The effect of sulfur, wollastonite, biotite, zeolite, graphite, perlite, and feldspar on oviposition and egg hatching of common pistachio psylla *Agonoscena pistaciae* Burckhardt & Lauterer (Hem.: Psyllidae) in orchard conditions

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Abstract

Background: Common pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer (Hem.*:* Psyllidae), is one of the most important pests of pistachio trees in Iran. Considering the risks of overusing synthetic chemical pesticides, it seems that the use of mineral compounds as insecticides is one of the ways to reduce the residual amount of dangerous toxins.

Materials and Methods: In this study, mineral compounds (sulfur, wollastonite, biotite, zeolite, graphite, perlite and feldspar) were used to investigate the oviposition rate of adult insects as well as egg hatching.

Results: The results showed that the leaves treated with feldspar (0.01 ± 0.00), zeolite (0.07 ± 0.001) and perlite (0.97 ± 0.021) at a concentration of 50,000 mg/l were reported to have the greatest decrease in terms of the oviposition rate of the pest in the first year. The results of oviposition rate in the second year indicated that the leaves treated with zeolite and biotite had a significant decrease and increase respectively, compared to the control group. Studies also showed that zeolite treatment could not make any changes in the process of egg hatching.

Conclusion: Given the favorable effect of feldspar, zeolite and perlite in reducing oviposition rate, foliar application of pistachio trees with these compounds can control the population of pistachio psylla.

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1. Introduction

Common pistachio psylla, *Agonoscena pistaciae* Burckhat & Lauterer, is the most important pest of the first degree group of Iranian pistachios. The outbreak and damage of common pistachio psylla, as a key pest, is one of the most important and biggest concerns of pistachio grower every year. This pest is spread in all pistachio growing areas of the country [1]. Adult insects have very high reproductive power. This pest causes a lot of damage to the crop. The period of pistachio kernel growth and filling, from the early June to the early August, is the most sensitive time for the pistachio plant in relation to the damage of this pest. If the conditions are proper to increase the growth of the pest population in this period of time and it is in a state of eruption, severe damage will be inflicted on the plant and the crop [2].

For this very reason, pistachio growers are highly sensitive to this pest and constantly try to control it by using pesticides; to control the damage of the pest, pistachio trees are sometimes sprayed 8 times a year. This increases the use of pesticides and environmental pollution. Therefore, the spread and outbreak of this pest calls for reviewing chemical control to reduce the use of pesticides. In controlling this pest, low-risk substances with specific concentrations and consumption times can be used [3].

Extensive research is conducted to control pistachio psylla, so that new compounds having lower environmental hazards will be used. One of these cases using mineral pesticides. Ability to control plant pests and diseases, lack of resistance to plant pests and diseases, non-toxicity to mammals, stimulation for plant immunity and prevention of environmental pollution, abundance of rich mineral resources and access to large amounts of mineral compounds are among the positive points of making and producing mineral insecticides. Mineral insecticides are considered as natural substances that are classified into low-risk compounds or substances with a high risk index for humans, depending on the type of elements and their structure. Some insecticides, such as sulfur, have been registered as an organic insecticide [4].

Compounds such as sulfur, wollastonite, biotite, zeolite, graphite, perlite and feldspar have been used in this study and their pesticidal properties have been proven in various studies.

Wollastonite is in the classification of silicates, it also has no magnetic properties and its source is adjacent metamorphism. Nano-wollastonite increases the resistance of wood to caries caused by fungi and insects [5].

Biotite, or black mica, is a triple silicate of iron, magnesium, and potassium. Inhalation of its dust produces pneumoconiosis. Hydrated magnesium talc silicate is rarely pure and has a round shape that has medical, health and agricultural uses [6].

Zeolites are also among the other porous compounds that contain minerals composed of aluminum silicate and are naturally produced in geological processes [7]. Zeolites have been declared as non-toxic to humans by the US Food and Drug Administration and the World Health Organization, and their use in agricultural products to protect the plant from pests is allowed in terms of health and carcinogenic effects [8].

Perlite is a natural silica rock. Expanded (heated) perlite is a light, porous material with a neutral pH that is able to absorb and retain water. Perlite is used as a carrier of toxins in insecticides due to its high adsorption properties.

Perlite particles adhere to the insect's body and gradually absorb the insect's body fluid [9].

The control of common pistachio psylla in recent years has been mainly conducted by using insecticidal chemical compounds, and so far many insecticides have been officially tested on this pest. Due to the emergence of the phenomenon of resistance in this insect, different insecticides have lost their effect one after another [10]. Since pistachio psylla is one of the most important pests of pistachios and the existing compounds have not yet been able to control it, there is a need to find new compounds. Although most pistachio orchards are infested with this pest, and if a garden is sprayed, the infestation reappears from adjacent orchards, if a compound can prevent re-oviposition of this pest in the garden, it can be very effective in controlling the next generation of this pest. For this reason, in this study, different mineral compounds have been used on the rate of oviposition and hatching of common pistachio psylla eggs.

2. Materials and methods

Experiment site specifications

The first year experiment was performed in Sharafabad region in Kerman province and the second year experiment was performed in Nazdikabad region of Kerman province.

Orchard's specifications and pistachio tree type

In this study, orchards were selected that were on the verge of economic loss in terms of population of nymphs and spraying had been done in these orchards. Experiments on mature 25-to-30-year-old trees of Akbari and Fandoghi cultivars were investigated.

Year	Region	Cultivar	Geographical coordinates
First year	Sharafabad	Akbari	30°19'34.0"N 56°58'43.9"E
Second year	Nazdikabad	Fandoghi	30°14'41.1"N 57°09'13.3"E

First year garden experiment: The effect of pesticides on oviposition of *A. pistaciae*

In the garden experiments, we have used the compounds of sulfur, wollastonite, biotite, zeolite, graphite, perlite and feldspar prepared by Kimia Pars Shayankar Company. The stones were ground and turned into a powder. Mineral powder with 3 concentrations: 5000, 25000 and 50,000 mg/l was mixed with water as a suspension. A garden with some psylla infestation and a large number of adult insects was selected. Several homogeneous trees were selected and their leaves were marked in 4 geographical directions with colored ribbons. The leaves were selected so that there were at least 4 leaves at the bottom of next year's cluster. For this purposes leaves having 3 and 5 leaflets were selected. In the next step, the surface of the marked leaves was thoroughly cleaned with water and cotton to be completely clean in terms of the presence of nymphs and psylla eggs. The suspensions prepared by spraying were homogeneously sprayed on the surface of the leaves. A control treatment was considered for each concentration. In the control treatment, the cleaned leaves of pistachio trees were treated with water. The treated leaves were exposed to psylla insects without any cover and after 7 days, all treated leaves were collected and transferred to the laboratory. In the laboratory, using a binocular, the number of eggs on each leaflet was counted and recorded.

Second year (repeating the experiment of the previous year)

In the second year, the treatments of zeolite, perlite and biotite, being significantly different from other pesticides in the first year, were selected and repeated at a concentration of 50,000 mg/l. The procedure was similar to that of the previous year.

The effect of zeolite on the hatching rate of pistachio psylla eggs in the second year

Due to the special effect of zeolite on the oviposition rate of the pest in the first and second years, to calculate the percentage of egg hatching, this treatment with a concentration of 50,000 mg/l was prepared as a suspension. In the first stage, a number of leaves were marked with colored ribbons. The surface of the leaves was then thoroughly cleaned with water and cotton. Clean leaves were exposed to pistachio psylla without any cover for oviposition of female pistachio psylla. After 3 days, the surface and the bottom of the cleaned leaves containing psylla eggs were sprayed 3 ml puff of zeolite by a hand sprinkler (model GM313); it was conducted on 5 leaflets for each treatment. The treatment was done and the same amount was used for spraying the bottom of the leaves as well. No spraying was performed on a number of leaflets used as controls. A number of leaflets were sprayed with water only to observe the effect of water on egg hatching. In the next stage, after spraying each leaflet, a net was placed as a clip cage. After 7 days, the leaves were separated and taken to the laboratory to be counted. The number of unhatched eggs and the number of nymphs were counted. Based on the recent data, the percentage of egg hatching was calculated.

Data analysis

In order to confirm the basic hypotheses, the data were first tested using Bartlett's test for natural distribution and homogeneity of variance [11]. Data analysis was performed by Statplus 2007 professional which is a statistical software. After calculating the means and standard error, the means were compared by Fisher's LSD test ($P < 0.05$).

3. Results

The effect of different treatments at concentrations of 5000, 25000 and 50000 mg/l on the oviposition rate of normal pistachio psylla in the first year

The results have indicated that the effect of different treatments on the reduction of oviposition at a concentration of 5000 mg / l, 25000 and 50,000 mg/l was significant compared to that of the control (Figure 1).

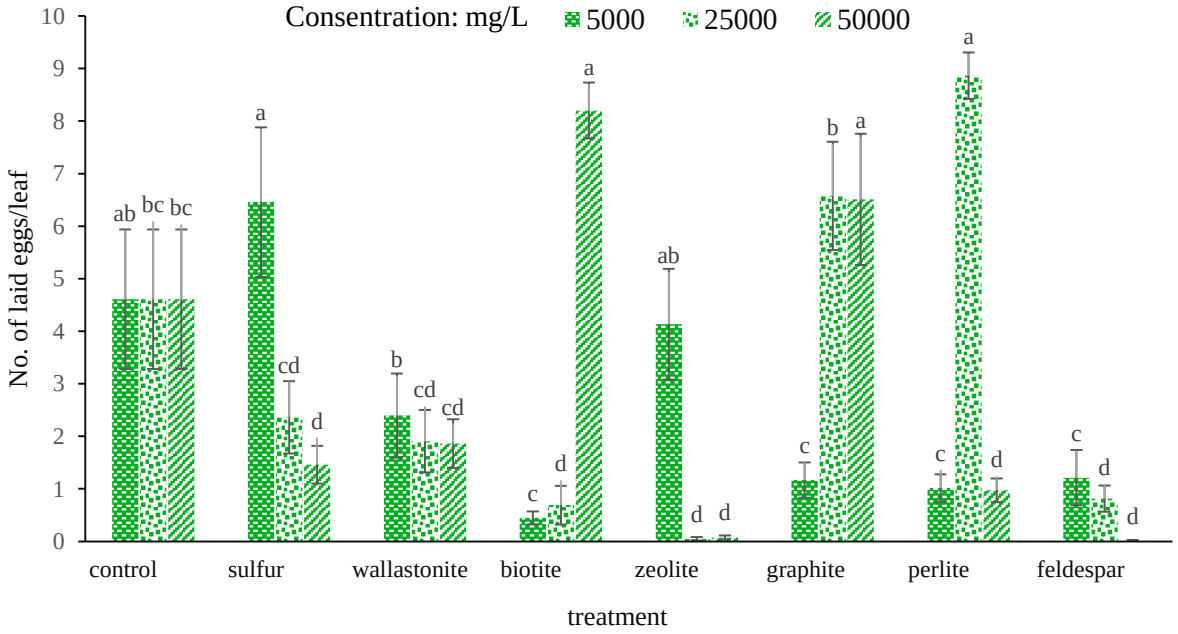

Fig. 1 The effect of different treatments at concentrations of 5000, 25000 and 50000 mg/l on the oviposition rate of common pistachio psylla in the first year

The results show that the highest oviposition rate of normal adult pistachio psylla on each leaf was related to perlite treatment with a concentration of 25000 mg/l ($P \geq 0.005$, $df_{t,e} = 7, 8$, $F = 15.76$) and the lowest oviposition rate was related to Feldspar treatment with a concentration of 50,000 mg/l ($P \geq 0.001$, $df_{t,e} = 7, 8$, $F = 11.05$). Moreover, no significant difference was observed between the treatment of wollastonite, graphite and sulfur with the control at a concentration of 25000 mg/l ($P \leq 0.01$, $df_{t,e} = 7, 8$, $F = 32.92$).

The effect of biotite, zeolite and perlite treatments at a concentration of 50,000 mg/l on the oviposition rate of normal pistachio psylla in the second year

The results of biotite, zeolite and perlite treatment on oviposition rate in the second year showed that the oviposition rate of leaves treated with perlite compared to that of the control was not statistically significant, while the leaves treated with zeolite and biotite respectively experience a significant decrease and increase in oviposition rate compared to that of the control (Figure 2) ($P \leq 0.022$, $df_{t,e} = 3, 4$, $F = 27.35$).

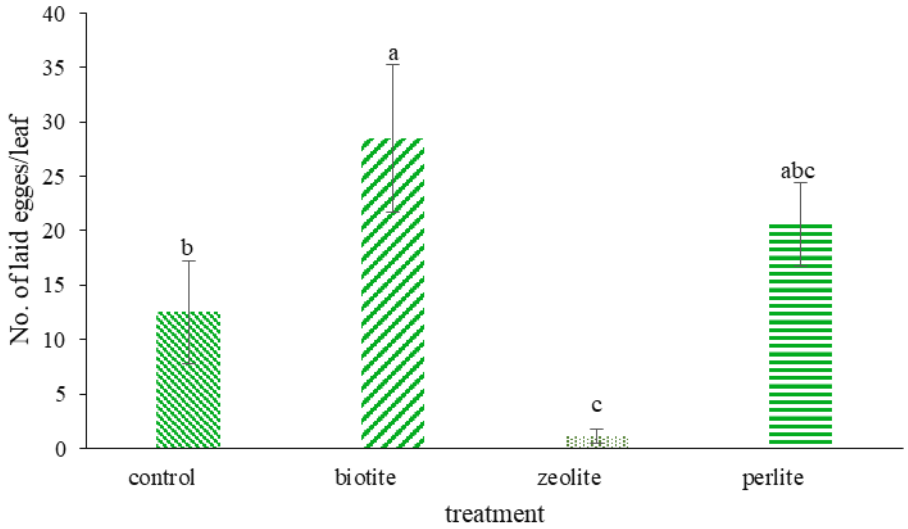

Fig. 2 The effect of biotite, zeolite and perlite treatments at a concentration of 50,000 mg/l on the oviposition rate of common pistachio psylla in the second year

The effect of zeolite at a concentration of 50,000 mg/l on the hatching rate of pistachio psylla eggs in the second year

The results of this experiment show that the zeolite used in this part of the experiment could not make any changes in the process of egg hatching (Figure 3) ($P \geq 0.01$, $df_{t,e} = 2, 3$, $F = 12.05$).

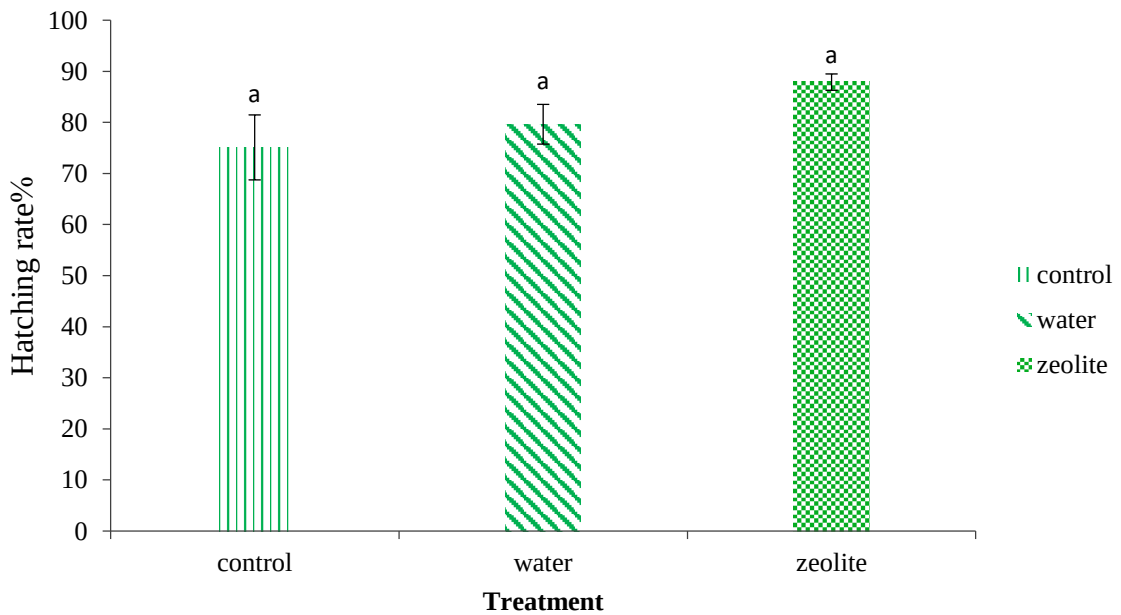

Fig. 3 The effect of zeolite at a concentration of 50000 mg/l on the hatching rate of common pistachio psylla eggs in the second year

4. Discussion

The use of environmentally friendly pesticides is one of the most important challenges for humans and nature and the use of integrated management methods including natural pesticides and biocontrol is very diverse[12 ,13]. Given the results in the first year, one of the compounds that had the lowest oviposition rate is related to feldspar treatment with a concentration of 50,000 mg/l. The structure of feldspars is formed by the connection of AlO^{-4} and SiO^{-4} tetrahedrals, by the participation of oxygen in the corners of the layers, in the form of an infinite three-dimensional network. In the structure of potassium feldspars, a silicon atom is replaced by aluminum and the resulting charge is neutralized by other cations, including potassium. The pesticidal properties of silicate in the feldspar structure are consistent with the findings of numerous studies [14, 15, 16]. Panahandeh [17] has reported that potassium silicate, in the presence of CADENCE GOLD (an additive compound containing three non-ionic surfactants, humectant and wetting agents) significantly reduced the oviposition rate of pistachio psylla. Toledo and Reis (2018) showed that foliar application of potassium silicate can be recommended as a control agent for southern red tick, *Oligonichus ilicis* (McGregor) on the coffee host in the integrated pest control program. The consumption of this compound is not considered a danger to the environment [16]. Feldspar also contains fertilizers such as potassium, which increases the plant's resistance to insects; Kalteh T, Turangi (2015) produced potassium sulfate fertilizer from potassium feldspar. Potassium sulfate fertilizer is one of the most important fertilizers providing potassium and sulfur needed by the plant; potassium is one of the main elements of the plant that increases plant resistance to pests. In their study, the potassium in *orthoclase feldspar* was calcinated, it can be extracted as water-soluble potassium hydroxide and can be easily converted to potassium sulfate fertilizer by adding sulfuric acid under normal conditions and ambient temperature [18].

The next compound with the lowest oviposition rate was zeolite with a concentration of 50,000 mg/l. Moreover, in the second year, the highest decrease of oviposition rate belonged to zeolite when compared to perlite, biotite and control. Zeolites have a high water absorption, which depends on the type of zeolite and the type of cations in its channels. Generally speaking, channel width, ionic or molecular diffusion, water content, and hydration are important determinants of their cation exchange capacity [8]. Zeolites can act as sieves due to their physical properties, and their physical and chemical features have made them useful compounds in agriculture and horticulture. Research has shown that the gradual release of fertilizer by zeolites can occur in natural and artificial soils through ion exchange reactions or a combination of ion exchange reactions or a combination of ion exchange reactions and the decomposition of mineral substances [7, 19, 20].

Zeolites with high silica to aluminum ratio, high negative charge, and crystal structure, have a distinct ability for ion exchange and adsorption of materials; they can be a good option in stabilizing pesticides and with their insecticidal and ovulatory properties, they can be helpful for plant protection [8, 20] According to the results of previous research, the mortality rate of zeolite-treated *Tuta absoluta* (Meyrick) larvae has increased significantly compared to the treatments of kaolin and spinosad. In addition, zeolite had no effect on egg hatching, but the

mortality of larvae of the first instar hatched from treated eggs increased significantly [21].

The effect of different concentrations on oviposition was quite evident in this study. In the treatment of sulfur, wollastonite, zeolite and feldspar, the oviposition rate decreased with increasing concentration. Huang et al (2012) investigated the effect of different concentrations of copper on *Spodoptera litura* and reported that the length of larval growth period of this pest decreases at low concentrations of copper (25 and 50 mg/kg). On the other hand, high concentrations (100 and 200 mg/kg) resulted in an increased growth period. The question that arises is "Why do the larvae experience a high growth rate at low concentrations of these metals, and why does the growth rate decrease with increasing mineral concentration?" Most research has shown that low concentrations of these metals improve growth, yet they have failed to mention the reason [22].

Moreover, in this study it was found that using perlite at a concentration of 25,000 mg/l, graphite at a concentration of 25,000 and 50,000 mg/l, biotite at a concentration of 50,000 mg/l and sulfur at a concentration of 5000 mg/l increase oviposition; these concentrations are not recommended to be used to control the pest. The results of the study conducted by Rohani M, Sami [23] indicated that urea and zinc-urea treatments increased the density of normal pistachio psylla eggs; these compounds provide pistachio leaves as a substrate for oviposition common pistachio psylla. Therefore, their use is not recommended to control common pistachio psylla. However, in treatments where the oviposition rate is significantly high, these compounds can be used as attractants for insect prey [24].

Studies showed that zeolite treatment failed to change the process of egg hatching. Panahandeh (2019) reported that fertilizer compounds with mineral origins including dipotassium phosphate, potassium sulfate, ammonium sulfate, calcium nitrate, potassium nitrate, potassium silicate, iron sulfate, zinc sulfate, manganese sulfate and sulfur have no effect on the hatching process of the eggs. This phenomenon was likely because the structure of the egg helps the egg to be protected from the harms exposed by external factors. Even compounds that absorb moisture do not have a negative effect on the hatching percentage of eggs [17].

5. Conclusion

Given their environmental hazards, irregular and improper use of chemical and synthetic pesticides can reduce the health of consumers and ultimately the community's health. In addition, it can eliminate natural enemies and pest resistance to chemical toxins. Recent studies have reported a significant effect of mineral compounds on pest control. Most of these compounds are safe for natural enemies, and their environmental hazards are far less than the chemical pesticides. In the present study, it was attempted to investigate the insecticidal effects of mineral compounds on common pistachio psylla. This pest is one of the most dangerous and important pests of pistachios in Iran, especially in Kerman province. The results indicated that the mineral compounds feldspar, zeolite and wollastonite are able to significantly reduce the oviposition of common psylla pests. In this study, the effect of zeolite on egg hatching rate was investigated, and the results showed that this compound has no effect on reducing egg hatching rate. In this regard, it is suggested that further research be done to determine how mineral compounds affect pests. It is also

recommended to conduct further detailed studies to investigate the effect of such compounds, in the presence of additive, on the most important enemies of common pistachio psylla.

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