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Effects of Foliar Application of Potassium and Zinc on Pistachio (*Pistacia vera* L.) Fruit Yield

Mohammadmehdi Norozi[1], Babak ValizadehKaji[1*], Rouhollah Karimi[2], Mohammadali Nikoogoftar Sedghi[1]

1. Department of Horticultural Sciences, Faculty of Agriculture and Natural Resources, Arak University, Arak, Iran

2. Department of Landscape Engineering, Faculty of Agriculture, Malayer University, Iran

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Abstract
The objective of this study was to investigate the effects of foliar applications of potassium and zinc on the fruit yield and quality as well as leaf nutrient concentrations of pistachio cv. ‘Chrokeh’. The experiment was conducted based on a completely randomized block design with nine treatments and three replications per treatment. Treatments were three levels of K_2SO_4 (0, 1 and 2%) and three levels of $ZnSO_4$ (0, 0.5 and 1%). The nutrition solutions were sprayed on trees at two times (bud swell stage and green tip stage) in 2017–2018. Based on the obtained results, nutrient treatments especially 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+1% $ZnSO_4$ caused a significant increase in chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents. Application of K_2SO_4 and $ZnSO_4$ significantly affected concentrations of P, K, Mg, Zn, Mn and Fe in the leaves of ‘Chrokeh’ pistachio, whereas nutrient treatments had no significant effect on leaf concentration of N. Nutrient treatments especially 2% K_2SO_4+1% $ZnSO_4$ led to significant increases in the fresh (up to 65%) and dry (up to 67%) yield when compared with the control trees. Moreover, nutrient applications had a significant effect on the percentage of splitting (an 11 % increase) and blankness (a 26% decrease). It can be concluded that foliar application of K and Zn fertilizers is necessary for obtaining better fruit yield and quality in pistachio.

Keywords: Blankness, Nutrition, Pistachio, Splitting, Yield.

Introduction

Pistachio (*Pistacia vera* L.) has been widely cultivated in Iran. The total area under pistachio cultivation in Iran is 346,000 ha with an annual pistachio production of 315,151 tones, ranking it second in pistachio production in the world (FAO, 2016). This is a subtropical, dioecious, deciduous, and drought-tolerant species, which well adapted to arid and semi-arid regions of Iran (Einali and Valizadeh, 2017; Javanshah et al., 2005). However, the soil in these areas is often poor and associated with high calcium carbonate content and alkaline pH and limited availability of some nutrients causing suffering of pistachio trees from potassium and zinc deficiencies (Tavalli and Rahemi, 2007). Therefore, addition of fertilizers to complement the natural soil fertility is important for modern crop production, and accurate management of nutrient elements is essential for a sustainable agriculture production.

In particular, potassium and zinc have important roles in fruit set and retention, as well as in fruit yield and quality (Davarpanah

* Corresponding author, Email: valizadehkaji@yahoo.com

et al., 2016; Fageria, 2009). Potassium is required for cellular osmotic and ionic balances, electrochemical processes, neutralization of organic acids, regulation of stomatal function, cell division, enzyme activation, protein synthesis, as well as the synthesis and translocation of sugars (Keller, 2010). In addition, zinc is required for the activity of different enzymes, including dehydrogenases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases, and is also involved in the synthesis of tryptophan, cell division, maintenance of membrane structure and photosynthesis, furthermore acts as a regulatory cofactor in protein synthesis (Marschner, 2012). Pistachio trees need potassium at the rate of 1-2 kg tree^{-1} per year and zinc at the rate of 200-250 g tree^{-1} per year ,in the form of K_2SO_4 and $ZnSO_4$, respectively) Hosseinifard et al ,.2005 ; Johnson and Brown ,2012).

Foliar fertilization is a useful alternative tool for plants when soil conditions may limit root uptake or during periods of fast growth when needs may exceed root supply (Girma et al., 2007). In addition, foliar sprays with fertilizers have been shown to be convenient for field use, have a good effectiveness and very rapid plant response (Fernández et al., 2013). Foliar fertilizers help to avoid toxic symptoms that may occur after soil application of the elements (Obreza et al., 2010). One of the efficacious timing for spray of nutrients is in late February and early March during swelling of the bud scales, when deficiency of nutrients negatively affect fruit set and nut development (Beede et al., 1991). Foliar applications of Zn have been successfully used to increase tree vigor , fruit set ,and yield in apple) Wojcik ,2007) , 'Washington Navel' orange (Hafez and El-Metwally, 2007(and walnut) Keshavarz et al ,.2011) .In accordance ,Karimi (2017) reported that the foliar application of potassium dramatically increased both quantitative and qualitative characteristics of 'Sultana' grapevine.

The aim of this study was to test the effects of K_2SO_4 and $ZnSO_4$ on the tree mineral nutrition status and fruit yield and quality in pistachio trees grown in an important agricultural area in the central part of Iran. In this area, soils are characterized with high pH, carbonate content and low organic matter, sandy loam texture and therefore they are poor in nutrients. To the best of our knowledge, no report has been conducted to investigate the effect of foliar application of potassium and the combination of potassium and zinc on pistachio trees so far. The pistachio cv. 'Chrokeh', is a leading cultivar in Qom province, Iran is characterized with late ripening, long shape, high nut and kernel weights.

Materials and Methods

Orchard selection and treatments

Field studies were conducted in commercial orchard located in Jafarieh, Qom province, Iran .In this climatic zone ,rainfall and relative humidity are very low while temperature is very high (Table 1). We selected 27 trees (15 year-old trees) for this experiment. The pistachio orchard, cv. 'Chrokeh', was planted at 7 × 4 m in a sandy loam soil and all trees received similar cultural practices such as irrigation and fertilization. The trees were trained to a vase form with uniform canopy volume ,and maintenance pruning was minimal due to the age of the trees and the dry growing conditions ;they were left un-pruned during the study period. Some physical and chemical properties of soil that related to this study are given in Table 2. Soil samples were taken from depth of 0–30 cm between the rows of trees at the beginning of the experiment. The experiment was conducted based on a completely randomized block design with nine treatments and three replications per treatment. Treatments were three levels of K_2SO_4 (0, 1 and 2 %) and three levels of $ZnSO_4$ (0, 0.5 and 1 %). The nutrient treatments were applied with 0.2% Tween 20 on each tree in two consecutive seasons 2017 (OFF) and 2018 (ON). The nutrient solutions were sprayed till runoff of the liquid on each tree in two times (bud swell stage and green tip stage) in 2017–2018. Distilled water with 0.2% Tween 20 was sprayed as the control. In a preliminary study, the pistachio trees were sprayed with different concentration of K_2SO_4 and $ZnSO_4$. It was found that treatment with K_2SO_4 at 1 and 2 % and $ZnSO_4$ at 0.5 and 1 % significantly affected fruit yield and quality of pistachio trees, therefore these concentrations was used in the experiments.

Table 1. Climatological data for a period spanning 2003–2018

Parameter	Level
Maximum absolute temperature (°C)	44.7
Minimum Absolute Temperature (°C)	-8.9
Average maximum temperature (°C)	26.3
Average minimum temperature (°C)	9.9
Average total temperature (°C)	17.7
Average relative humidity (%)	42.1
Average annual rainfall (mm)	143.8

Table 2. Soil mineral contents, physical and chemical traits of the experimental orchard and comparison with suggested desirable ranges

Traits	Experimental orchard	Desirable ranges (Benton Jones et al., 1991; Benton, 2003; Hosseinifard et al., 2016)
P (ppm)	9.5	7-10
K (ppm)	237	250-300
Zn (ppm)	0.8	1
Mn (ppm)	9.2	8
Fe (ppm)	8.5	10
Organic matter (%)	1.6	> 2
Texture	Sandy loam	Loam
EC (ds m^{-1})	2.1	< 4
pH	8.2	7

Leaf mineral contents

Leaf samples were collected in mid-July 2017 and 2018 from each tree and their N, P, K, Mg, Zn, Mn and Fe concentrations were measured. Three leaves were taken from the middle of growing shoots. Leaf samples were dried at 65 °C for 48 h in a forced-air oven, and then ground to a powdery texture; and 0.2 g was taken to determine aforementioned elements. Total N was determined by the Kjeldahl. P was determined using a spectrophotometer. K was flame photometrically determined. The sample extracts were analyzed for Mg, Zn, Mn and Fe using an atomic absorption spectrophotometer (Varian, 220). The results of the leaf analyses are given in Table 3, along with the desirable levels published by Sedaghati et al .(2008).

Chlorophyll and carotenoid

Leaf samples were collected in mid-July 2017 and 2018 from each tree. Approximately 0.5 g of the leaf samples was used for chlorophyll and carotenoid extraction using acetone (80% v/v). The absorbance of the upper solution was assayed using a UV–visible spectrophotometer (Cary Win UV 100; Varian, Sydney, Australia) after centrifuging at 6000×*g* for 10 min according to Lichtenthaler (1987). Total chlorophyll concentrations were determined at 652 nm, and carotenoids at 470 nm, and all pigments were expressed as mg g^{-1} FW leaf.

Fruit yield and the percentage of splitting and blankness

Pistachio fruits were harvested during the commercial harvest period when the fruit reached the stage of physiological maturity, signaled by a reddish hull. All pistachio clusters were removed from the trees by hand. Fresh yield for each treatment was determined by weighing clusters (including split, non-split, and blank nut). To estimate dry yield, the reddish hull was removed and nuts dried at 65 °C for 72 h in a forced-air oven. Then, evaluations for dry yield were determined by weighing nuts (including split and non-split). Determinations for the splitting rate in fruit were made with the naked eye by counting and rating split nuts to non-split ones. The number of blank nuts was determined from samples of 100 nuts and evaluated as a percentage.

Statistical analysis

The data were analyzed using SAS Version 9.1. Significant differences were assessed using Duncan's multiple range test at $P \leq 0.05$. Data expressed as percentages were subjected to arcsine transformation before statistical analysis. All transformed data are presented in original values.

Results

The experiment was done during two years (2017–2018) and because data were same, therefore, results of both years have not shown for chlorophyll and carotenoid concentration and mineral contents of leaves.

Leaf nutrient concentrations

With the exception of P ,leaf nutrient concentrations of untreated control trees were lower than the recommended desirable ranges, suggesting that tree nutrient status is generally inadequate. While ,with the exception of N ,the foliar application of K and Zn fertilizers increased leaf nutrient concentrations to the desirable levels or even higher (Table 3). K_2SO_4 and $ZnSO_4$ treatments significantly affected concentrations of P, K, Mg, Zn, Mn and Fe in the leaves of 'Chrokeh' pistachio, whereas nutrient treatments had not significant effects on leaf concentration of N (Table ٤). The highest leaf concentration of K (1.66-2.21%) were obtained with 1% K_2SO_4+0% $ZnSO_4$, 2% K_2SO_4+0.5% $ZnSO_4$, 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+0% $ZnSO_4$ treatments, which led to two to three times increase compared to K concentration in control trees (0.73%). Furthermore, leaf concentration of Zn markedly increased from 12.15 ppm in the control to 26.09 ppm (more than two times increase) under 2% K_2SO_4+1% $ZnSO_4$ treatment, although no significant difference was found between this treatment and most of the other nutrient treatments regarding this micronutrient. The highest leaf concentration of P (0.92-0.93%) were obtained with 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+1% $ZnSO_4$ treatments, which led to more than three times increase compared to the control (0.27%). Leaf concentration of Mg noticeably increased from 0.23% in the control to 0.83% (approximately 3.5 times increase) under 2% K_2SO_4+1% $ZnSO_4$ treatment. The highest leaf concentration of Fe was found in 2% K_2SO_4+1% $ZnSO_4$ and 1% K_2SO_4+1% $ZnSO_4$ treatments, which led to 42-54% increase in concentration of this element (134.65-145.911 ppm compared with the control value of 94.33 ppm). Leaf concentration of Mn remarkably increased from 29.52 ppm in the control to 36.81-38.74 ppm (a 24-38% increase) in 2% K_2SO_4+1% $ZnSO_4$ and 1% K_2SO_4+1% $ZnSO_4$ treatments (Table 4).

Table 3. Leaf mineral contents of the untreated and nutrient-treated trees and comparison with suggested desirable ranges

Minerals	Untreated trees	Nutrient-treated trees	Desirable ranges (Sedaghati et al., 2008)
N (%)	1.73	1.76-1.87	2.2-2.5
P (%)	0.27	0.39-0.93	0.14-0.17
K (%)	0.73	1.41-2.21	1.8-2
Mg (%)	0.23	0.35-0.83	0.6-1.2
Zn (ppm)	12.15	12.47-26.09	15
Mn (ppm)	29.52	31.03-38.74	30-80
Fe (ppm)	94.33	102.63-145.91	110

Table 4. Effects of foliar application of K and Zn fertilizers on concentrations of N, P, K, Mg, Zn, Mn and Fe in the leaves of 'Chrokeh' pistachio

Treatments		N (%)	P (%)	K (%)	Mg (%)	Zn (ppm)	Mn (ppm)	Fe (ppm)
K_2SO_4 (%)	$ZnSO_4$ (%)							
0	0	1.73±0.32	0.27±0.11 b	0.73±0.15 c	0.23±0.10 d	12.15±0.30 b	29.52±2.12 c	94.33±1.74 f
1	0	1.76±0.10	0.39±0.17 b	1.66±0.24 ab	0.45±0.14 bcd	12.80±0.99 b	32.87±3.40 bc	112.20±3.22 de
2	0	1.81±0.10	0.58±0.35 b	2.21±0.59 a	0.60±0.02 abc	12.47±1.84 b	32.48±2.21 bc	120.01±4.12 cd
0	0.5	1.85±0.10	0.47±0.17 b	1.26±0.55 bc	0.47±0.19 bcd	24.46±2.03 a	33.00±4.35 bc	102.63±2.12 ef
1	0.5	1.87±0.07	0.51±0.12 b	1.48±0.40 b	0.52±0.12 bc	23.33±3.79 a	31.23±1.06 c	126.98±12.09 bc
2	0.5	1.76±0.27	0.56±0.10 b	1.83±0.16 ab	0.55±0.26 abc	20.65±3.80 a	31.66±2.88 bc	131.76±11.84 bc
0	1	1.78±0.20	0.52±0.21 b	1.41±0.45 b	0.35±0.13 cd	23.65±2.08 a	31.03±1.30 c	104.30±2.04 ef
1	1	1.78±0.07	0.92±0.01 a	1.90±0.05 ab	0.70±0.10 ab	25.32±3.16 a	38.74±0.99 a	134.65±6.67 ab
2	1	1.85±0.52	0.93±0.02 a	1.55±0.35 b	0.83±0.08 a	26.09±1.33 a	36.81±3.38 ab	145.91±5.30 a
P-value		0.1291	0.0016	0.0057	0.0059	<.0001	0.0154	<.0001

Values represent the mean ± SD.
Mean values followed by the similar letters within a column are not significantly different from each other at $P \leq 0.05$ (Duncan's multiple range test)

Table 5. Chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents in leaves of 'Chrokeh' pistachio under different nutrient treatments

Treatments		Chlorophyll a (mg g^{-1} FW)	Chlorophyll b (mg g^{-1} FW)	Total chlorophyll (mg g^{-1} FW)	Carotenoid (mg g^{-1} FW)
K_2SO_4 (%)	$ZnSO_4$ (%)				
0	0	1.47±0.37 b	0.58±0.34 b	1.80±0.21 b	0.94±0.02 c
1	0	1.48±0.43 b	0.62±0.30 b	2.32±0.56 b	1.16±0.21 bc
2	0	1.65±0.22 b	0.72±0.34 b	2.54±0.34 b	1.55±0.57 abc
0	0.5	1.53±0.33 b	0.67±0.28 b	2.20±0.43 b	1.44±0.58 abc
1	0.5	1.69±0.23 b	0.76±0.31 b	2.45±0.60 b	1.76±0.17 ab
2	0.5	1.69±0.22 b	0.76±0.35 b	2.63±0.26 b	1.77±0.25 ab
0	1	1.77±0.28 b	0.73±0.34 b	2.57±0.30 b	1.54±0.70 abc
1	1	2.45±0.48 a	1.44±0.49 a	3.76±0.20 a	1.92±0.06 a
2	1	2.85±0.05 a	1.72±0.37 a	3.55±0.56 a	2.10±0.69 a
P-value		0.0006	0.0085	0.0012	0.0407

Values represent the mean ± SD.
Mean values followed by the similar letters within a column are not significantly different from each other at $P \leq 0.05$ (Duncan's multiple range test)

Chlorophyll and carotenoid contents

Nutrient treatments had a significant effect on chlorophyll a (P = 0.0006), chlorophyll b (P = 0.0085), total chlorophyll (P = 0.0012) and carotenoid (P = 0.0407) contents (Table 5). The highest chlorophyll a content (2.45-2.85 mg g^{-1} FW) were obtained in the 2% K_2SO_4+1% $ZnSO_4$ and 1% K_2SO_4+1% $ZnSO_4$ treatments, whereas the lowest one (1.47 mg g^{-1} FW) was detected in control treatment, although no significant difference was found between control and the other nutrient treatments regarding this index. Chlorophyll b content of the control trees was 0.58 mg g^{-1} FW, whereas the highest ones (1.44-1.72 mg g^{-1} FW) were obtained with the 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+1% $ZnSO_4$ treatments. In addition, nutrient treatment significantly increased total chlorophyll content of leaves from 1.80 in control to 3.76 mg g^{-1} FW in 1% K_2SO_4+1% $ZnSO_4$ treatment. Similarly, carotenoid content in the leaves markedly increased from 0.94 in the control to 2.10 mg g^{-1} FW in 2% K_2SO_4+1% $ZnSO_4$ treatment (Table 5).

Fruit yield

This experiment was done during two years (2017–2018) and because of severe alternate bearing in 2017; only data from the ON year of 2018 were available for yield.

K_2SO_4 and $ZnSO_4$ treatments positively affected fresh and dry yield (Fig. 1). The highest fresh yields (23.33-28.66 kg tree^{-1}) were obtained in 2% K_2SO_4+0% $ZnSO_4$, 1% K_2SO_4+0.5% $ZnSO_4$, 2% K_2SO_4+0.5% $ZnSO_4$, 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+1% $ZnSO_4$ treatments, which led to 34-65% increases when compared to the control trees (17.33 kg tree^{-1}). Similarly, the application of K_2SO_4 and $ZnSO_4$ led to significant increases in the dry yield (by 35–67%, depending on the treatments) (Fig. 1).

The percentage of splitting and blankness

Nutrient treatments had a significant effect on the percentage of splitting (Fig. 2) and blankness (Fig. 3). The percentage of splitting increased from 80.76% in 1% K_2SO_4+0.5% $ZnSO_4$ treatment to 89.70% (an 11 % increase) under 2% K_2SO_4+0% $ZnSO_4$ treatment (Fig. 2). Furthermore, the blankness percentage of fruits markedly decreased from 24.33% in the control to 18% (a 26% decrease) under 2% K_2SO_4+1% $ZnSO_4$ treatment, although no significant difference was found between this treatment and most of the other nutrient treatments (Fig. 3).

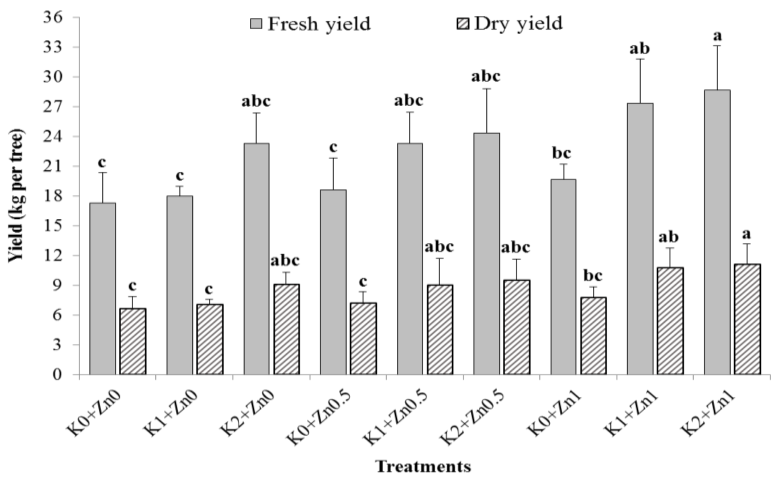

Fig. 1. Effects of foliar application of K and Zn fertilizers on fresh and dry yields of 'Chrokeh' pistachio. Significant difference ($P \leq 0.05$) between data is expressed by different letters. Vertical bars indicate mean value and standard deviation.

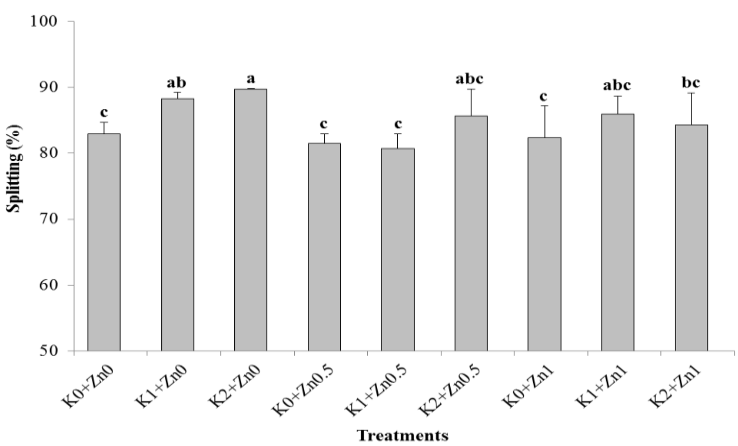

Fig. 2. Effects of foliar application of K and Zn fertilizers on the splitting percentage of 'Chrokeh' pistachio. Significant difference ($P \leq 0.05$) between data is expressed by different letters. Vertical bars indicate standard deviation.

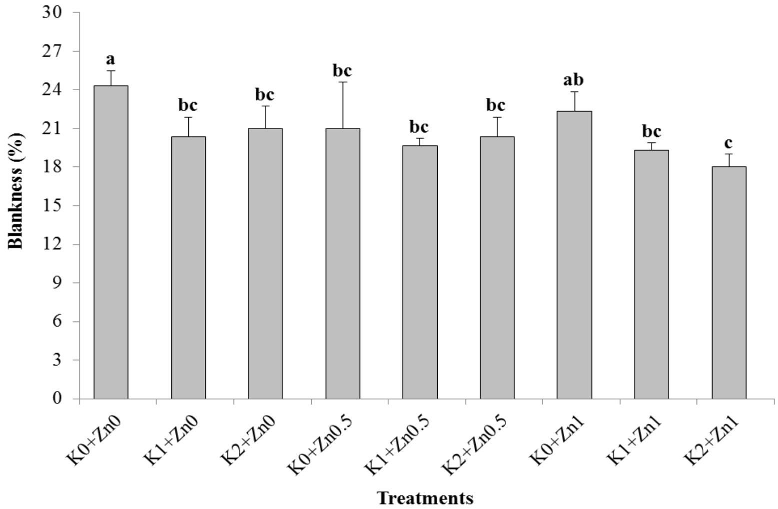

Fig. 3. Effects of foliar application of K and Zn fertilizers on the blankness percentage of 'Chrokeh' pistachio. Significant difference ($P \leq 0.05$) between data is expressed by different letters. Vertical bars indicate standard deviation.

Discussion

In the present study, most of the soil mineral contents, physical and chemical traits related to the experimental orchard were low compared to the recommended desirable ranges) Table 2 .(In such conditions ,spring foliar fertilization has several advantages including low application rate, uniform distribution of fertilizer materials, efficacy before leaf development, and quick response (Umer et al., 1999 .(The leaf concentrations of K and Zn in control trees were 0.73% and 11.88 ppm, respectively (Table 4). Leaf concentrations of K below 1.8% are usually found in K-deficient plants (Sedaghati et al., 2008). Regarding Zn, leaf concentrations below 15 ppm have been reported as Zn-deficient (Sedaghati et al., 2008; Ojeda-Barrios et al., 2014). Therefore, leaf concentrations of the K and Zn found in the studied orchard point out to the presence of a mixed deficiency of K and Zn. In this study, potassium and zinc fertilizers, alone or in combination, considerably increased leaf concentrations of K, P, Mg, Zn, Fe and Mn with no significant effect on the leaf concentrations of N (Table 4). Previous studies have revealed that K and Zn sprays usually increase leaf concentrations of K and Zn, although in many of these studies a number of fertilizer applications and/or higher K/Zn concentrations have been used. For example, spraying K increased leaf concentration of K in grapevine (Karimi, 2017) and red raspberry trees (Reickenberg and Pritts, 1996), and spraying Zn improved the leaf concentration of Zn in pistachio (Kizilgoz et al., 2010; Soliemanzadeh et al., 2014) pomegranate (Davarpanah et al., 2016) and pecan nut trees (Ojeda-Barrios et al., 2014). In a number of fruit trees, application of fertilizers has been reported to cause changes in the concentrations of other nutrients, maybe due to interactions in ion uptake and/or transport (Davarpanah et al., 2016). For example, foliar applications of $ZnSO_4$ decreased the leaf concentrations of Mn and P in pomegranate (Hasani et al., 2012), whereas the application of $ZnSO_4$ increased leaf concentrations of Zn and K in mandarin tree (Khan et al., 2012). In pistachio, it was found that there is an antagonistic effect between Zn and Fe, Mn and Cu, since the concentration of Fe was considerably higher in Zn-deficient trees, soil application of Zn decreased concentrations of Fe up to 13% (Shahriaripour and Tajabadipour, 2010). In the present study, a synergistic effect of Zn with other nutrients was observed that differs from findings reported by Shahriaripour and Tajabadipour (2010) and Hasani et al. (2012).

The most nutrient treatments especially 1% K_2SO_4+1% $ZnSO_4$ and 2% K_2SO_4+1% $ZnSO_4$ caused a significant increase in chlorophyll a, chlorophyll b, total chlorophyll and carotenoid contents of 'Chrokeh' pistachio plants (Table 5). Zn has key roles in chlorophyll synthesis in plants (Fageria, 2009). Sharma et al. (1994) reported that adding Zn improves the chlorophyll content and photosynthetic activity in the leaves of cabbage. The soil in arid and semi-arid regions of Iran is often poor in available Zn associated with high calcium carbonate content and alkaline pH (Tavalli and Rahemi, 2007), therefore, pistachio trees usually suffer from Zn deficiency. Therefore, application of Zn could be a solution for this problem. One of the efficacious timing for Zn spray is in late February and early March during swelling of the bud scales, when deficiency affects fruit set and nut development (Beede et al., 1991). In addition ,K ions in the cell cystocele play an important role in activity of many enzymes of the photosynthesis and because of the ability of K in assisting detoxification of reactive oxygen species) ROS ;(higher K might prevent decomposition of chlorophyll and increase the content of chlorophyll)Alipour, 2018 .(K deficiency also caused an increase in NADPH dependent O_2 generation in root cells which indicates that increased ROS production during both photosynthetic electron transport and NADPH-oxidizing enzyme reactions may be involved in membrane damage and chlorophyll degradation in K-deficient plant (Waraich et al, 2011).

Nutrient treatments especially 2% K_2SO_4+1% $ZnSO_4$ positively affected fresh and dry yields of 'Chrokeh' pistachio trees (Fig. 1). Increases in fruit yield with K fertilization have been reported in different fruit crops, including grapevine (Karimi, 2017), olive (Restrepo-Diaz et al., 2008) and pineapple (Razzaquea and Hanafib, 2001). The combined application of K and Zn increased olive yield (Ramezani and Shekafandeh, 2011). Moreover, Zn fertilization increased yield in citrus trees (Swietlik, 2002) apple (Amiri et al., 2008), Nagpur (Srivastava and Singh, 2009), pistachio (Kizilgoz et al., 2010; Soliemanzadeh et al., 2014), walnut (Keshavarz et al., 2011) and pomegranate (Davarpanah et al., 2016). Increase in the yield of pistachio trees as the result of K application are likely to be due to the known critical roles of K in protein synthesis, stomatal movement, photosynthesis, osmoregulation, enzyme activation, phloem transport, energy transfer, cation-anion balance and stress resistance (Marschner, 2012). Increase in the yield of pistachio trees as the result of Zn application are also in agreement with previous reports. Zn plays important roles in reproductive bud formation, flowering (Usenik and Stampar, 2002), the production of tryptophan, an auxin precursor, and in the translocation of metabolites to buds (Day, 1994).

In pistachio, splitting is a genetic trait; however, it has been stated that several factors such as cultivar, rootstock, cultural management, climatic conditions, alternate bearing, pollen source, and plant nutrition could affect the percentage of nut splitting (Okay et al., 2010). In this study, K_2SO_4 and $ZnSO_4$ treatments positively affected the percentage of nut splitting (Fig. 2), although Zn alone did not increase splitting of nuts. Our results corroborate those of Tsipouridis et al. (2005) who reported Zn fertilization did not affect splitting of pistachio nuts. We did not found any published research about the effect of potassium on the percentage of nut splitting in pistachio. It has been observed that 2% K_2SO_4+0% $ZnSO_4$ treatment tends to increase dramatically nut splitting of pistachio. Increase in the percentage of nut splitting in pistachio trees as the result of K application may be related to the known essential roles of this element in most of the biochemical and physiological processes.

In the present study, nutrient treatments had significant effects on the percentage of blankness (Fig. 3). Soliemanzadeh et al. (2014) reported that the percentage of blankness was not affected by the nutrient treatment which is not in line with the results observed in the present study. Blanking may occur during two different phases of pistachio nut development: nut setting and nut filling. It can also be affected by crop load and production practices (Ferguson et al., 2005).

Conclusion

Application of K and Zn as foliar spray in bud swell stage and green tip stage affected leaf nutrients, chlorophyll and carotenoid contents, fruit yield and the percentage of splitting and blankness of pistachio fruits, which could be considered as an applied nutrition program in pistachio orchards. It can be concluded that in the calcareous soils, foliar application of K and Zn fertilizers is necessary for obtaining better fruit yield and quality in pistachio.

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