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EFFECT OF ZN, CU AND FE FOLIAR APPLICATION ON FRUIT SET AND SOME QUALITY AND QUANTITY CHARACTERISTICS OF PISTACHIO TREES

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ABSTRACT. *Fruit dropping in pistachio orchards is one of the numerous problems which country's orchard men face with it. Therefore, experiment was carried out based on factorial and randomized complete block design with 12 treatments and 4 replications in 25-year-old trees with Owhadi cultivar in 2010 and 2011. Zn was supplied from zinc sulfate source in three levels (0, 1000 and 2000 mg* L^{-1}*), Cu was supplied from copper sulfate source in two levels (0and 200mg* L^{-1}*) and Fe was supplied from iron sulfate source in two levels (0 and 300mg* L^{-1}*). Results revealed that the highest level of primary fruit set was detected in a combination of Fe and Zn (1000 mg* L^{-1}*). The maximum final fruit set percentage was measured in a combination of Fe and Cu. The highest of Splitting rate was detected in a combination of Cu and Fe and the lowest one in control. But spray of Zn, Cu and Fe did not affect the blankness compared with the control. Highest yield was produced in two levels of Zn and maximum vegetative growth took place in Cu treatment. Foliar application with Zn, Cu and Fe increased the Zn, Cu and Fe concentration of leaves, respectively.*

KEYWORDS: *copper, fruit set, iron, pistachio, zinc*

INTRODUCTION

Pistachio (*Pistacia vera* L.) is the principal and one of the most important horticultural products of Iran. During the past 50 years, it has been embraced as one of the main commercial products in Iran (Razavi 2005). According to the extensive pistachio growing in Iran, soil salinity is a serious problem and deficiencies of micronutrients are widespread. Soil in which pistachio is grown is characterized by high pH, carbonate content and low organic matter. In these soils, deficiencies of Zn, Fe and Cu, can become severe (Tavalli & Rahemi 2007). In recent years because of some deficiency in micro elements in some pistachio area of production in Kerman province (Iran), low fruit set can be observed in many orchards (Mozafari 2005). One of the reasons of low fruit set can be deficiency of zinc, copper (Gursoz et al. 2010) and some other elements. Fruit set is an important component of yield (Rosati et al. 2010).

Fruit set was calculated as the percentage of fruits per total remaining flowers and, therefore, is an expression of flower quality or fertility. However, fruit set is also determined by weather conditions during bloom, which affects pollination, pollen tube growth, ovule fertility and plant nutrition (Williams 1965). Zinc is required to make auxin, the plant hormone responsible for cell elongation and growth (Beede et al. 2005). Pistachio tree in many regain of Iran suffer from zinc difficiency, The foliar fertilization could be a solution this problem. One of the efficacious timing for zinc spray is in late February and early March during swelling of the bud scales, when deficiency effects on fruit set and nut development (Beede et al. 1991). Like zinc, copper is a component of many enzymes in the plant and plays a role in energy metabolism (Beede et al. 2005). Beede (1989) reported that no correlation between soil copper level and pistachio tree deficiency. The risks associated with soil treatment are also not justified since foliar treatment has proven highly effective. Iron (Fe) deficiency is a common disorder affecting plants in many areas of the world, and is chiefly associated with high pH, calcareous soils. Plant Fe deficiency has economic significance, because crop quality and yields can be severely compromised, and the use of expensive corrective methods is often required (Alvarez-Fernandez et al. 2004). Therefore, the present experiment was designed to study the effect of micro nutrients (Zn, Cu and Fe) on the fruit set, yield, quality and leaf composition of pistachio in the Rafsanjan orchards.

MATERIALS AND METHODS

Experimental Setup

The experiment was carried out on pistachio trees (cv. Owhadi) over 25years of age, which had been grafted on pistachio cv. Badami rootstocks, at a commercial orchard in Rafsanjan region, Iran, in 2010 and 2011. The trees were spaced 6 and 3 m between and along the row, respectively. Trees received routine cultural practices for commercial fruit production including fertilization and irrigation. The layout was a 3×2×2 factorial experiment in a randomized complete block design with four replications. Each block contains twelve trees. Four branches (different directions of each tree) with approximately uniform length, diameters and number of flower bud were used for each treatment. Sprays were applied to the point of drip with a hand gun sprayer. Zn treatment, was supplied from zinc sulfate source in three levels (0, 1000 and 2000 mg L^{-1}), Cu was supplied from copper sulfate source in two levels (0 and 200 mg L^{-1}) and Fe was supplied from iron sulfate source in two levels (0 and 300 mg L^{-1}). Tween 20 (0.01%) used as wetting agent. All treatments were applied in time of swollen bud (middle of March). To determination soil nutrient status, soil samples were collected at depths of 0-30 and 30–60 cm. Soil characteristics of the pistachio orchard presented in Table 1.

Table 1. Soil characteristics of experimental orchard

Depth	Sand	Clay	Silt	pH	EC	Zn	Cu	Fe
(cm)		(%)			(dS m^{-1})		(mg kg^{-1})	
0-30	81	4	15	7.61	2.81	1.3	0.3	1.24
30-60	83	1	16	7.60	3.28	0.5	0.25	0.38

Fruit set and vegetative growth

Only data from the ON year of 2010 are available for fruit set, yield and yield component. The alteration of high and low crop year is widespread in pistachio trees. The pistachio is deciduous fruit tree, presenting a unique alternate bearing (Picchioni et al. 1997). Therefore, in OFF year (2011) we could not measure fruit set, yield and yield component. After treatment primary fruit set was measured in May and final fruit set was measured after harvested yield (including cluster and nut). Flowers on the labeled shoots counted at the first week of April. For primary fruit set, fruit on the shoots counted after post-bloom (end of April to early May) and fruit set percentage was calculated according to the following equation:

$$\text{Primary fruit set (\%)} = \frac{\text{No. of fruit (after post-bloom)}}{\text{Total no. of flower}}$$

Final fruit set was estimated by dividing the number fruits just after harvesting by the total number of flower.

$$\text{Final fruit set (\%)} = \frac{\text{No. of fruit (middle of September)}}{\text{Total no. of flower}}$$

For vegetative growth length of new shoot were measured on the early of May, mid-July and end of September.

Yield and yield component

Pistachios were harvested during the commercial harvest period in Rafsanjan when the fruit reached a physiological maturity stage signalled by a reddish hull. All pistachio nuts were removed from the branches of trees by hand so as to determine the gross yield of each tree. Yield per tree (four branches) for each treatment was determined by weighing the red, fresh, and unshelled nuts. In these fruits, the splitting rate was determined with the naked eye by counting and rating split nuts to unsplit ones. Nut weight was measured by weighing 100 inshell nuts and blank nut rate were measured in 100 nuts as percentages.

Leaf sampling

Leaf samples were collected in mid-July from the each tree. All samples were initially washed once with tap water and twice with distilled water. Leaf samples were dried in a forced draft oven at 68◦C for 72h, weighed, ground, and dry ashed at 550◦C for five hours. Zn, Cu and Fe concentration by atomic absorption spectrophotometry were determined.

Statistical analysis

The effects of treatments were evaluated using analysis of variance and the means compared separately for each growing season by using the Duncan Multiple Range Test (DMRT) at the 95% significance level, using the SAS software. Pearson correlation coefficients were calculated with ON year data, using SPSS 16. Software.

RESULTS AND DISCUSSION

Fruit set

Data as shown in Figure 1 cleared that all treatment significantly increased primary fruit set in comparison with control. Highest primary fruit set was obtained from the trees received Zn (1000 mg L^{-1}) with Fe spray (40% more than control treatment), while the lowest primary fruit set was obtained from the control. The present results are in agreement with the finding obtained by Ranjbar Kabotarkhani et al. (2009) who concluded Zn and Cu treatments increased primary fruit set in pistachio trees. Result showed the foliar application of Zn, Cu and Fe increased final fruit set in comparison with control (Figure 2). Highest final fruit set was obtained form Fe and Cu

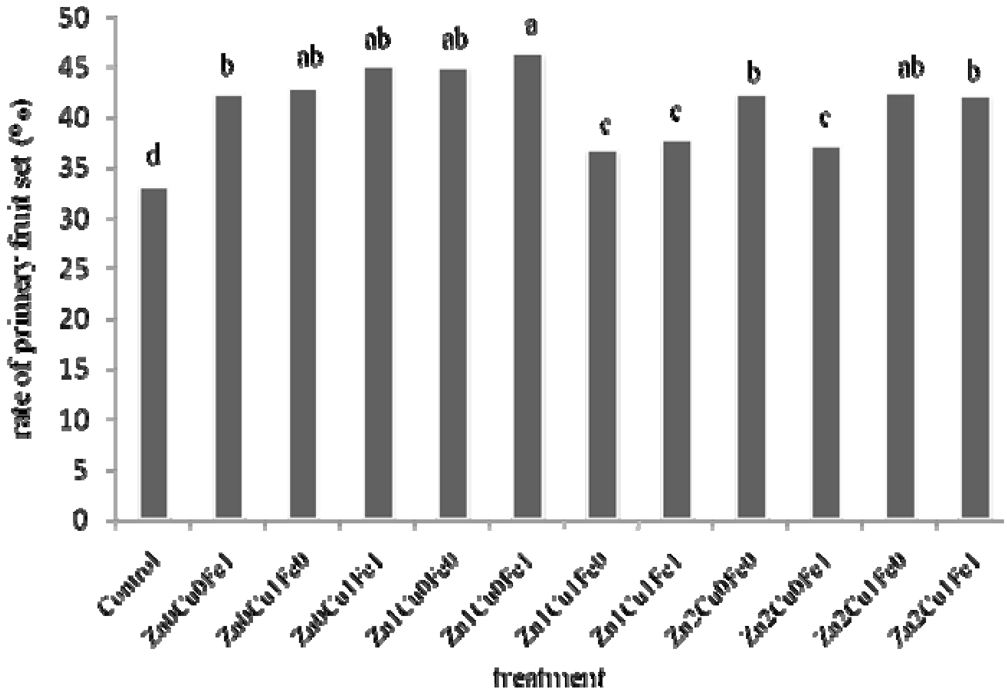

Figure 1. Effect of foliar spray zinc, copper and iron on primary fruit set of pistachio trees. Bars with the same letters are not significantly different according to Duncan at 5% level.

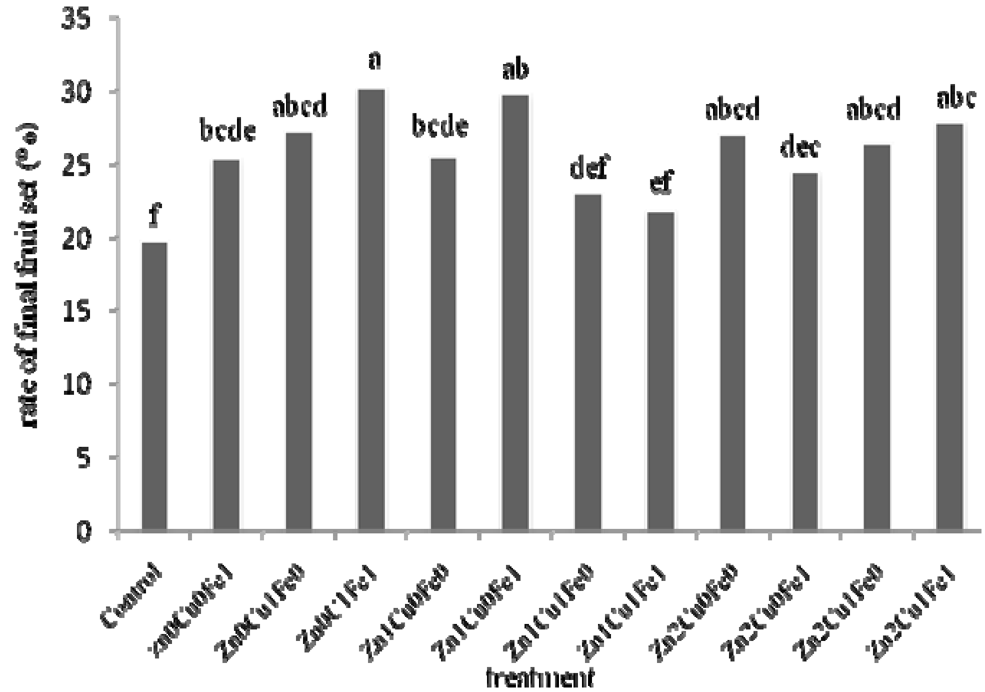

Figure 2. Effect of foliar spray zinc, copper and iron on final fruit set of pistachio trees. Bars with the same letters are not significantly different according to Duncan at 5% level.

combination treatment (50% more than control treatment). Baybordi and Malakouti (2009) reported foliar application of Zn increased the final fruit set of pistachio trees. Zn-deficiecy lead to the number of nuts per cluster dramatically reduced and most of them can be blanks (Beede et al. 2005). Copper deficiency effects on grain, seed, and fruit formation much more than vegetative growth, For fruit formation a much greater copper supply was required (Marschner 2002). Dell (1981) found that the reduction seed set in copper-deficient plants might be the result of the inhibition of pollen release from the stamina, since lignification of the anther cell walls is required to rupture the stamina and the subsequent release of the pollen. In addition, this result emphasizes on the importance of adequate copper supply during fertilization for final seed and fruit yield. Marschner (2002) reported the grain and seed yield are depressed in a relatively greater extent by zinc deficiency than the total dry matter production, probably due to at least in part to impaired pollen fertility in deficient plants. The improving effect of Zn and Fe on fruit set was supported by Abd El Motty et al. (2006), who reported foliar application of Zn and Fe increased primary and final fruit set in citrus trees. It is also possible that the critical level for Zn, Cu and Fe for pistachio is above the critical level used for other plant species, especially when pistachio is grown in calcareous soils with low Zn, Cu and Fe concentrations as in this study the response to Zn, Cu and Fe applications can be higher.

Yield and yield component

Results showed that just foliar application of Zn and Fe significantly increased the yield of pistachio in comparison with control treatment (table 2). The maximum yield of 12.77 g cluster^{-1} was obtained form the treatment receving Zn (1000 mg L^{-1}) followed by 10.86 g cluster^{-1} form Zn (2000 mg L^{-1}), 10.79 g cluster^{-1} form Cu+Fe and 10.51 g cluster^{-1} form Fe alone treatment, but the yield difference among such treatment were statiscally at par with each other, indicating foliar spray of micronutrients were effective in increasing the yield of pistachio. Perhaps these increases in yield were due to significant increase in leaf Zn and Fe concentrations, which in turn induce more flowering an minimize fruit let drop in pistachio trees. It was reported in orange trees that fruit let drop decreased as leaf Zn content increased (Garcia et al., 1984). However, Foliar application of zinc sulfate (1 and 2 g L^{-1}) increased yield of pistachio (Kizilgoz et al. 2010). Amiri et al. (2008) also reported thatzinc sulfate ($ZnSO_4$, $7H_20$) spray with 8 g L^{-1} concentration increased yield of apple trees.

The highest nut weight 95.86 (g 100 nut^{-1}) attained form Zn (1000 mg L^{-1}) + Fe treatment (Table 2). Results showed that foliar application of Zn in two levels significantly increased nut weight. Beede et al. (2005) reported nuts on Zn-deficient shoots are markedly smaller in size and much redder than normal. This results indicating foliar spray of Zn were effective in increasing the nut weight of pistachio trees.

Table 2. Effect of zinc, copper and iron foliar spray on yield, nut size, splitting rate, blank nut rate and vegetative growth

Treatments	Yield(dry weight, gcluster^{-1})	Nut size (g 100 nut^{-1})	Splitting rate (%)	Blankness (%)	Vegetative growth (cm)	
		2010			2010	2011
Control	8.09d*	90.57bc	83.03c	11.53a	11.55ab	18.17ab
$Zn_0Cu_0Fe_1$	10.51bc	89.69c	85.89bc	21.27a	10.45ab	18.10ab
$Zn_0Cu_1Fe_0$	8.55dc	91.11bc	91.86ab	10.82a	13.12a	19.72ab
$Zn_0Cu_1Fe_1$	10.79ab	94.53ab	95.52a	20.88a	11.97ab	18.27ab
$Zn_1Cu_0Fe_0$	12.77a	95.55a	89.25abc	15.28a	10.70ab	18.07ab
$Zn_1Cu_0Fe_1$	8.032d	95.86a	82.22c	14.90a	11.42ab	20ab
$Zn_1Cu_1Fe_0$	9.12bcd	92.86abc	86.88bc	18.54a	10.57ab	17.25bc
$Zn_1Cu_1Fe_1$	8.37cd	85.53d	87.21bc	16.27a	10.12ab	18.10ab
$Zn_2Cu_0Fe_0$	10.86ab	95.82a	88.68bc	20.58a	9.82b	17.32bc
$Zn_2Cu_0Fe_1$	7.12d	84.10de	81.50c	20.94a	13.25a	19.12ab
$Zn_2Cu_1Fe_0$	7.27d	93.26abc	85.19bc	17.08a	10.85ab	20.47a
$Zn_2Cu_1Fe_1$	8.37cd	80.92e	89.75abc	14.14a	12.55ab	19.52ab

*Means separation by Duncans multiple range test at P= 0.05. The same letters within a column are not significantly different.

The effect of copper and iron on the split nut rate was significant in Cu (91.86%) and Cu + Fe treatments (95.52 %) in comparison with control (Table 2). However, foliar application of zinc had not got any significant effect on the percentage of shell splitting (Table 2). Probably zinc does not play an important role in shell splitting of pistachio. Tsipouridis et al. (2005) also reported that the zinc spray had no significant effect on the split of pistachio nut. This may result from the limited mobility of applied Zn, which has been attributed, at least in part, to the high binding capacity of leaf tissue for Zn (Zhang and Brown 1999a). But results showed foliar spray of copper and iron had significant effect on split nut of pistachio. Tekin and Guzel (1992) reported that iron increased the splitting of pistachio nut.

The effect of zinc, copper and iron treatments on the blankness was not significant (Table 2). Blanking can occur during two different phases of pistachio nut development, nut setting and nut filling. It can be affected by crop load and production practices (Ferguson et al. 2005). However, maintaining boron leaf levels above 120 mg L^{-1} and providing sufficient water to avoid water stress during the season will at least avoid exacerbation of blank nut production (Ferguson et al. 2005). In other hands, foliar application of zinc, copper and iron during swelling of the bud scales, had no effect on blankness of pistachio trees.

The vegetative growth show no difference between the treatments compared with control in two year (Table 2). In the ON year, The higher vegetative growth for $Zn_2Cu_0Fe_1$ treatment could be explained by the competition for assimilates between vegetative and fruit growth. The yield of the trees of this treatment is lower than the others (respectively 7.12 g compare to 12.77 gto 10.86 g). Marra et al. (1998) showed the effect of crop load on vegetative growth, the pistachio nuts is the major sink for assimilates.

Relationship between fruit set and vegetative growth

Rugini and Pannelli (1993) observed active competition between vegetative and reproductive in olive trees. Increased vegetative growth is not necessarily a benefit in mature tree crops, as it may not be correlated specifically with increased yield (Johnson & Handley 2000). Fruit set and Vegetative growth varied in all treatment during growth season. Fruit set decreased sharply at April (Figure 3a), but Vegetative growth increased between April and May (Figure 3b)

Fruit dropping severely increased in time of swelling bud till after flowering (middle of April) and then it continued with very slightly steep (Figure 3a). However, the vegetative growth increased in middle of April but it continued with stable steep (Figure 3b). The competition between reproductive (fruit formation) and vegetative growth (new shoot length) maybe due to the consumption of the metabolites which were made in plant and we can increased it by good nutrition and controlling the vegetative growth. Also, most of the metabolites that were made in plant on the end of May were used for nut filling and splitting, which stopped the vegetative growth (Ferguson et al. 2005). Further evidence for the role of nutritional competition in fruit set at bloom was provided by Rugini and Pannelli (1993) who found that alleviating competition between vegetative and reproductive activities at bloom, via vegetative shoot removal or via growth regulators, increased fruit set compared to the control. In pistachio, vegetative and apical inflorescence buds swells at almost the same time in late March (Barone et al. 2005). Shoot extension begins generally in April and terminates in the middle part of May while concurrent inflorescence growth and endocarp (but not seed) enlargement occurs (Caruso et al. 1987).

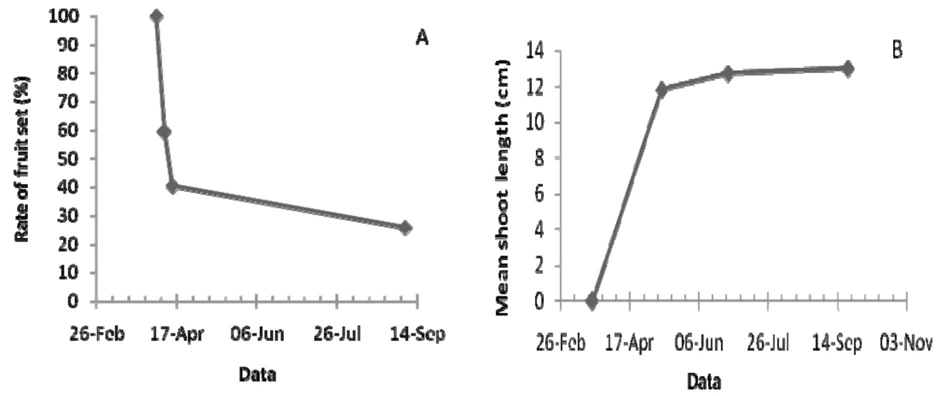

Figure 3. Seasonal variability of fruit set (A)
and vegetative growth (B) in 2010

Caruso et al. (1993) reported significant effects between crop load adjustment and both the percentage of inflorescence bud sretention and shoot growth. Takeda and co-workers (1980) strongly supported the idea that fruits are the strongest sinks and that most of the photosynthates are accumulated in developing fruits.

Leaf nutrient

Results showed that the foliar spray of Zn significantly increased the Zn concentration in pistachio leaves (Table 3). Similar increased in the Zn concentration of apple leaves were reported (Wojcik 2007). Although soil and foliar application of Zn relatively increased the leaf Zn concentration in pistachio (Tsipouridis et al. 2005). Zhang and Brown (1999b) reported that pistachio leaves retained 12% of the total Zn applied, with approximately half of it subsequently translocated away form the treated area. Similary,

Table 3. Effect of Zn, Cu and Fe foliar application on zinc, copper and iron concentration in the leaves in 2010 and 2011

Treatments	Zn (mg kg^{-1})		Cu (mg kg^{-1})		Fe (mg kg^{-1})	
	2010	2011	2010	2011	2010	2011
Control	7.87d*	15.85bcd	10.20ed	5.57e	53.87bcd	78.97cde
$Zn_0Cu_0Fe_1$	9.07bcd	14.52cd	9.97e	6.17ed	58.50a	100.37a
$Zn_0Cu_1Fe_0$	7.45d	14.07d	15.52a	8.97a	53.87bcd	88.75ef
$Zn_0Cu_1Fe_1$	9.82abc	16.52b	12.67cb	7.92bc	54.70bc	92.97ab
$Zn_1Cu_0Fe_0$	11.45a	16.27bc	9.87e	5.57e	53.62bcd	67.27f
$Zn_1Cu_0Fe_1$	10.90a	15.43b	10.57ed	5.35e	53.17bcd	70.90ef
$Zn_1Cu_1Fe_0$	7.48d	14.63bcd	14.50a	7.07cd	52.60cd	92.75ab
$Zn_1Cu_1Fe_1$	10.77ab	15.40bcd	15.10a	6.10de	54.82bc	87.62bc
$Zn_2Cu_0Fe_0$	11.40a	18.70a	12.72bc	5.15e	53.42bcd	86.82bcd
$Zn_2Cu_0Fe_1$	10.62ab	14.81bcd	11.72cde	5.12e	55.82b	81.87cd
$Zn_2Cu_1Fe_0$	8.30cd	15.61bcd	14.05ab	8.27ab	54.50bc	76.75def
$Zn_2Cu_1Fe_1$	9.95abc	14.90bcd	11.20cde	6.12de	51.75d	68.77ef

*Means separation by Duncan multiple range test at P= 0.05. The same letters within a column are not significantly different.

the Cu concentration of the leaf tissues increased with Cu application with the control treatment (Table 3). Kallsen et al. (1998) also reported that Cu spray significantly increased copper concentration of the leaf compared to control. However, foliar spray of iron (300 mg L^{-1}) significantly increased the Fe concentration in pistachio leaves (table 3).Similar increase in Fe concentration and changed dramatically the mineral composition of peach leaves were reported (Fernandez et al. 2008). Mann et al. (1985) found that spray micronutrients (Zn, Cu, Fe and Mn) on the leaves of sweet oranges increased the concentration of the respective nutrient in the leaves.

The concentration of Zn correlated positively with primary fruit set, final fruit set and yield (Table 4). Fruit set is considered as one most important indices of improved response fruit yield (Srivastava & Singh 2009). However, they reported fruit set and yield in citrus were significantly influenced by Zn-fertilization. Positive correlation between yield and zinc leaf concentration has been reported for pistachio trees (Kizilgoz et al. 2010). The result presented here showed a correlation (r= 0.56) between leaf zinc concentration and nut size (Table 4). The correlation between leaf zinc concentration and nut weight indicated that zinc play an important role in the nut size of pistachio. Also zinc deficiency in pistachio tree decreased the nut size and number of fruits on the cluster (Uriu and Pearson 1986). Khayyat et al (2007) reported foliar application of zinc sulfate (600 mg L^{-1}) in Date palm increased fruit size compared with control. However, on grape fruit trees foliar spray zinc increased fruit size (Swietlik 2002). A positive correlation (r= 0.65) was obtained between the splitting rate with copper concentration in leaves (Table 4). In pistachio, splitting is a genetic characteristic, however, it has been reported that some factors such as rootstock, cultivar, plant nutrition, alternate bearing, climatic conditions, cultural management and pollen source could affect the splitting ratio of nuts (Crane & Takeda 1979; Crane et al. 1982). In this current research, splitting increased as a function of Cu leaf concentration, indicating pistachio nutrition effect, specially copper on splitting nuts. This result indicates that foliar Cu sprays in swollen bud timing are successful in improving splitting of pistachio nuts. There was a negative correlation between primary and final fruit set with nut weight (Table 4). Probably, high fruit set led to competition between fruit and decreased the fruit weight. But there was no information on this competition (Wubs et al. 2009). However, Rosati et al. (2010) showed that fruit set in olive trees decreased with increased fruit weight.

Table 4. Pearson correlation coefficients among fruit set, yield, yield component and some leaf nutrients that were measured in this study in 2010

	Zn	Cu	Fe	Primary fruit set	Final fruit set	yield	Splitting rate	Blank ness	Nut weight
Zn	-								
Cu	-0.142	-							
Fe	0.228	-0.046	-						
Primary fruit set	0.460**	-0.134	-0.037	-					
Final fruit set	0.309*	-0.104	0.115	0.410**	-				
yield	0.352*	-0.206	0.172	0.118	0.194	-			
Splitting rate	0.105	0.65**	-0.070	0.295*	0.313*	0.452**	-		
Blank ness	-0.277	0.202	0.057	0.205	-0.192	-0.504**	-0.077	-	
Nut weight	0.56**	-0.044	-0.048	-0.297*	-0.382*	0.089	0.125	0.126	-

*significant at the 0.05 level of probability
**significant at the 0.01 level of probability

In conclusions, soil in which pistachio is grown is characterized by high pH, carbonate content and low organic matter. Therefore zinc, copper and iron deficiency was widespread throughout pistachio areas. Results of present study showed that foliar application of Zn, Cu and Fe in late February and early March during swelling of the bud, increased primary and final fruit set in pistachio trees. Also spray these micronutrients provided higher yield, nut weight and splitting rate, but no significant effect on blank nut rate was observed. It can be concluded that in the calcareous soils, foliar application of Zn, Fe and Cu-fertilizers is necessary for obtaining better fruit set, yield and quality in pistachio.

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