



Effect of volk oil and potassium nitrate on budbreak, yield and some quantitative and qualitative characteristics of pistachio (*Pistacia vera* L.) nuts

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ABSTRACT

Purpose: The aim of this study was to improve yield, and characteristics of pistachio nuts of three cultivars by foliar application of volk oil and potassium nitrate. **Research method:** The study was carried out during the bud swelling stage using a factorial design, following a randomized complete block design with four replications. The experimental factors consisted of three cultivars, namely 'Fandoghi', 'Hasan-Abbasi', and 'Haj-Abdollahi', and three treatments: volk oil (1% and 2%), potassium nitrate (KNO₃) (0.3% and 0.5%), and a mixture of volk oil and KNO₃ (1% volk oil + 0.3% KNO₃, and 1% volk oil + 0.5% KNO₃). A control treatment was also included in the study. **Findings:** The results of this study showed that the highest percentage of open shell nuts (52.17%) was observed in 'Hasan-Abbasi' cultivar, and the highest fresh weight of 100 nuts in 'Haj-Abdollahi' (202.2 g). The lowest ounce (29.07), the highest dry weight of 100 nuts and 10 kernels weight were obtained 76.26 and 26.56 g in 'Fandoghi' cultivar, respectively. The use of 2% volk oil treatment was effective in budbreaking, as well as increasing the percentage of open shell nuts and reducing the percentage of balt nuts. **Research limitations:** There was no limitation. **Originality/Value:** 0.5 % KNO₃ increased the fresh and dry weight of 100 nuts and decreased ounce of pistachio in all cultivars. Therefore, the use of volk oil and KNO₃ treatments can be effective in pistachio orchards, and increase the quantity and quality of the yield.

INTRODUCTION

Pistachio (*Pistacia vera* L.) is a dioecious tree belonging to the Anacardiaceae family (Al-Saghir, 2010). It is one of the most important horticultural products and is compatible with the salty regions and arid and semi-arid climatic conditions of Iran, which is one of the richest sources of pistachios in the world (Akbari, 2015; Azarmi-Atajan & Sayyari-Zohan, 2022). The US, Turkey, and Iran produce 97% of the world's pistachio (I.N. & D. Nuts & Dried Fruits Statistical Yearbook, 2021). In recent years, the global temperature has increased abnormally, which is the result of the greenhouse phenomenon and global warming, and has affected human activities, especially the agricultural sector. Recent reports from agricultural meteorological authorities and horticulturists have indicated the effectiveness of these changes following the damage of providing chilling requirements and shifting the date of the phenological stages. Horticulture is one of the most important sectors in agriculture, and global climate changes with the average change and variance of meteorological data, especially its warming, increase the possibility of serious events, which can have major consequences in the annual cycle of orchards. An increase in temperature in the future affected by climate change may disrupt the process of meeting the chilling requirements of the winter season and affect the production of orchard products (Bhatti et al., 2006;).

Pistachios require dry summers and cold winters, and if the winter is warm, the budbreak is delayed. Pistachio tolerates heat to +40 and cold to -18. The chilling requirement of pistachio cultivars is between 600 hours in 'Kaleh- Ghochi' and 1200 hours in 'Ghafouri' cultivar (Akbari et al., 2015; Beriner et al., 1985). Rahemi and Pakkish (2009) investigated the chilling requirement of pistachio in 'Kaleh- Ghochi', 'Ahmad-Aghaei', 'Owhadi' and 'Akbari' cultivars and found that 'Kaleh- Ghochi' with a chilling requirement of 750-800 hours has the lowest cold requirement and 'Akbari' had the highest chilling requirement with 1200 hours in both years.

Many chemicals have remedial effects on dormancy, but few have been found to be suitable for use in field conditions. Chemical substances that have been studied in different countries include mineral oils (volk oil), potassium nitrate (Khayyat et al., 2010), thiourea, and cyanamides, which are used as nutritional supplements and agents for dormancy breaking (Lamont et al., 1987). Horticultural mineral oils are widely used to control the blossoming of buds in apples, pears, peaches, and apricot trees. In addition, the use of volk oil in winter accelerates flowering, enhances the uniformity of flowering, and increases the quality and quantity of pistachios (Beede & Padillia, 1998).

Some studies have also been conducted on the effects of these materials on pistachio chilling requirements. In a study, it was shown that the use of volk oil, soybean oil, and fatty acids makes the trees go to the flowering stage faster in 2-4 days (Nazouri, 2007). Rahemi and Asghari (2004) studied the effects of volk oil, hydrogen cyanamide, and potassium nitrate on the cultivar 'Ahmad-Aghaei' and found that the use of these substances increased the yield, open shell nuts, and decreased the percentage of blank nuts. The results of a study investigating the effect of foliar spraying with volk oil showed that this treatment increased the fresh weight of 'Qazvini' and 'Owhadi' cultivars, and other characteristics such as blanks, as well as the dry weight of the whole fruit (Kashanizadeh, 2006).

Ghrab et al. (2014) studied the use of cyanamide hydrogen and its effect on breaking bud dormancy, flowering, and performance of pistachio trees in hot regions. The results showed that 4% hydrogen cyanamide broke the natural dormancy and caused the simultaneous flowering of male and female trees, which increased the pollination of trees. In addition, the results showed that the growth of stem and leaf surfaces and starch were affected by the use of

this substance. The application of cyanamide 45 days before budbreak improved crop production and prevented anomalies in the lack of chilling requirement.

Due to the global warming and the lack of chilling requirements of pistachio trees, a study was conducted with the aim of investigating the chilling requirements and the effect of Volk oil on the vegetative and reproductive characteristics of pistachio trees of ‘Owhadi’ and ‘Akbari’ cultivars. The results showed that this treatment was very effective in improving the measured characteristics (Mahmoudi et al., 2022).

The climate of the Yazd Province is hot and dry. Pistachio trees grown in this province often do not meet chilling requirements. Therefore, the purpose of this research is to investigate the effect of foliar spraying with volk oil and potassium nitrate on bud break, yield and characteristics of pistachio nuts of the cultivars Fandoghi’, ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’.

MATERIALS AND METHODS

This research was conducted in a 15-year-old pistachio orchard in Ardakan County (32.20° N, 53.48° E), Yazd Province, Iran, during 2015. The three selected cultivars were: ‘Fandoghi’, ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’. The distance between the trees was 4 × 5 m, and trees were irrigated using flood irrigation. The soil characteristics are shown in Table 1. The annual fertilizer applied was 450 kg ammonium sulfate, 6 kg iron, and 70 kg calcium per hectare. The experiment was conducted concurrently with the bud swelling stage, which typically occurs in early March. It followed a factorial design within a randomized complete block, comprising four replications. Additionally, three chemical treatments were applied, including volk oil (1% and 2%), potassium nitrate (KNO₃) (0.3% and 0.5%), as well as a combination of volk oil and KNO₃ at concentrations of 1% volk oil + 0.3% KNO₃ and 1% volk oil + 0.5% KNO₃. A control treatment (water) was also included in the experimental design.

The desired factors were evaluated after treatment application. The date of beginning of flowering and leaf formation were measured. Fruit harvesting was performed in summer from four uniform branches in four directions of the tree that were marked, and then all measurements, such as percentage of blank, and open shell nuts, fresh and dry weight of 100 nuts, weight of 10 kernels, ounce, cluster weight, nuts per clusters, and number of open shell and blank nuts in the cluster, were measured. To determine the ounce, the number of pistachio nuts in 142 g was divided by five, and the resulting number shows the ounce of the pistachio. In addition, the number of pistachios in 28.4 grams can be used as the basis for an ounce of pistachios (Mirabzadeh Ardakani et al., 2021).

Data analysis

Data were analyzed using the procedure for analysis of variance (ANOVA) of the SAS (ver. 9.1), and the mean comparison of data was performed based on Duncan's test (5%).

Table 1. Physicochemical characteristics of the experimental soil during the experiment season.

Parameters	Clay (%)	Silt (%)	Sand (%)	Soil texture	pH	EC (ms/cm)	Organic Carbon (OC) %	CaSO ₄ (%)	N (%)	P (ppm)	K (ppm)	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)
Amount	9	36	55	Sandy loam	7.7	8.1	0.456	22.48	0.039	7.2	589.4	45.5	21.4	29.6	0.58	1.06	3.4	2.4

RESULTS AND DISCUSSION

Vegetative and reproductive budbreak time

The results showed that ‘Haj-Abdollahi’ cultivar had flowering and leafing later than other cultivars. Among the treatments, the 2% volk oil treatment accelerated flowering and leafing, and the control treatment had the longest flowering and leafing (Table 2). In relation to cluster formation, foliar spraying of trees with chemical treatments caused the uniformity in fruit formation in Hasan-Abassi, ‘Haj-Abdollahi’, and ‘Fandoghi’ cultivars compared with the control treatment. In addition, foliar spraying caused the budbreak of more reproductive buds in the treated trees than in the control treatment (without treatments).

Insufficient annual chilling of fruit trees, especially pistachios, is a major problem observed in many regions with warm winters (Eskandari Torbaghan, 2023). In winter, the plant is in the dormancy stage, which does not grow and develop even if it is placed in a suitable environment. The dormancy period was activated by a decrease in temperature and daylight. However, getting out of it requires chilling, so without this stage, the plant's annual cycle is not completed and the plant will not be able to grow naturally (Talaie et al., 2006).

The results of this research showed that the use of mineral oils such as 1% volk oil and its combination with 0.3 and 0.5 % potassium nitrate accelerated uniform flowering (Table 2), which was similar to the results of Beede and Ferguson (2001), who stated that volk oil is effective in dormancy breaking. The effect of volk oil in breaking the dormancy is due to the reaction of the plant to a moderate stress, in which case the plant increases its metabolism for breathing, so that it can break down the oil, and this increase in activity causes the early growth of buds. In this study, the best treatment for early flowering was 2% volk oil treatment, which increased the risk of spring frost. Nazouri (2007) showed that the use of volk oil, soybean oil, and fatty acids makes the trees go to the flowering stage faster by 2-4 days. In addition, the use of oils had a positive effect on the germination of pollen grains in male pistachio trees. The results of this study showed that potassium nitrate alone did not play a role in flowering and early leafing and caused a delay in flowering and fruit formation, but caused the uniformity of fruit formation, and using volk oil with potassium nitrate in cultivars caused coordination in cluster formation and uniform cluster formation. The results also showed that foliar spraying caused the reproductive buds of the trees to open compared with the control treatment. Trees that were not treated had fewer reproductive buds, which are consistent with the results of previous studies (Asghari, 2002, Javanshah & Esmailizadeh, 2004).

Table 2. Interaction effects of treatments and cultivars on the beginning time of flowering and leafing.

Cultivars	Fandoghi		Hasan-Abbasi		Haj-Abdollahi	
Treatments	Beginning of flowering (day)	Beginning of leafing (day)	Beginning of flowering (day)	Beginning of leafing (day)	Beginning of flowering (day)	Beginning of leafing (day)
Control	18b	21b	18b	20c	19a	22a
Volk oil (1%)	13g	16f	14f	16f	15e	18d
Volk oil (2%)	12h	15g	12h	14h	14f	17e
KNO ₃ (0.3%)	17c	20c	16d	18d	17c	20c
KNO ₃ (0.5%)	18b	21b	18b	20c	17c	20c
Volk oil (1%)	14f	17e	14f	16f	15e	18d
+ KNO ₃ (0.3%)						
Volk oil (1%)	14f	17e	14f	16f	15e	18d
+ KNO ₃ (0.5%)						

Means followed by different letters in each column indicate significant differences at $p < 0.05$ (Duncan test).

Table 3. Interaction effects of treatments and cultivars on open shell and blank nuts.

Cultivars	Fandoghi		Hasan-Abbasi		Haj-Abdollahi	
	Open shell (%)	Blank (%)	Open shell (%)	Blank (%)	Open shell (%)	Blank (%)
Control	41 ij	28 ab	39.25i	29.75a	38.75j	29.5a
Volk oil (1%)	50.75 cde	23 defg	55.5b	25.25bcd	45gh	26.5bc
Volk oil (2%)	62.5 a	17 j	65a	21.25fgh	51.5cde	21fgh
KNO ₃ (0.3%)	43.5 hi	23.5def	49.25def	22efgh	46.5fgh	23.5def
KNO ₃ (0.5%)	48 efg	22 efgh	53bcd	20ghi	53.25bc	25cde
Volk oil (1%)	52.5bcd	22.5 defg	51.75bcd	21fgh	52bcd	17.75ij
+ KNO ₃ (0.3%)						
Volk oil (1%)	52.25bcd	22.5 defg	51.5cde	20.5fghi	54.5bc	19.25hij
+ KNO ₃ (0.5%)						

Means followed by different letters in each column indicate significant difference at $p < 0.05$ (Duncan test).

Nuts characteristics

The results of this research showed that the highest open shell nuts was obtained with 2% volk oil treatment in ‘Hasan-Abbasi’ cultivar (65%) and ‘Fandoghi’ cultivar (62.5%), which had a significant difference with other treatments. Also, the lowest open shell nuts was obtained with the control treatment of ‘Fandoghi’, ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’ cultivars, 41%, 39.25%, and 38.75%, respectively, which had significant differences in other treatments as well (Table 3).

The highest percentages of blank nuts in the control treatments were 28% for ‘Fandoghi’, 29.5% for ‘Haj-Abdollahi’ and 29.75% for ‘Hasan-Abbasi’. Also, the lowest percentage of blank nuts was obtained in the treatment of 2% volk oil for ‘Fandoghi’ (17%), and with the combined treatments of 1% volk oil with 0.3 and 0.5% potassium nitrate for ‘Haj-Abdollahi’ cultivar (19.25 and 17.75%, respectively) (Table 3).

The maximum fresh weight of 100 nuts was obtained in the treatment of 0.5 % potassium nitrate for ‘Haj-Abdollahi’ cultivar (260.32 g) and 0.3 and 0.5 % potassium nitrate for ‘Fandoghi’ cultivar, (223.02 g and 230.32 g, respectively) which was significantly different from that of the other treatments. The lowest fresh weight of 100 nuts was obtained in the control and volk oil and potassium nitrate combined treatments (Table 4).

Based on the results of this research, the maximum dry weight of 100 nuts was obtained in the potassium nitrate treatment in the cultivars of ‘Fandoghi’ and ‘Haj-Abdollahi’, (88.15 and 95.85 g, respectively). Also, the lowest dry weight of 100 nuts was observed in the control treatments of ‘Haj-Abdollahi’ and ‘Hasan-Abbasi’ cultivars (61.5 and 54.5 g, respectively) (Table 4).

Table 4. Interaction effects of treatments and cultivars on fresh and dry weight of 100 nuts.

Cultivars	Fandoghi		Hasan-Abbasi		Haj-Abdollahi	
	Fresh weight of 100 nuts (%)	Dry weight of 100 nuts (%)	Fresh weight of 100 nuts (%)	Dry weight of 100 nuts (%)	Fresh weight of 100 nuts (%)	Dry weight of 100 nuts (%)
Control	172.62hi	72.55cd	163.85i	61.5e	164.8i	54.5f
Volk oil (1%)	187.75defgh	71.85d	178.52efghi	72.92cd	206.9c	74.62cd
Volk oil (2%)	191.075def	78.97c	172.57hi	72.75cd	208.82c	74.62cd
KNO ₃ (0.3%)	223.025b	75.4cd	184.45efgh	73.55cd	183.05efgh	74.15cd
KNO ₃ (0.5%)	230.32b	95.85a	193.75cde	75.27cd	260.325a	88.15b
Volk oil (1%)	178.05efghi	71.35d	176.17fghi	69.87d	201.77cd	75.2cd
+ KNO ₃ (0.3%)						
Volk oil (1%)	176.67fghi	69.25d	174.27ghi	69.47d	189.75defg	72.32cd
+ KNO ₃ (0.5%)						

Means followed by different letters in each column indicate significant difference at $p < 0.05$ (Duncan test).

Table 5. Interaction effects of treatments and cultivars on ounce and weight of 10 kernels.

Cultivars	Fandoghi		Hasan-Abbasi		Haj-Abdollahi	
	Ounce	Weight of 10 kernels (g)	Ounce	Weight of 10 kernels (g)	Ounce	Weight of 10 kernels (g)
Control	32 cdef	4.8fgh	33bcd	4.15i	37a	3.45j
Volk oil (1%)	28.5 h	5.32bcd	33.5bc	4.95defg	31.25def	4.82efgh
Volk oil (2%)	26.5 i	5.5bc	31.5def	4.52ghi	28.5h	4.5hi
KNO ₃ (0.3%)	29 gh	4.95defg	32.5bcde	4.82efgh	30.5fg	4.5hi
KNO ₃ (0.5%)	25 ij	6.125a	29gh	5.25bcde	24j	5.5b
Volk oil (1%)	31.5 def	5.1cdef	32.5bcde	5.05def	31.75cdef	4.35t
+ KNO ₃ (0.3%)						
Volk oil (1%)	31ef	5.05def	31ef	4.9defgh	34.25b	4.27i
+ KNO ₃ (0.5%)						

Means followed by different letters in each column indicate significant difference at $p < 0.05$ (Duncan test).

The highest ounces were obtained in the control treatment of ‘Haj-Abdollahi’ (37) and the lowest ounces were obtained in 0.5 % potassium nitrate in ‘Haj-Abdollahi’ and Hasan-Abbasi cultivars (25, 24), respectively (Table 5).

In the 0.5 % potassium nitrate treatment, the highest weight of 10 kernels (6.12 g) was observed in ‘Fandoghi’ cultivar, and the lowest weight was obtained in the control treatment of ‘Haj-Abdollahi’ cultivar (3.45 g) (Table 5).

The results showed that ‘Hasan-Abbasi’ had the highest cluster weight (92.03 g), and the cluster weight of ‘Haj-Abdollahi’ and ‘Fandoghi’ were 77.76 and 60.53 g, respectively (Table 6).

‘Hasan-Abbasi’ cultivar had the highest number of pistachios in a cluster (47.82), and also ‘Fandoghi’ cultivar had the least number of fruits in a cluster (32.53) (Table 6).

The results showed that the ‘Fandoghi’ had the highest split percentage of the cluster (54.96%) and there was no significant difference between ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’ cultivars (Table 6). Among the treatments, the control with 25.66% split percentage had the lowest split percentage, and there was no significant difference between the other treatments (Table 7).

Among the treatments, the 2% volk oil treatment and 1% volk oil treatment with 0.5% potassium nitrate had the lowest blank percentage of cluster (17.66%-17.16%, respectively), and the control treatment had the highest blank percentage of clusters (29.16%) (Table 7).

The use of 2% volk oil had the most positive effect on open-shell nuts, and the control treatments had the lowest percentage of open-shell nuts (Table 3), which is in line with the results of Kashanizadeh (2006) that the effect of foliar spraying of volk oil on commercial cultivars of pistachios was similar. They stated 6% volk oil increased the weight of nuts in cv. ‘Qazvini’ and other characteristics such as blank nuts and the dry weight of the whole fruit were also affected.

Table 6. Effect of cultivars type on pistachio cluster characteristics.

Cluster characteristics	Fandoghi	Hasan-Abbasi	Haj-Abdollahi
Cluster weight (g)	60.53c	92.03a	77.36b
Nuts/cluster	32.53c	47.82a	39.28b
Split percentage of cluster (%)	54.96a	51.21b	55.14b
Blank percentage of cluster (%)	21.32a	21.64a	21.42a

Means followed by different letters in each column indicate significant difference at $p < 0.05$ (Duncan test).

Table 7. Effect of treatments on pistachio cluster characteristics.

Treatments	Open shell (%)	Blank (%)
Control	25.66e	29.16a
Volk oil (1%)	43.08d	25.83b
Volk oil (2%)	63.83ab	17.16e
KNO ₃ (0.3%)	54.5c	22.5c
KNO ₃ (0.5%)	62.58ab	20.41d
Volk oil (1%) + KNO ₃ (0.3%)	60.16b	176.6e
Volk oil (1%) + KNO ₃ (0.5%)	66.58a	17.5e

Means followed by different letters in each column indicate significant difference at $p < 0.05$ (Duncan test).

Rahemi and Asghari (2004) also reported similar results when investigating the effect of volk oil, hydrogen cyanamide, and potassium nitrate on the cultivar ‘Ahmad-Aghaei.’ They used cyanamide at three levels (3%, 1.5%, 0), volk oil (7%, 3.5%, 0), potassium nitrate (3%, 1.5%, 0), and a combination of cyanamide and volk oil. Volk oil and potassium nitrate were used 4-8 weeks before bud break in two phases (January 5 and February 4). The use of these materials increased the yield of open shell nuts and decreased the percentage of blank nuts.

In a study, 4% and 6% volk oil treatments had the greatest effect on increasing the percentage of open shelled nuts and reducing the percentage of blank nuts (Javanshah et al., 2018). The results of Mahmoudi Meimand et al. (2022) also confirm the results of this research, and the use of volk oil increased the fresh and dry weight of nuts, decreased their blank nuts, and improved vegetative characteristics.

In one research, using potassium improved nut quality (fruit weight and percentage of split nuts) in pistachio orchards (Mimoun et al., 2004). Also potassium fertilization improved nut quality of mature pistachio trees (Zeng et al., 2001).

CONCLUSION

The results of the treatments carried out on the cultivars of ‘Fandoghi’, ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’ showed that 2% volk oil caused earlier flowering of trees in all cultivars, and also increased the percentage of open shell nuts in ‘Fandoghi’ and ‘Hasan-Abbasi’ cultivars, decreased the percentage of blank nuts and increased cluster weight in ‘Fandoghi’ cultivar. The combination treatments of 1% volk oil with 0.3 and 0.5% potassium nitrate increased the ounce in all cultivars, decreased the percentage of blank nuts in ‘Hasan-Abbasi’ and ‘Haj-Abdollahi’ cultivars, and increased the percentage of open shell nuts in ‘Haj-Abdollahi’ cultivar. Potassium nitrate (0.5 %) increased the fresh and dry weight of 100 nuts and the weight of 10 kernels and decreased the ounce in all cultivars. In all cultivars, the control treatment had the lowest fresh and dry weights of 100 nuts, percentage of open-shell nuts, and the highest percentage of blank nuts. Therefore, considering global warming and the lack of chilling requirements for pistachio orchards, the use of these chemical compounds is effective in increasing the quantity and quality of the product.

Conflict of interest

The authors declare that they have no conflict of interests.

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