differences among 'Keylet' and 'Mission' cultivars on the percentage of final and harvest fruit set. There was positive correlation between final fruit set percentage with harvest fruit set percentage. As a result, fruit number at harvest determined by final fruit set.

The obtained results are in agreement with the finding of Singh and Maurya [17] on mango who emphasized that boron treatment increased initial fruit set percentage. In this respect, it seems that improvement in fruit set percentage could be explained as a result to increase pollen grains germination and pollen tube elongation due to boron treatment. Also, the present data are in agreement with the findings by Talaie et al. [10] on olive, Motesharezade et al. [4] on sweet cherry, who reported that, foliar spray of zinc and boron combination solution increased final fruit set. This might be due to roles of zinc and boron in reducing nutrients competition among fruitlets and hormonal balance and thus preventing fruit drop and increased their survival.

Fruit physical properties

Fruit dimensions: The effects of Zn and/or B spraying treatments on pit and fruit dimension (length and diameter) of 'Keylet', 'Coronaiki' and 'Mission' cultivars are presented in Tables 4 and 5. Spraying with zinc sulphate treatment significantly increased fruit length (2.08×10^{-2} m) compared to other treatments. All treatments resulted in higher values of fruit diameter compared to control treatment. No significant differences were found in fruit and pit length/diameter, pit length and diameter using different treatments. Highest fruit length and diameter in 'Mission' cultivar (2.31×10^{-2} m and 1.56×10^{-2} m, respectively) and highest fruit and pit length/diameter were achieved in 'Coronaiki' cultivar (1.67 and 2.55, respectively).

Our results are in agreement with those reported by Ramezani and shekafandeh [9] on Shengeh cultivar of olive, Ghaderi et al. [18] on Shahroodi cultivar of almond, Khafagy et al. [19] on Navel orange and Attalla et al. [20] on Zaghloul cultivar of date palm. They found that trees sprays with zinc or boron improved fruit physical properties.

Table 1: Some physical and chemical characteristics of the experimental soil of olive orchard.

Some physical and chemical characteristics of the experimental soil of olive orchard.										
Depth (cm)	Sand %	Silt %	Clay %	OC (%)	CEC (meq/ 100 g)	pH	EC_e ($dS.m^{-1}$)	N	P	K
								($\times10^{-4}$%)		
0-30	46	32	22	1.1	13	7.7	2.5	110	22	200
30-60	27.2	44.5	28.3	0.7	10	7.6	3.9	70	8	90
Note: OC= Organic Carbon; CEC= Cation Exchange Capacity ; ECe= Saturated soil paste electrical conductivity; N= Total nitrogen; P= Phosphorus; K= exchangeable potassium										

Table 2: Effect of zinc and boron nutrient solutions on fruit set % of 'Keylet', 'Coronaiki' and 'Mission' olives.

Treatment	Initial fruit set (%)				Final fruit set (%)				Harvest fruit set (%)			
	K	C	M	Mean**	K	C	M	Mean**	K	C	M	Mean**
Control	48 cd	55.3bcd	41d	48.1C	1.8e	7.2c	2.6de	3.9C	1.5f	7cd	2.5ef	3.7C
$ZnSO_4$	59.7abc	66.7abc	47.3cd	57.9B	3.8de	9.1bc	3.7de	5.5B	3.6ef	8.3bc	3.6ef	5.2B
H_3BO_3	76.7ab	71.7abc	82.3a	76.9A	3.1de	10.7b	4.8de	6.2B	3ef	10.6b	3.7de	5.8B
$ZnSO_4$+H_3BO_3	58.3abc	69.3abc	53bcd	60.2B	4.3de	15a	5.2d	8.2A	4.3def	15a	4.8de	8.0A
Mean*	60.7AB	65.7A	55.9B		3.3B	10.5A	4.1B		3.1B	10.2A	3.7B	
K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.												
Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.												

doi:http://dx.doi.org/10.5958/2229-4473.2016.00021.5

Fruit and pit weight and pulp/pit ratio: Data in Table 6 indicated that all treatments increased the fruit weight compared to the control. Pit weight was not affected by any of the treatments. The highest pulp/pit ratio was observed using boric acid application. 'Mission' cultivar was attained the highest fruit and pit weight and pulp/pit ratio (3.2×10^{-3} kg, 0.82×10^{-3} kg and 2.9, respectively). Acid boric caused cell division or nucleic acid synthesis within fruit growth and development period and consequently improved the fruit growth. similar results were reported by others on enhancing fruit weight of date palm as a result of foliar application of boric acid [14,21,22].

Zinc and boron contents

The data in Tables 7 and 8 indicate the effects of spraying zinc sulphate and boric acid on Zn and B contents of the olive cultivars. Zinc content in the leaves was significantly affected by zinc sulphate and zinc sulphate + boric acid treatments 51.78×10^{-4}% and 53.11 $\times10^{-4\%}$, respectively. Also, the highest zinc content in fruits (25.11×10^{-4}%) was obtained using zinc sulphate.

Results indicated that the application of boric acid and zinc sulphate + boric acid significantly increased boron content of leaves of all cultivars. Boric acid treatment raised boron fruit content (23.84 $\times10^{-4}$%) compared to other treatment.

Nutrients within the plants tend to move more to the sites, where metabolic activities are for any reason high [23]. Olive is a rich source of oleuropein, a potent antioxidant compound and Zn may enhance their contents in the fruits. Our results are in harmony with Ghaderi et al. [18], who demonstrated that the foliar application of zinc and/or boron was improved the nutritional status of 'Shahroodi' almond trees. Khorsandi et al. [24] found that spraying pomegranate trees with $ZnSO_4$ increased Zn concentration in leaves and fruits juice.

Boron can be redistributed to younger plant parts to meet the demands of the growing sinks. The boron remobilizing of olive trees is owed to the formation of mannitol-borate complexes with appropriate low molecular weight ligands [25,26]. Thus, the increased B concentration could be related to direct uptake by the reproductive tissue following treatment. Significant translocation from treated leaves to flowers may also occur, since Delgado et al. [27] suggested that B was mobilized from young olive leaves during anthesis to supply the needs of flowers and fruits.

Conclusions

The foliar application of zinc sulphate and/or boric acid significantly increased fruit set and zinc and boron contents of leaves

Table 3: Correlations between fruit set and zinc and boron content in leaves and fruits

Correlations between fruit set and zinc and boron content in leaves and fruits							
	Initial fruit set (%)	Final fruit set (%)	Harvest fruit set (%)	Leaf Zn $\times10^{-4}$ (%)	Fruit Zn $\times10^{-4}$ (%)	Leaf B $\times10^{-4}$ (%)	Fruit B $\times10^{-4}$ (%)
Initial fruit set (%)							
Final fruit set (%)	0.316						
Harvest fruit set (%)	0.283	0.917**					
Leaf Zn (mgkg^{-1})	-0.116	0.420*	0.431**				
Fruit Zn (mgkg^{-1})	-0.170	0.151	0.197	0.576**			
Leaf B (mgkg^{-1})	0.518**	0.270	0.256	-0.015	-0.039		
Fruit B (mgkg^{-1})	0.527**	0.247	0.256	0.094	0.235	0.334*	

Note: [** correlation is significant at the 0.01 level], [*correlation is significant at the 0.05 level]

Table 4: Effects of zinc and boron nutrient solutions on pit dimension of 'Keylet', 'Coronaiki' and 'Mission' cultivars.

Treatment	Pit length $\times10^{-2}$ (m)				Pit diameter $\times10^{-3}$ (m)				Length/diameter pit			
	K	C	M	Mean**	K	C	M	Mean**	K	C	M	Mean**
Control	1.63c	1.46d	1.81ab	1.63A	8.4a	5.5c	8.7a	7.5A	1.93c	2.66a	2.03bc	2.21A
$ZnSO_4$	1.68c	1.47d	1.83a	1.66A	8.8a	5.6c	8.7a	7.7A	1.91c	2.63a	2.11bc	2.22A
H_3BO_3	1.70c	1.47d	1.84a	1.67A	8.5a	5.7c	8.6a	7.6A	1.99c	2.61a	2.14bc	2.25A
$ZnSO_4$+H_3BO_3	1.72bc	1.49d	1.85a	1.69A	8.6a	6.5b	8.6a	7.9A	2.00c	2.29b	2.15bc	2.15A
Mean*	1.68B	1.47C	1.83A		8.6A	5.8B	8.6A		1.96C	2.55A	2.11B	

K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.

Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.

Table 5: Effects of zinc and boron nutrient solutions on fruit dimension of 'Keylet', 'Coronaiki' and 'Mission' cultivars.

Treatment	Fruit length $\times10^{-2}$ (m)				Fruit diameter $\times10^{-2}$ (m)				Length/diameter fruit			
	K	C	M	Mean**	K	C	M	Mean**	K	C	M	Mean**
Control	1.94d	1.68e	2.25b	1.96B	1.41d	0.97g	1.52ab	1.30B	1.37a	1.73a	1.47a	1.52A
$ZnSO_4$	2.07c	1.78e	2.38a	2.08A	1.49bc	1.02fg	1.56a	1.36A	1.39a	1.66a	1.45a	1.50A
H_3BO_3	2.05c	1.69e	2.34ab	2.03B	1.47bc	1.08e	1.57a	1.37A	1.40a	1.65a	1.48a	1.51A
$ZnSO_4$+H_3BO_3	2.06c	1.72e	2.27ab	2.02B	1.45cd	1.05ef	1.58a	1.36A	1.42a	1.63a	1.50a	1.52A
Mean*	2.03B	1.72C	2.31A		146B	1.03C	1.56A		1.40C	1.67A	1.48B	

K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.

Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.

Table 6: Effects of zinc and boron nutrient solutions on fruit and pit weight of 'Keylet', 'Coronaiki' and 'Mission' cultivars.

Treatment	Fruit weight ×10⁻³ (kg)				Pit weight ×10⁻³ (kg)				Pulp/pit Weight			
	K	C	M	Mean**	K	C	M	Mean**	K	C	M	Mean**
Control	2.14d	0.85e	3.08b	2.02B	0.64b	0.24c	0.82a	0.57A	2.3a	2.5a	2.8a	2.5B
$ZnSO_4$	2.66c	0.99e	3.16ab	2.27A	0.68b	0.24c	0.83a	0.58A	2.9a	3.1a	2.8a	2.9AB
H_3BO_3	2.51c	1.02e	3.32a	2.28A	0.63b	0.26c	0.80a	0.56A	3.0a	3.0a	3.1a	3.0A
$ZnSO_4$+H_3BO_3	2.53c	0.97e	3.14ab	2.21A	0.67b	0.26c	0.81a	0.58A	2.8a	2.7a	2.9a	2.8AB
Mean*	2.46B	0.96C	3.2A		0.66B	0.25C	0.82A		2.8B	2.8B	2.9A	

K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.

Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.

Table 7: Effects of zinc and boron nutrient solutions on leaf and fruit Zn content of 'Keylet', 'Coronaiki' and 'Mission' cultivars.

Treatment	Leaf Zn ×10⁻⁴ (%)				Fruit Zn ×10⁻⁴ (%)			
	K	C	M	Mean**	K	C	M	Mean**
Control	18.00 e	18.22 e	33.78 d	23.33 B	15.55 f	18.00 def	20.14 de	17.90 C
$ZnSO_4$	54.00 ab	45.55 c	55.78 a	51.78 A	18.95 def	28.67 a	27.71 ab	25.11 A
H_3BO_3	32.45 d	20.89 e	20.45 e	24.60 B	15.59 f	21.45 cd	18.22 def	18.45 C
$ZnSO_4$+H_3BO_3	50.45 b	54.67 ab	54.22 ab	53.11 A	17.21 ef	24.45 bc	25.82 ab	22.49 B
Mean*	38.73 B	34.83 A	41.06 A		16.83 B	23.14 A	22.97 A	

K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.

Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.

Table 8: Effects of zinc and boron nutrient solutions on leaf and fruit B content of 'Keylet', 'Coronaiki' and 'Mission' cultivars.

Treatment	Leaf B ×10⁻⁴ (%)				Fruit B ×10⁻⁴ (%)			
	K	C	M	Mean**	K	C	M	Mean**
Control	20.71 de	19.49 e	20.85 de	20.35 AB	14.95 d	17.00 cd	16.60 cd	16.18 B
$ZnSO_4$	23.67 cd	22.15 d	21.99 d	22.60 B	16.32 cd	19.72 bcd	16.12 cd	17.39 B
H_3BO_3	24.04 bcd	25.80 ab	27.00 a	25.61 A	28.99 a	23.3 abc	19.23 bcd	23.84 A
$ZnSO_4$+H_3BO_3	24.31 bcd	25.33 abc	25.75 ab	25.13 A	16.54 cd	24.18 ab	18.27 bcd	19.66 AB
Mean*	23.18 A	23.19 A	23.90 A		19.20 AB	21.05 A	17.56 B	

K = 'Keylet' cv. C = 'Coronaiki' cv. M = 'Mission' cv.

Note: * and **refer to specific effect of olive cultivars and foliar application of nutrient solution respectively. Means followed by the same letter/s (small letter/s for interaction effect of cultivar and nutrient solution, and capital letter/s for specific effect of olive cultivars and nutrient solution) did not significantly different according to Duncan's multiple range test (DMRT) at 5% level.

and fruits. Application of zinc and boron were improved fruit quality, although zinc was more effective in quality characteristics such as increasing fruit length. Our results also highlighted that the analytical parameters were influenced by the genetic characteristic, namely cultivar.

Acknowledgements

We would like to thank the Experts and faculty members for support and assistance. Also the authors wish to thank Shahid Chamran University of Ahvaz for supporting this work.

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