Improving the quantitative-qualitative characteristics and nutritional value of Kaleh Ghouchi pistachio by the foliar application of potassium and zinc

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Abstract

Background: Pistachio is one of the most important horticultural products in Iran. In recent years, its yield and quality have been declined to some extent. One of the main reasons for the reduced yield and quality of pistachio is poor nutrition and deficiency of some nutrients. The present study aims at investigating the effect of foliar application of potassium and zinc on some quantitative-qualitative characteristics of *Kaleh Ghouchi* pistachio.

Materials and Methods: The experiment was conducted in a randomized complete block design with 9 treatments and 3 replications. Treatments included three levels of potassium sulfate (0, 1, and 2%) and three levels of zinc sulfate (0, 0.5, and 1%). The foliar application was conducted at two phases (swell bud and green tip stages).

Results: The results indicated that nutritional treatments, especially the treatment with 1 or 2 % of potassium sulfate and 1% of zinc sulfate, resulted in significant increases in fresh weight (by about 44%) and dry weight (by about 41%) compared to those of the control. Moreover, nutritional treatments significantly affected the splitting percentage (a 10 % increase), while the blankness percentage was not affected; though its amount was lower in the nutritional treatments than the control treatment. In terms of fruit appearance, kernel appearance, and kernel taste, the highest quality was related to treatments with 1 or 2 % of potassium sulfate and 1% of zinc sulfate. Furthermore, nutritional treatments, especially the treatment with 2% potassium sulfate and 1% zinc sulfate, caused a significant increase in the amount of fat and carbohydrates in the kernel. Similarly, foliar application of potassium sulfate and zinc sulfate significantly affected the concentrations of potassium and zinc in pistachio kernels.

Conclusion: In calcareous soils of Iran, foliar application of potassium and zinc can be considered a practical nutritional program to achieve fruits with better quantity and quality in pistachio orchards.

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1. Introduction

Pistachio is one of the most important horticultural crops in Iran. Over the recent years, its yield and quality have been declined to some extent. After years of being ranked first in the world for pistachio production, Iran is now ranked third after the United States and Turkey. The production of Iranian pistachios is about 190,000 tons, while it is about 470,000 tons for the United States and about 300,000 tons for Turkey [1]. One of the main reasons for the decreased yield and quality of pistachio is poor nutrition and deficiency of some nutrients [2]. The soil of most pistachio growing areas of the country has high amounts of calcium carbonate and alkaline pH; there is, thus, a lack of some nutrients such as potassium and zinc [3]. Therefore, using fertilizers to increase the quantitative-qualitative characteristics of this valuable crop is of high significance. In particular, potassium and zinc play important roles in fruit set, prevention of fruit drop, and quantity and quality of fruits [4]. Potassium is required for osmotic regulation, ionic balance, electrochemical processes, organic acid neutralization, regulation of stomata opening and closing, cell division, enzyme activation, protein synthesis, and sugar transport [5]. Zinc is also involved in many processes, including various enzymes activation, tryptophan synthesis, protein synthesis, cell division, membrane structure preservation, and photosynthesis [6].

Foliar nutrition can be beneficial when poor soil conditions reduce root uptake or the plant grows so fast that the roots cannot meet its needs [7]. In addition, foliar application of nutrients is effective, associated with a very fast reaction of plants [8]. Moreover, foliar application of fertilizers prevents the appearance of toxicity symptoms of elements in the plant; in contrast, their soil application may increase the levels of some elements in the plant to a toxicity level [9]. One of the best times for foliar application of nutrients is during the swelling of buds since the deficiency of nutrients at this stage affects fruit set and its subsequent growth [10]. The zinc concentration in pistachio kernels is about 24 ppm, and to produce one ton of dried pistachios, 65.5 grams of pure zinc is required [11]. Increased root growth has also been reported after zinc foliar application [12]. Zinc foliar application has been used successfully to improve the quantity and quality of walnuts [13]. Furthermore, according to other studies, the quantitative-qualitative characteristics of grapes have been significantly increased by potassium foliar application [14].

Given the problems in the soils of pistachio orchards where nutrient absorption by roots is limited and due to the valuable properties of pistachio, this study aims to investigate the effects of foliar application of different concentrations of potassium and zinc sulfate on the quantitative-qualitative characteristics of *Kaleh Ghouchi* pistachio.

2. Materials and Methods

Selection of orchards and treatments

Horticultural studies were conducted in a commercial orchard located in Jafariyeh in Qom province. The soil of this orchard is sandy loam with high in pH and calcium carbonate and low in organic materials and nutrients (Table 1). The region has latitude of 34.78 degrees north, a longitude of 50.58 degrees south, an altitude of 928 meters above sea level, an average annual rainfall of 144 mm, a minimum temperature of -9 °C, a maximum temperature of 45 °C, and

average relative humidity of 42%. For this experiment, as many as 27 15-year-old grafted trees of the *Kaleh Ghouchi* cultivar, planted at a distance of 6 by 5 meters, were selected. The horticultural operations, including irrigation and feeding, were the same for all trees.

Table 1. Properties of orchard soil of the site of the experiment

Fe (ppm)	Mn (ppm)	Zn (ppm)	K (ppm)	P (ppm)	Electric conductivity (ds m^{-1})	Acidity pH	Organic matter (%)	Soil texture
8.5	9.2	0.8	237	9.5	2.1	8.2	1.6	Sandy loam

The experiment was conducted as a randomized complete block design with 9 treatments and 3 replications for each treatment. Treatments included three levels of potassium sulfate (0, 1, and 2%) and three levels of zinc sulfate (0, 0.5, and 1%). Nutritional treatments with 0.2% of tween 20 were applied on each tree. Nutritional solutions were sprayed on the trees in rainless climates at two phases (swell bud and green tip stages) until the dripping stage. Distilled water was used with 0.2% of tween 20 as the control treatment.

Quantity and quality of fruit

To investigate the quantity and quality, the fruits of each tree were harvested in late summer at the stage of physiological maturity, i.e., when hull turns completely red and is easily separated from the shell. All pistachio clusters were picked from the tree by hand. The fresh weight for each treatment was determined by weighing all clusters. To determine the dry weight, the outer red skin was removed, and the fruits (kernels and shell) were dried for 72 hours in an oven at 65 °C. After drying the fruits, the dry weight was determined by weighing the fruits. The splitting rate of fruits was determined by counting the number of split and non-split fruits. The blankness rate was determined by counting 100 fruits and expressed as a percentage.

The scoring method (1-5), as well as tasting and asking for opinions of different individuals, was used to determine the appearance of the fruit and the appearance and taste of the kernel. Five panelists were selected, each being given 5 pistachio fruits from each treatment. Excellent, good, moderate, poor, and very poor fruits were given scores of 5, 4, 3, 2, and 1, respectively.

In late summer, at the stage of physiological maturity, three fruits were randomly selected from each tree, and the fat percentage of their kernel was measured using an aqueous solvent and Soxhlet device according to the method of Erturk et al. [15].

In late summer, at the physiological maturity stage, three fruits were randomly selected from each tree, and their carbohydrate measurements were conducted based on the method of Panahi and Khezri [16] with a slight change. The concentration of soluble carbohydrates was obtained according to the regression equation in mg/l; finally, the number of soluble carbohydrates in pistachio kernels was expressed as a percentage.

Measurement of fruit elements

In late summer, at the physiological maturity stage, three fruits were randomly selected from each tree, and the amounts of their potassium and zinc were measured. The fruit samples were

dried in an oven at 65 °C for 48 hours, and they were completely powdered. Then, one gram of powdered sample was placed in an oven at 550 °C for 6 hours to turn into ash. Subsequently, 10 ml of 2 a normal hydrochloric acid was added to this ash and it was placed on a laboratory *water bath* for half an hour; this extract reached 100 ml with distilled water. It was used to extract potassium and zinc. The amount of potassium was determined using the flame photometry method. Atomic absorption spectrophotometer (Varian, 220) was used to measure the amount of zinc [14].

Data analysis

The data were analyzed using SAS V-9.1. Comparison of means was conducted using Duncan's multiple range test at the level of 0.05. The data in a percentage were converted to data by the Arc Sin method before statistical analysis. The original values of all the converted data are provided in the text.

3. Results

Quantity and quality of fruit

Different concentrations of potassium and zinc sulfate positively affected fresh weight, dry weight, splitting percentage, fruit appearance, kernel appearance, kernel taste, fat percentage, and carbohydrate content. In contrast, the blankness percentage was not affected by the nutritional treatments (Table 2). However, the blankness percentage in nutritional treatments was less than that of the control treatment (Figure 1).

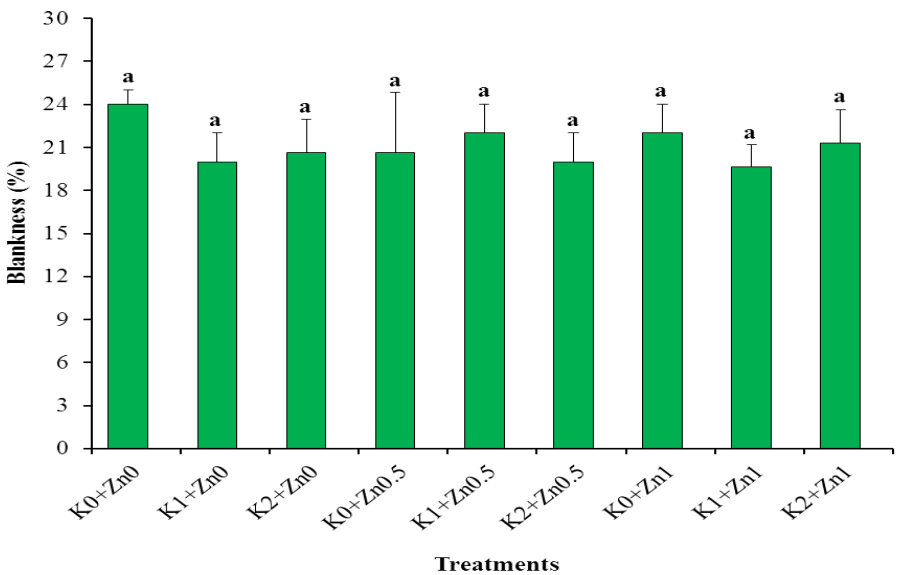

Figure 1. Effects of nutrient treatments on fruit blankness of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

Table 2. Variance analysis of the effect of foliar application of K and Zn fertilizers on quantitative-qualitative characteristics of 'Kaleh Ghouchi' pistachio

Source of distribution	Mean square											
	df	Fresh yield (Kg/tree)	Dry yield (Kg/tree)	Blankness (%)	Splitting (%)	Carbohydrates of kernel (%)	Fat of kernel (%)	Fruit appearance	Kernel appearance	Kernel flavor	K (%)	Zn (ppm)
Treatment	8	50.78*	7.98*	9.95^{ns}	28.08**	10.63*	30.28**	0.83**	1.08**	1.34**	0.27**	114.68**
Block	2	15.81	2.26	1.037	23.24	2.50	0.01	0.11	0.33	0.14	0.007	3.78
Error	16	18.23	2.70	3.12	7.34	2.99	0.04	0.11	0.08	0.18	0.06	8.58
CV		19.15	18.86	8.53	3.20	16.61	0.46	7.89	6.83	10.40	19.49	14.61

*, ** and ns: Significant (P<0.05), highly significant (P<0.01), and not significant, respectivel.

The highest fresh weight (37 kg/tree) was related to the treatments of 1% potassium sulfate with 1% zinc sulfate, with a 44% increase, compared to that of the control treatment (25.66 kg/tree) (Figure 2). Similarly, the application of potassium and zinc sulfate, depending on the type of treatment, increased the dry weight by 23-41% (Figure 2). However, in terms of fresh and dry weight, no significant difference was observed between most nutritional treatments (Figure 2).

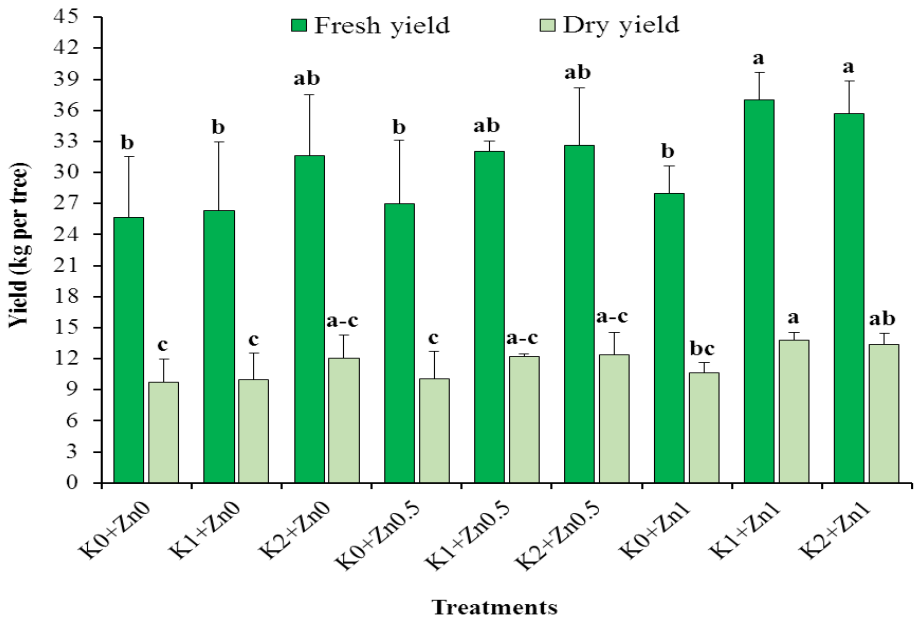

Figure 2. Effects of nutrient treatments on fresh and dry yield of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

In terms of fruit appearance, kernel appearance, and kernel taste, the highest quality (score 5) was related to the 1% potassium sulfate and 1% zinc sulfate treatment and the 2% potassium sulfate and 1% zinc sulfate treatment. In contrast, the lowest score was related to the fruits of the control treatment (Figures 4, 5, 6).

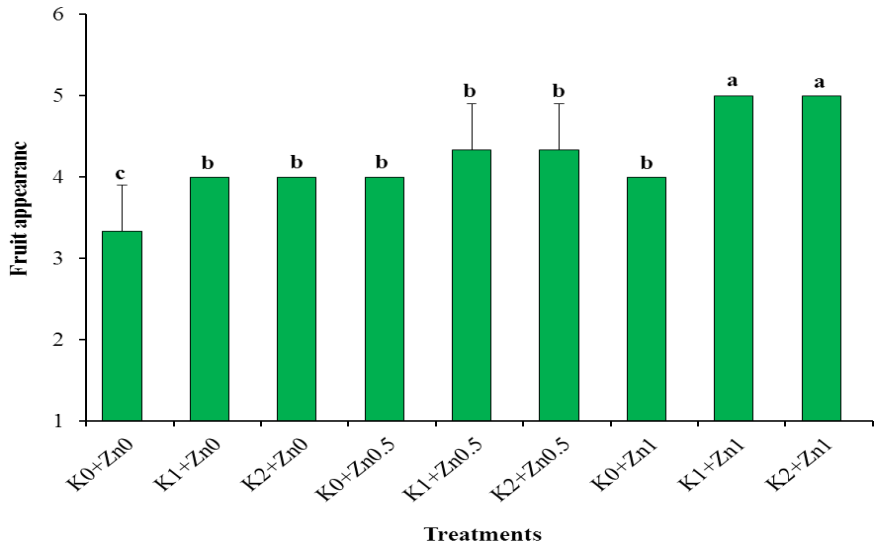

Figure 4. Effects of nutrient treatments on fruit appearance of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

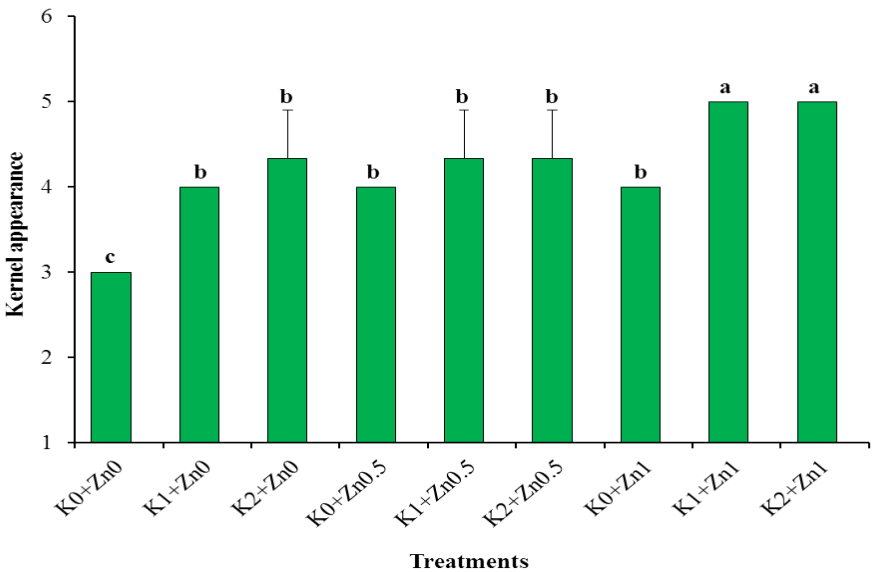

Figure 5. Effects of nutrient treatments on kernel appearance of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

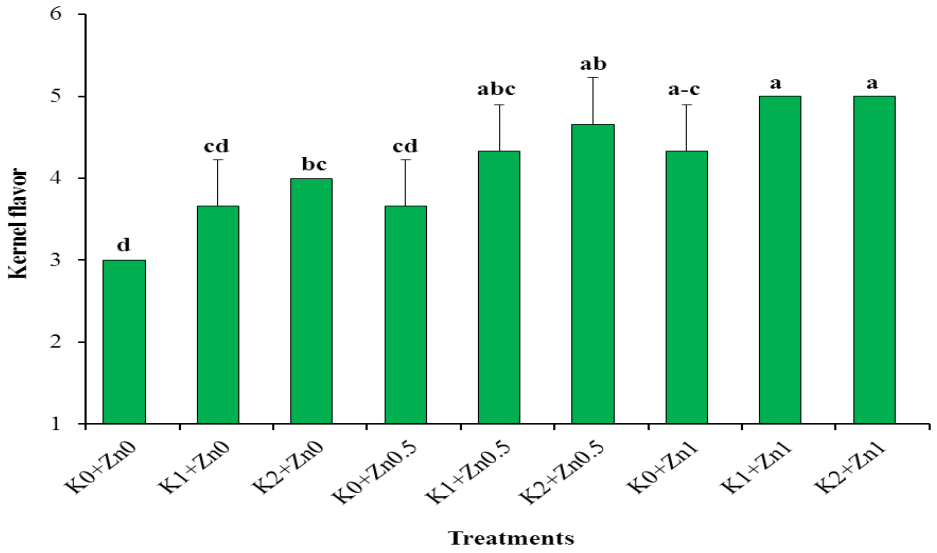

Figure 6. Effects of nutrient treatments on kernel flavor of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

The highest amount of kernel fat (52.07 to 52.43%) was associated with the 1% potassium sulfate and 1% zinc sulfate treatment and the 2% potassium sulfate and the 1% zinc sulfate treatment. In contrast, the lowest amount of fat (43.33%) was recorded for the control treatment (Figure 7).

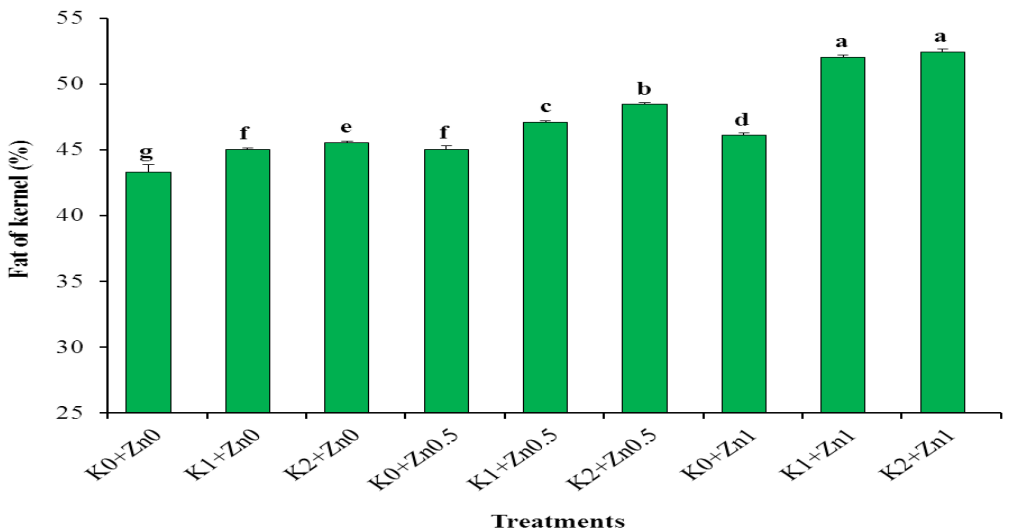

Figure 7. Effects of nutrient treatments on the fat percentage in the kernels of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

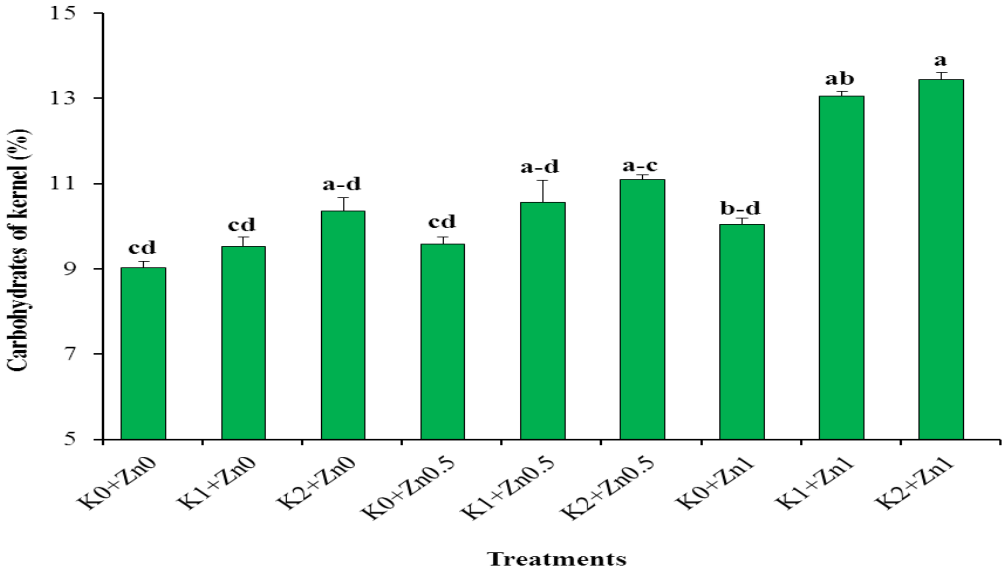

Figure 8. Effects of nutrient treatments on the percentage of carbohydrates in the kernels of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

The concentration of leaf elements

The analysis of variance showed that nutritional treatments significantly affected the concentration of potassium in the kernel of *Kaleh Ghouchi* pistachio (Table 2). The highest concentration of kernel potassium (1.78%) was related to the 2% potassium sulfate and 0% zinc sulfate treatment, with a 91.39% increase, compared to that of the control treatment (0.93%). However, no significant difference was observed between the 2% potassium sulfate and 0% zinc sulfate treatment and some other nutritional treatments (Figure 9).

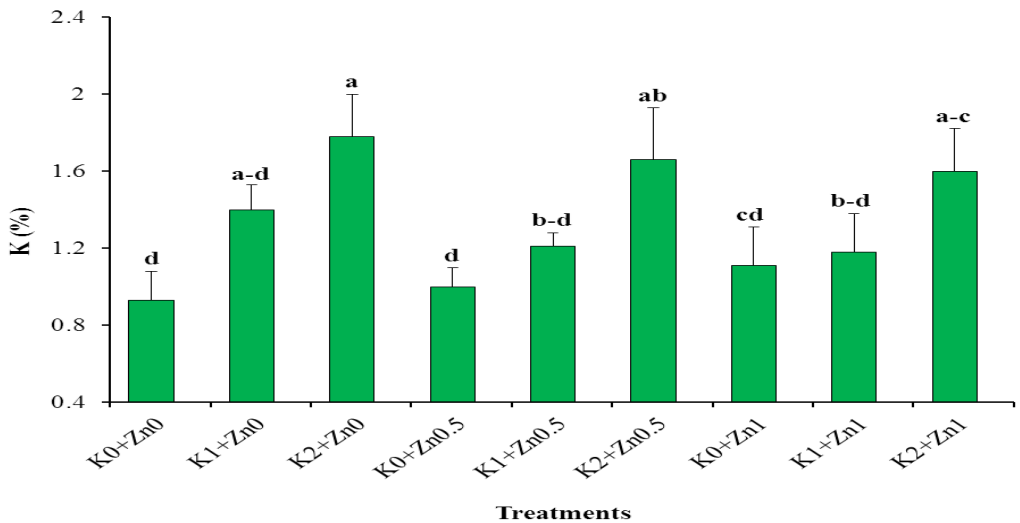

Figure 9. Effects of nutrient treatments on the percentage of K in the kernels of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

In addition, the concentration of the kernel zinc increased significantly from 11.55 ppm in the control treatment to 25.78 in the 1% potassium sulfate and 1% zinc sulfate treatment (a 123% increase). However, in terms of this micronutrient, no significant difference was observed between this treatment and most other nutritional treatments (Figure 10).

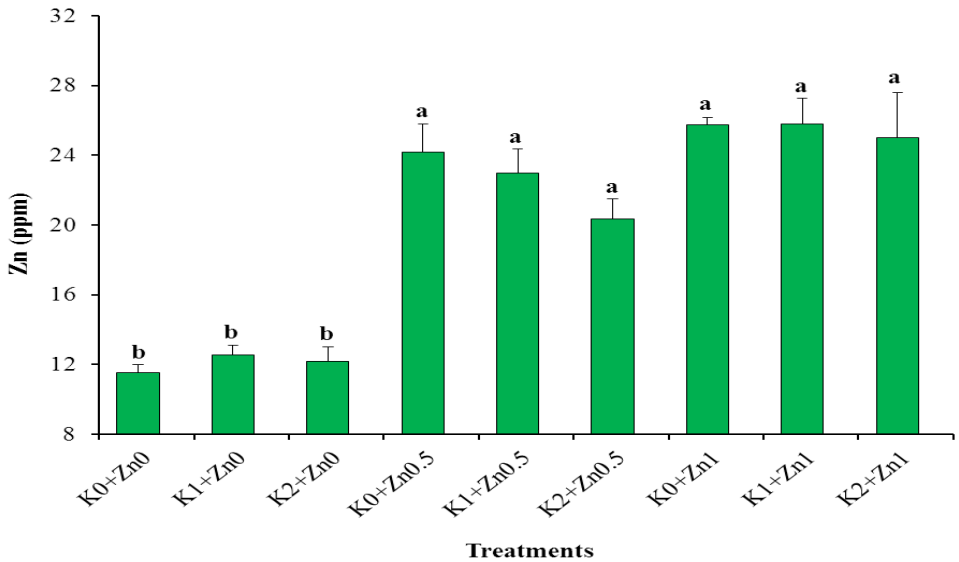

Figure 10. Effects of nutrient treatments on the percentage of Zn in the kernels of 'Kaleh Ghouchi' pistachio; Bars with similar letters are not significantly different at $P \leq 0.05$ (Duncan's multiple range test); Vertical bars indicate standard deviation.

4. Discussion

Providing nutrients for plants in optimal amounts is one of the essential factors in increasing the quantitative-qualitative yield of crops. In this study, different concentrations of potassium and zinc sulfate had a positive effect on the quantitative-qualitative characteristics of pistachio (Figures 1, 2, 3, 4, 5, 6). In line with results of this study, using potash fertilizers increased yield in many fruit trees, including grapes [14] and olives [17]. Co-application of potassium and zinc also increased olive yield [18]. In addition, using zinc in pistachio [19] and pomegranate [20] led to improved yield. Increased quantitative-qualitative properties of pistachio as a result of potassium foliar application may be owing to the key and well-known role of potassium in protein synthesis, stomata opening and closing, photosynthesis, osmotic regulation, enzyme activation, energy transfer, material transfer within vessels, anion-cation balance, and increased stress tolerance [6]. Moreover, zinc is involved in reproductive bud formation, tryptophan synthesis, flowering [21], and transfer of metabolites to buds [22]; increased quantitative-qualitative characteristics of pistachio trees as a result of zinc foliar application may be due to this very reason.

In pistachio, the splitting percentage is a genetic trait; yet, it has been found that several factors such as cultivar, rootstock, climatic conditions, horticultural operations, alternative bearing, pollen source, and plant nutrition can affect the splitting percentage [23]. In this study, the splitting percentage was affected by nutritional treatments (Figure 2), although zinc alone did not increase the splitting percentage of pistachios. This study is in line with that of Tsipouridis et al. [24], indicating that fertilizer

application did not affect the splitting percentage of pistachio. In addition, according to Norozi et al. [2], potassium significantly increases the splitting percentage of pistachio, possibly due to the vital role of this element in most biochemical and physiological processes.

In this study, different concentrations of potassium and zinc sulfate positively affected the amount of pistachio kernel fat (Figure 7). Researchers reported that the fat percentage was affected by genetic factors; yet, availability of essential elements in vital and sensitive plant activities can affect the rate of photosynthesis and production of plant metabolites and ultimately fat accumulation. Potassium and zinc play a major role in plants' physiological activities and enzyme systems that control the metabolism of photosynthetic substances and their conversion into oil, thereby increasing the yield of fat [6, 25].

The results obtained from this experiment on the increase in carbohydrates after using potassium and zinc (Figure 8) are in line with those of the study conducted by Nowjavan et al. [26] on grapes. The reason for the increased sugars after using potassium and zinc is that increasing the concentration of potassium and zinc increases the photosynthesis rate. Moreover, potassium can increase carbohydrates in fruits by increasing the phloem and sugar load. Zinc is involved in auxin synthesis and starch formation, thus increasing carbohydrates in the fruit (Nowjavan et al., 2016).

In line with this research (Figures 9 and 10), previous studies have also shown that foliar application of potassium and zinc usually increases potassium and zinc concentrations in the kernel. For example, foliar application of hazelnut with zinc significantly increases the element concentration in this fruit [27]. Similarly, zinc foliar application improves the element concentration in the fruits of different trees [25]. Enriching plants with nutrients can increase the concentration of elements in the edible parts of fruits; thus, humans can meet a significant portion of their needs by consuming these fruits.

5. Conclusion

Foliar application of potassium and zinc can significantly affect potassium and zinc concentration, fresh weight, dry weight, splitting percentage, fruit appearance, kernel appearance, kernel taste, fat percentage, and carbohydrates percentage of *Kaleh Ghouchi* pistachio. This can be considered a practical nutrition program for pistachio orchards. It can be concluded that in calcareous soils, foliar application of fertilizers containing potassium and zinc (1 or 2% potassium sulfate and 1% zinc sulfate) is essential for obtaining fruits with a higher quantity and quality in pistachio orchards.

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Conflict of interest

The author declare that they have no conflict of interest.

References

1- FAOSTAT 2020. http://www.faostat.fao.org

2- Norozi M, ValizadehKaji B, Karimi R, Nikoogoftar Sedghi M. Effects of foliar application of potassium and zinc on pistachio (Pistacia vera L.) fruit yield. International Journal of Horticultural Science and Technology. **2019**;6:*113–123*.

3- Tavallali V, Rahemi, M. Effect of rootstock on nutrient acquisition by leaf, kernel and quality of pistachio (*Pistacia vera* L.). American-Eurasian Journal of Sustainable Agriculture. **2007**;2(3):*240–246*.

4- Fageria N.K. The use of nutrients in crop plants. Boca Raton, FL. CRC Press. USA, 2009; pp. 430.

5- Keller M. The science of grapevines: anatomy and physiology. Academic Press, Burlington, **2010**; pp 400.

6- Marschner H. Mineral Nutrition of Higher Plants. Academic Press Limited Harcourt Brace and Company, Publishers, London, **2012**; pp *347–364*.

7- Girma K, Martin KL, Freeman KW, Mosali J, Teal RK, Raun WR, Moges SM, Arnall DB. Determination of optimum rate and growth for foliar applied phosphorus in corn. Communications in Soil Science and Plant Analysis. **2007**;38:*1137–1154*.

8- Fernández V, Sotiropoulos T, Brown PH. Foliar fertilization. In: Scientific Principles and Field Practices. International Fertilizer Industry Association, Paris. **2013**.

9- Obreza TA, Zekri M, Hanlon EA, Morgan K, Schumann A, Rouse R. Soiland Leaf Tissue Testing for Commercial Citrus Production. University of Florida Extension Service SL, **2010**; pp 253.

10- Norozi M, ValizadehKaji B, Karimi R, Solgi M. Potassium and zinc-induced frost tolerance in pistachio flowers is associated with physiological and biochemical changes. Trees. **2020**; 34:*1021–1032*.

11- Hosseinifard SJ, Basirat M, Sedaghati N, Akhyaee A. Integrated management of soil fertility and plant nutrition in pistachio trees. Soil and water research institute. (in Persian), **2016**.

12- Fernández V, Sotiropoulos T, Brown P.H. Foliar fertilization. In: Scientific Principles and Field Practices. International Fertilizer Industry Association, Paris. **2013**.

13- Keshavarz K, Vahdati K, Samar M, Azadegan B, Brown PH. Foliar application of zinc and boron improves walnut vegetative and reproductive growth. HortTechnology. **2011**;21(2):*181–186*.

14- Karimi R. Potassium-induced freezing tolerance is associated with endogenous abscisic acid, polyamines and soluble sugars changes in grapevine. Scientia Horticulturae. **2017**;215:*184–194*.

15- Erturk U, Mert C, Soylu A. Chemical composition of fruits of some important chestnut cultivars. Brazilian Archives of Biology and Technology. **2006**;49:*183-188*.

16- Panahi B, Khezri M. Effect of harvesting time on nut quality of pistachio (*Pistacia vera* L.) cultivars. Scientia horticulturae. **2011**;129(4):*730-734*.

17- Restrepo-Diaz H, Benlloch M, Fernandez-Escobar R. Plant water stress and K^+ starvation reduce absorption of foliar applied K^+ by olive leaves. Scientia Horticulturae. **2008**;116:*409–413*.

18- Ramezani S, Shekafandeh A. Influence of Zn and K sprays on fruit and pulp growth in olive (*Olea europaea* L. cv. 'Amygdalifolia'). Iran Agricultural Research. **2011**;30:*1-10*.

19- Soliemanzadeh A, Mozafari V, Kamal, M. Treatment of pistachio trees with zinc and copper in time of swollen bud in two consecutive years. Communications in Soil Science and Plant Analysis. **2014**;45: *1025–1036*.

20- Davarpanah S, Tehranifar A, Davarynejad G, Abadía J, Khorasani R. Effects of foliar applications of zinc and boron nano-fertilizers on pomegranate (*Punica granatum* cv. Ardestani) fruit yield and quality. Scientia Horticulturae. **2016**;210:*57–64*.

21- Usenik V, Stampar F. Effect of foliar application of zinc plus boron on sweet cherry fruit set and yield. Acta Horticulture. **2002**;594:*245–249*.

22- Ojeda-Barrios DL, Perea-Portillo E, Hernández-Rodríguez OA, Martínez-Téllez J, Abadía J,

Lombardini L. Foliar fertilization with zinc in pecan trees. HortScience. **2014**;49:*562-566*.

23- Okay Y, Gunes NT, Koksal AI, Koroglu M, Alagoz R. The effects of pruning and fertilization applications on yield and some fruit characteristics of pistachio nuts (*Pistacia vera* L.). African Journal of Agricultural Research**. 2010**;5(24):*3417–3426*.

24- Tsipouridis C, Thomidis T, Zakinthinos I, Michilidis Z, Michaillides T. Treatment of pistachio with boric acid, Zn sulfate, and Zn chelate. Agronomy for Sustainable Development. **2005**;25:*377–379*.

25- Soliemanzadeh A, Mozafari V, Kamali M. Treatment of pistachio trees with zinc and copper in time of swollen bud in two consecutive years. Communications in Soil Science and Plant Analysis. **2014**;45: *1025–1036*.

26- Nojavan S, Naseri L, Hassanpour H. Effect of Potassium Sulfate and Zinc Sulfate Foliar Spray on some Physical and Chemical Traits of Grape (*Vitis vinifera* cv. Bidaneh Ghermez). Plant production Technology. **2016**;8(2):*195-213*.

27- Meriño-Gergichevich C, Luengo-Escobar A, Alarcón D, Reyes-Díaz M, Ondrasek G, Morina F, Ogass K. Combined Spraying of Boron and Zinc During Fruit Set and Premature Stage Improves Yield and Fruit Quality of European Hazelnut cv. Tonda di Giffoni. Frontiers in plant science. **2021**; 12:*661542*.