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Evaluation of effect of biorational insecticides on horticultural indices of the pistachio trees infested with the pistachio psylla, *Agonoscena pistaciae*

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ABSTRACT
Field experiments were conducted during 2016–2017 on pistachio trees (*Pistacia vera* L., Anacardiaceae) in Kashan pistachio orchards to assess the effects of some insecticides on horticultural characteristics of the pistachio trees infested with the pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer. This research was conducted in the ten-year-old pistachio orchards (Akbari variety) of Kashan, Iran. The treatments were included palizin®, pistagaurd ®, kaolin (Surround®) 5%, kaolin 10%, movento® (registered chemical insecticide to compare) and control. Spraying was carried out three times a year, with one-month interval (4th of July, August and September). The results showed that in 2016, the effect of treatment in terms of twig length was significant. In terms of number of healthy buds was not significant and in terms of number of lost buds was highly significant. The number of unhealthy flower buds was positively affected by application of kaolin, pistaguard and palizin in 2016. However, no significant effect was recorded in 2017 for all tested pesticides. Kaolin 5 or 10%, was the only pesticide with positive effect on yield traits. These results provide support the potential use of this technology as an alternative pest management tool against pistachio psylla.

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Agonoscena pistaciae; insecticide; Kaolin; horticultural characteristics

Introduction

The pistachio, *Pistacia vera* L. (Anacardiaceae), is one of the most important horticultural products in Iran, Armenia, Iraq, Turkmenistan, and Turkey and is known as the green-gold tree (Ozden-Tokatli et al. 2005; Alizadeh et al. 2007). The common pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hem.: Aphalaridae), is one of the most significant pests of pistachio trees due to its widespread distribution in all pistachio-producing regions of Iran. Both nymphs and adults suck

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the sap of leaves and produce large amounts of honeydew. Direct feeding reduces plant vigor and encourages defoliation, stunting, poor yield, and bud drop (Samih et al. 2005). Nowadays various pesticides are used to control the common pistachio psylla. In warm weather, psyllas are difficult to control with insecticides because they are active for a large portion of the year, during which morphotypical, physiological, and behavioral changes occur (Dreistadt and Hagen 1994; Horton 1999). However, systemic organophosphates, botanical or insect growth regulator (IGR) are widely used to control pistachio psylla in commercial pistachio orchards and will likely continue to be a primary component of pistachio management programs (Lababidi 2002; Roshani 2018). However, continued use of chemicals has made *A. pistaciae* resistant to several of the insecticides such as Phosalone, Deltamethrin, Amitraz, Dinotefuran, and Aberon currently in use. Additionally, some of these pesticides adversely affect biological control agents used to control the psyllid, resulting in subsequent pest resurgence (Mehrnejad 2003).

In contrast to the destructive impacts of chemical insecticides, the use of biorational pesticides seems a safe and convenient solution to control the pests (Oguh et al. 2019). Palizin is a water-soluble wetting agent having an herbal origin (sirinol, peppermint, and eucalyptus extracts) and formulated as a 65% water-soluble concentrated liquid (Gholamzadeh-Chitgar and Pourmoradi 2017). Pistagaurd product is a new plant probiotic product with protective and nutritional effects that promote the growth and liveliness of pistachio trees (Karimi et al. 2019). Besides improving the functionality of pistachio trees, it can protect the trees against some biotic (plant pests and diseases) and abiotic stresses. Pistagaurd based on *Bacillus subtilis* as probiotic is used as a compound to promote the health and growth of pistachio and pear trees and is claimed to provide protection against pathogens as well as some insect pests (particularly the pistachio psylla, *A. pistaciae* and pear psylla, *Psylla pyricola*) and abiotic stresses by Biorun Company (Roshani 2018).

Kaolin clay has been commonly used in the green industry for several years as an effective alternative pest management tactic for a variety of insect pests. It's a white, non-porous, non-swelling, nonabrasive fine-grained aluminosilicate mineral that easily disperses in water and is chemically inert over a relatively wide pH range (Harben 1995). Kaolin particle film has proven successful in the management of insect pests and some diseases (Puterka et al. 2000; Thomas 2000). Kaolin particle film consists of 95% kaolin clay that is suspended in water for application. Pests are controlled by visual repellency of the white film protectant and from irritating particles adhering to insect integuments (Glenn et al. 1999). Unruh et al. (2001) demonstrated the effectiveness of kaolin

particle film against codling moth in apple and pear orchards. Apple maggot fly (Puterka et al. 2000) and plum curculio (Puterka et al. 2000; Thomas 2000) were also controlled with kaolin particle film. Disease suppressiveness against flyspeck and sooty blotch was obtained with kaolin particle film (Thomas 2000), due to the hydrophobic film created on the leaf or apple fruit (Glenn et al. 1999).

Kaolin clay is a management option for insect control for tree nurseries and various crops such as cotton, blueberry, and roses (Maier and Williamson 2016). The mechanisms of action of Kaolin clay against insect pests include repellency, tactile or visual cue interference and impairment or disruption of oviposition and feeding activity (Puterka et al. 2000). The abrasive mineral particles promote insect desiccation due to cuticle disruption and digestive system obstruction and also change the host plants' colour, affecting the recognition and attractiveness of the plant (Showler 2002). In addition to the aforementioned benefits of Kaolin clay regarding insect pests, it is also proclaimed to have characteristics or properties that are beneficial to the plants. Thomas et al. (2004) reported that Kaolin clay can reduce the canopy temperature of apple trees, which in turn increased productivity. Because kaolin clay is reported to produce desirable attributes in fruit, it is also equally important to understand any potential negative characteristics or effects. This is especially important when working with high-value crops including fruit; potential negative attributes or side effects could have an adverse economic impact due to poor fruit quality.

Results of previous studies (Roshani 2018; Roshani et al. 2019) showed that the effect of different treatments of biorational insecticides including palizin, pistaguard, kaolin 5 and 10% and the interaction of treatment and time on nymphs of the common pistachio psylla, *A. pistaciae* was significant. Mean comparison showed that the highest pest mortality by kaolin 10% was observed three days after spraying. Also, palizin and kaolin treatments had the highest effect.

Also, regarding the effect of kaolin on physiological and morphological characteristics of Akbari, Oohadi and White pistachio cultivars in a study by Nourzadeh Namaghi (2013), it was found that the effect of kaolin concentration on all physiological characteristics except vegetation index was significant. Finally, it was concluded that concentration of 5% kaolin in a single spray is the best treatment to achieve optimum performance of pistachio trees in tropical regions in order to reduce the use of chemical and organic pesticides (Nourzadeh Namaghi 2013). In a recent study in Ravar region of Kerman province, regarding the effect of Kaolin and Palizin foliar application at different times on sunburn and pistachio psylla population and some physiological characteristics of Kalleh-Ghochi

cultivar by Sifouri (2014), the results showed that foliar application with Kaolin and Palizin in July, August and September had the highest impact on sunburn of fruit and leaves, leaf chlorophyll content, annual shoot length and number of vegetative and reproductive buds and reduced population of pistachio psylla.

Previous studies showed the proper effect of biorational insecticides on pistachio psylla population, so we decided to investigate the effect of these insecticides on quantitative and qualitative yield indices of pistachio trees. The specific objective was to compare the effects of different biorational insecticides and to assess potential adverse effects on characteristics of the pistachio trees.

Materials and methods

Study site

Field trials were conducted during July, August and September of 2016 and 2017 in commercial pistachio in the 10-year-old pistachio orchard (Akbari variety) located on the Ismailabad region of Abu Zaidabad, from the Kavirat section of Aran and Bidgol, Kashan whose geographic coordinates are UTM according to the following: 56°31̀N latitude and 37°52̀E longitude. In this garden, before the start of the research, no insecticide or composition was used during the winter and spring to control pistachio pests. A total of 24 trees were selected based on the experimental design. The experiments were based on the randomized complete block design in six treatments and four replicates. They were conducted during the three months of July, August and September of the years 2016 and 2017. Determination of spraying time was based on population of psylla nymphs (economic injury level: 2 nymphs per leaf) (Hassani et al. 2009; Mehrnejad 2010). A total of three spray application of insecticides were carried out on the 4th of July, August and September of 2016 and it was repeated in the second year on the ninth of July, August, and September of 2017.

Insecticides

The insecticides and formulations used in this research were: The kaolin compound used was processed kaolin (Sepidan®) made by Kima Sabzavar Company of Iran; Movento® 240 SC (Spirotetramat 10%) manufactured by Bayer Crop Science, Germany; Palizin® (Coconut Soap 65%) produced by Kima Sabzavar Company of Iran and Pistagaurd® (probiotic compound (Biorun) from Goldsat Agricultural Company of Karaj, Iran. Treatments included: kaolin (Sepidan, WP) at a dose of 5%; kaolin (Sepidan, WP) at a dose of 10%; movento insecticide at a dose of

0.5 L/1000, palizin (Coconut soap) at a dose of 1.5 L/1000, pistaguard (probiotic compound- Biorun) at a dose of 3 L/1000 and control (water).

Horticultural characteristics and crop yield

Measurement of tree indices included the twig length, number of flower buds in the following year, in healthy and diminutive manner, and quantification of green pistachio yield including fresh weight, dry weight, dry open-shell weight, dry closed-shell weight, and dry blankness weight obtained at the end of the crop season was carried out in each of the experimental treatments. Comparison of the effects of the applied product-son the improvement of properties of harvested pistachios was performed.

Data analysis

ANOVA procedures for a randomized complete block design were used to test for experimental factors (block and treatment) using SPSS software. Treatment differences in horticultural indices and yield properties were gauged at a 5% significance level. Mean comparisons were carried out by Tukey's Honest Significant Difference (HSD) test at $\alpha = 0.05$ (Statgraphics Plus for Windows 4 1999).

Results

Tree horticultural indices

The results of the combined analysis of tree horticultural indices including the twig length, number of healthy and unhealthy flower buds in the following year showed there are not significant differences between two years ($p > 0.05$), except for the twig length and number of unhealthy flower buds in 2016. The results of the analysis of variance showed that the effect of treatments on the twig length and number of unhealthy flower buds was significant for the year 2016 ($F = 2.96$, $p < 0.05$, $df = 5$ and $F = 18.59$, $p < 0.01$, $df = 5$). Also for the year 2016, the results of the analysis of variance showed that the effect of replication on the twig length and number of healthy flower buds was significant ($F = 10.67$, $p < 0.01$, $df = 3$ and $F = 5.98$, $p < 0.01$, $df = 3$), but it was not significant on the number of unhealthy flower buds (Table 1).

The results of the mean comparison of different treatments in year 2016 showed that, in terms of the twig length, only kaolin 10% in first group (a) with kaolin 5% and pistagaurd in second group (b) had significant difference. Among them, kaolin 5% treatment had the highest twig length and pistagaurd treatment had the lowest twig length, respectively

Table 1. Results of analysis of variance of different treatments on the horticultural traits of the treated pistachio trees in 2016–17.

		Mean of Squares					
		Twig length		Healthy flower buds		Unhealthy flower buds	
Variance source	df	2016	2017	2016	2017	2016	2017
Treatment	5	2861.86*	260.96 ns	722.20 ns	218.17 ns	1004.84**	374.77 ns
Replicate	3	10331.04**	1180.12 ns	1607.22**	227.22 ns	51.71 ns	74.06 ns
Error	15	968.04	1266.90	268.75	221.56	54.04	262.00
CV (%)		15.62	16.64	23.09	27.23	23.56	40.45

* and ** show significant difference at $\alpha = 0.05$, 0.01, respectively and ns non-significant.

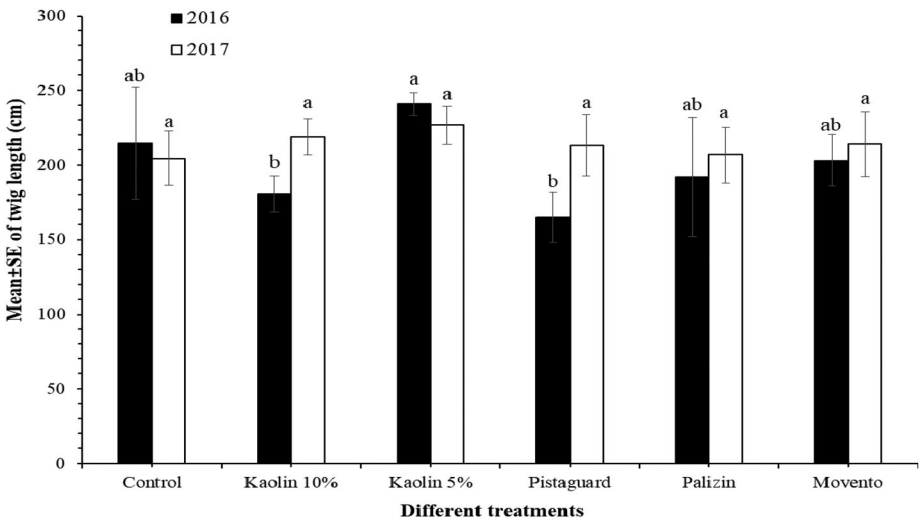

Figure 1. Mean comparison of number of twig length on the treated pistachio trees in 2016–2017 (Tukey's HSD test at $\alpha = 0.05$). The mean of the similar letters is not statistically significant.

(Figure 1). In year 2017, there were no significant differences between the treatments for pistachio twig length.

The results of the mean comparison of different treatments in the year 2016 showed that there was significant difference in terms of the number of healthy flower buds trait in control, kaolin 5%, pistagaurd, and palizin treatments. Control treatment had the lowest number of healthy flower buds (Figure 2). In year 2017, there were no significant differences between the treatments for pistachio healthy flower buds, i.e., none of them had any effect on this trait.

The results of the mean comparison of different treatments in the year 2016 showed that only control treatment had significant difference with others in terms of the number of unhealthy flower buds (Figure 3). The highest number of unhealthy flower buds was seen in control treatment and others were statistically equal. In year 2017, the results showed that there was a significant difference between control, kaolin 10%, kaolin 5%, palizin and movento treatments. But without any significant difference with pistagaurd treatment.

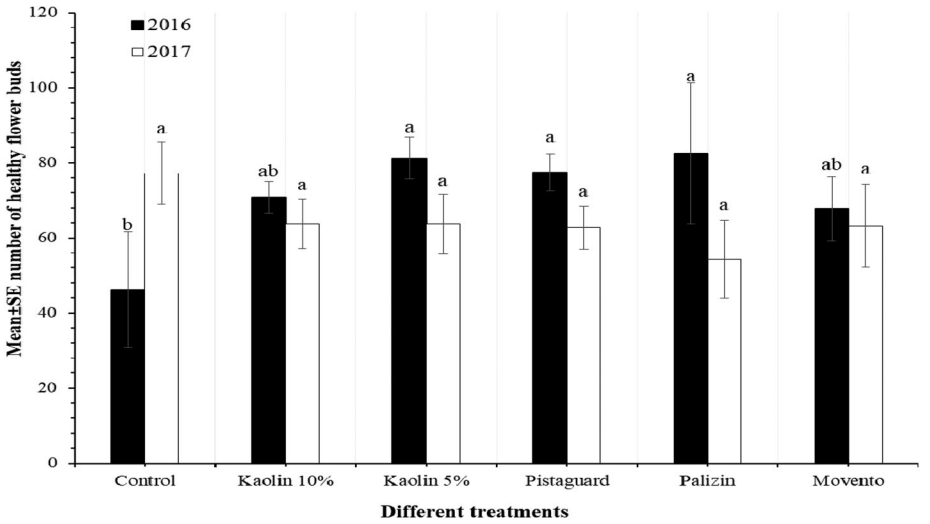

Figure 2. Mean comparison of number of healthy flower buds on the treated pistachio trees in 2016–2017 (Tukey's HSD test at $\alpha = 0.05$). The mean of the similar letters is not statistically significant.

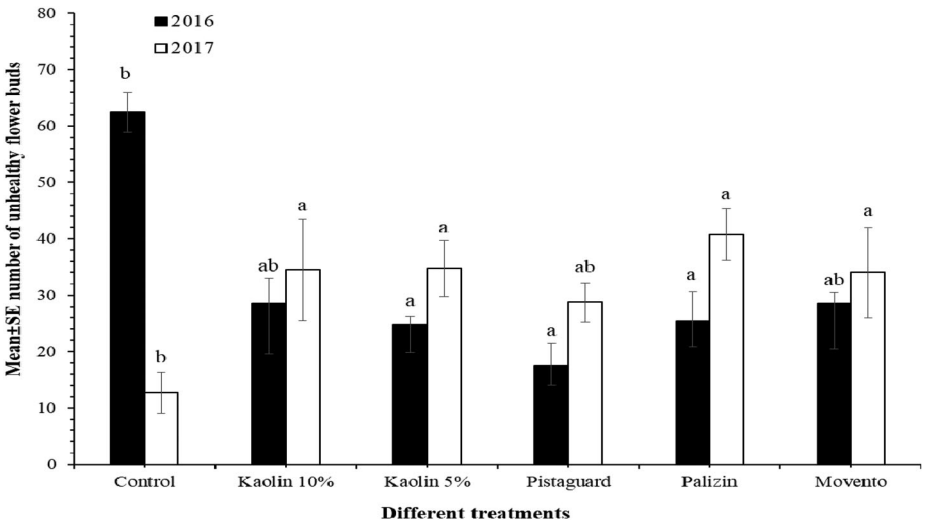

Figure 3. Mean comparison of number of unhealthy flower buds on the treated pistachio trees in 2016–2017 (Tukey's HSD test at $\alpha = 0.05$). The mean of the similar letters is not statistically significant.

Yield properties of pistachio trees

The results of analysis of variance of tree yield properties showed there are not significant differences between blocks and yield traits ($p > 0.05$). Treatment had significant effect on pistachio total fresh weight ($F = 2.90$, $p < 0.05$, $df = 5$). In addition, dry weight, dry open-shell weight, dry

Table 2. Results of analysis of variance of different treatments on the yield traits of the treated pistachio trees in 2017.

		Mean of Squares				
Variance source	df	Fresh weight	Dry weight	Dry open-shell weight	Dry closed-shell weight	Dry blankness weight
Block	3	257500.00	1877.61	1575.49	53.44	137.70
Treatment	5	775000.00*	86622.27**	20186.68**	10410.50**	12968.84**
Error	15	266833.33	918.38	1421.05	422.34	280.42
Total	23	37.6086.96	19674.78	5520.68	2545.57	3020.04
CV (%)		17.22	3.43	8.24	9.03	8.42

* and ** show significant difference at $\alpha = 0.05$, 0.01, respectively and ^{ns} non-significant.

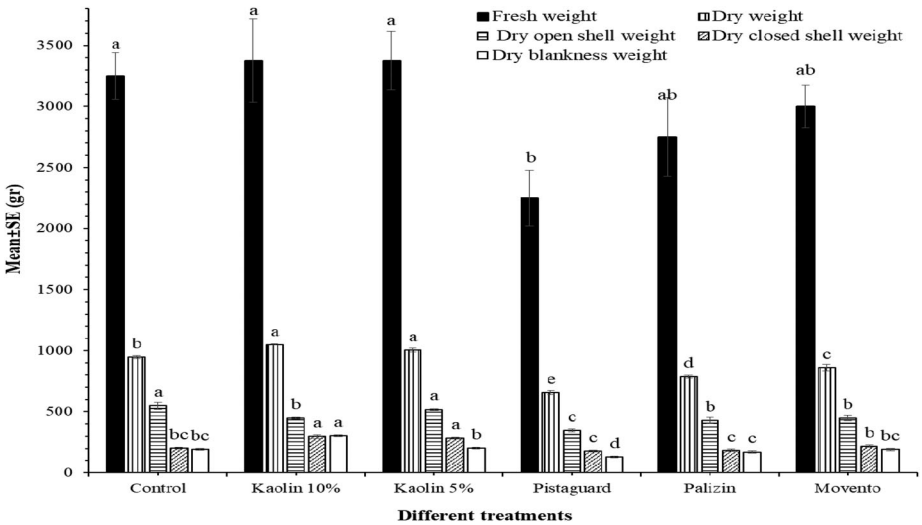

Figure 4. Mean comparison of the fruit yield characteristics including fresh weight, dry weight, dry open-shell weight, dry closed-shell weight and dry blankness weight on the treated pistachio trees in 2017 (Tukey's HSD test at $\alpha = 0.05$). The mean of the similar letters is not statistically significant.

closed-shell weight, and dry blankness weight traits were significant ($F = 94.32$, $p < 0.01$, $df = 5$; $F = 14.20$, $p < 0.01$, $df = 5$; $F = 24.64$, $p < 0.01$, $df = 5$; $F = 46.\ 27$, $p < 0.01$, $df = 5$), respectively (Table 2).

The results of comparison of means between different treatments showed that there was a significant difference in fresh weight of pistachio fruits between pistagaurd treatment and the untreated control, The fresh weight of pistagaurd treatment was lower than the control band to kaolin 10 and 5% treatments (Figure 4).

The mean comparison results showed that in terms of the dry weight of pistachio fruits, the highest dry weight was observed in kaolin 10% and kaolin 5% (group a) but the two treatments had no significant difference with the other treatments. The lowest dry weight of pistachio fruits was observed in pistagaurd treatment (Figure 4).

Also the results of mean comparison in regard to dry open-shell weight of pistachio fruits showed that control with kaolin 5% treatment were placed in group a and had the highest weight without significant difference between them, but had significant difference with other treatments. Kaolin 10%, palizin and movento's treatments without significant difference were also in group b, but were significantly different with pistagaurd. This treatment had the lowest dry open-shell weight among other treatments (Figure 4).

In addition, the results of mean comparison in terms of dry closed-shell weight of pistachio fruits showed that Kaolin 10 and 5% treatments were in group a and had the highest weight. Control treatment did not show significant differences with pistagaurd, palizin and movento treatments. Pistagaurd and palizin treatments also had a significant difference with movento (Figure 4).

Finally, the results of mean comparison in terms of dry blankness weight of pistachio fruits showed that kaolin 10% treatment had the highest weight with significant differences with other treatments. The kaolin 5%, control, and movento treatments in the next group and the pistagaurd treatment had the lowest dry blankness weight in comparison with the other treatments (Figure 4).

Discussion

This work revealed that kaolin 5% had no measurable negative effect on important tree pistachio characteristics (including the twig length, number of healthy and unhealthy flower buds) that common pistachio psylla, *A. pistaciae* reduced. This outcome has been described in several other related studies on different fruit pests involving the effects of kaolin clay on fruit production, most studies had reported either no or positive effects of kaolin film on plant productivity and yield. Garcia et al. (2004) showed significant increase in fruit weight, firmness, and fruit size of kaolin clay on apples. Puterka et al. (2000) reported an increase in fruit set and less fruit drop regarding the yield of pears with the use of Kaolin clay. Therefore, the main recommended composition in comparison with other treatments was kaolin 5% with mean shoot growth of 240.88 ± 7.51 and mean damaged flower buds of 24.75 ± 1.44. This result is in line with the findings of Nourzadeh Namaghi (2013) research.

According to the results of this study, the effects of different treatments on the yield properties of pistachio trees, treatments had significant effect on the fresh weight, dry weight, dry open-shell weight, dry closed-shell weight, and dry blankness weight traits. The Pistagaurd treatment had significant difference with all other traits and had the lowest values. Kaolin

10% treatment had the highest value for all measured traits except for dry blankness weight of pistachio fruit. Therefore, considering all the above treatments that had the most positive effect on yield traits was belong to kaolin 10%. Overall, based on the above results, kaolin 5% increased pistachio fresh weight and kaolin 10% increased dry pistachio weight. Also, kaolin 10% had the highest effect on pistachio weight after kaolin 5%. On the other hand, dry closed-shell weight and dry blankness weight traits were also high in these treatments, which were not suitable qualitatively for pistachio yield and gardener. For dry open-shell weight, control treatment (water) had better effect than kaolin 5% and movento and had the highest amount of dry weight of pistachio fruit, which is in contradict with previous results (Zarei Mohammadabad 2012; Vatandoost Jerottoda 2013). In addition, the lowest dry weight, dry open-shell weight, dry closed-shell weight, and dry blankness weight was belong to the pistagaurd treatment, which was different from the results of Zarei Mohammadabad (2012).

Conclusions

Based on the two-year results obtained from this study, kaolin 5% and kaolin 10% had both positive and suitable effects yield properties of pistachio trees. Therefore, they are recommended in order to improve shoot growth, preservation of flower buds of next year and thus increase the yield of pistachio and dry fruits.

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No potential conflict of interest was reported by the author(s).

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