Journal of Entomological Research
Volume 13, Issue 3, pages: 54-67

Islamic Azad University, Arak Branch
ISSN 2008-4668
http://jer.iau-arak.ac.ir

The effect of several inorganic compounds on oviposition and egg hatching rate of common pistachio psylla *Agonoscena pistaciae* Burckhardt & Lauterer (Hem.: Psyllidae) in orchard conditions

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Abstract

Common pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer is a serious economic pest of pistachio orchards in the world. Chemical control is a widely applied method to manage this pest problem. The intensive use of chemical insecticides has led to the development of resistant populations of the common pistachio psylla and environmental hazards. It seems that the use of inorganic compounds as insecticides is one of the ways to reduce the residual amount of dangerous toxins. In this study, the insecticidal effects of 10 kinds of inorganic compounds (subarkose, calcite, biomicrite, granite, coarse crystal sparitic limestone, monzogabbro, fine crystal sparitic limestone, monzodiorite, oomicrite and pelsparite) on oviposition and egg hatching rate were investigated. The results showed that the treated leaves with monzogabbro (0.00 ± 0.00), granite (0.54 ± 0.01), biomicrite (1.50 ± 0.21) and calcite (1.56 ± 0.17) at a concentration of 50 g/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 treated leaves with biomicrite had a significant increase compared to calcite, granite and control. This study also showed that biomicrite treatment could not make any changes in the process of egg hatching. So, based on the results of the present study, monzogabbro, granite and calcite can be used to control pistachio psylla in pistachio orchards.

Keywords: Common pistachio psylla, inorganic compounds, egg laying, hatching rate

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Received: 10 Oct. 2021 – Accepted: 11 Dec. 2021

1. Introduction

Pistacia vera Linnaeus (Sapindales: Anacardiaceae) is the most important Iranian horticulture product. Numerous insects and herbivorous mites attack pistachio trees (Dehghani-Yakhdani *et al*. 2018). The common pistachio psyllid (CPP), *Agonoscena pistaciae* Burckhardt & Lauterer (Hemiptera: Psyllidae), is one of the most significant pests of pistachio trees due to its widespread distribution in all pistachio-producing regions of Iran (Roshani *et al.* 2020). The widespread distribution causes severe problems in kernel development and leads to subsequent bud drop and defoliation, resulting in significant economic losses. For this reason, psylla infestations have received particular attention from pistachio-growers, who insist on spraying to reduce the psyllid damage (Mehrnejad, 2010; Sheibani *et al.* 2016). Unforeseen side effects of chemical pesticide applications, such as pest resurgence, pest resistance and outbreaks of secondary pests may occur when overuse of chemical insecticides is employed in crops over prolonged periods. These damaging side effects show the need for alternative methods of control that do not rely on chemical insecticides alone (Azimizadeh *et al.* 2012; Valiadeh *et al.* 2020)

Nowadays extensive research is underway to control pistachio psyllids to use new compounds that have lower environmental hazards. Insecticides developed from inorganic sources mined from the earth are classified as natural products and often cost less than other processed or harvested insecticides (Porkhosravani *et al.* 2020). Inorganic compounds can be investigated as alternatives for pesticides. The use of inorganic compounds and their derivatives is one of the common strategies applied to prevent pest damages (Arthur 1996). Inorganic insecticides are compounds lacking carbon atoms in their molecules; they are commonly made up of white crystals. These compounds are stable and do not evaporate. Moreover, they can solved be in water (Talebi Jahromi *et al.* 2007).

The toxicity of inorganic-based insecticides depends on the chemical properties of the mined elements. Some inorganic insecticides such as sulfur are registered for organic use and have relatively low toxic effects on people and non-target organisms. In contrast, lead arsenate is a natural inorganic product that was stopped as a pesticide in 1988 due to its toxicity and persistence in the environment (Murray *et al.* 2013).

Compounds of subarkose, calcite, biomicrite, granite, coarse crystal sparitic limestone, monzogabbro, fine crystal sparitic limestone, monzodiorite, oomicrite and pelsparite have been used in this study. The insecticidal properties of inorganic compounds have been proven in various studies.

Few studies have been conducted on the effects of these inorganic compounds on insects. The application of nano calcite foliar fertilizer has positive effects on seed quality, growth, yield, insect resistivity and used as a fungicide (Kumara *et al.* 2019; Fierascu *et al.* 2020). Calcite is the stable form of calcium carbonate at ordinary temperatures, and may be regarded as the principal inorganic of limestones (Greensmith 1989). Limestone powder is used in cement concretes (Ramezanianpour *et al.* 2009).

During the first century AD, powdered limestone (calcium carbonate) was added to grains for deterring storage insect-pests. A combination of hydrated lime and sulfur was one of the primary fungicides and insecticides of early agri-horti production systems (Secoy and Smith 1983). Hydrated lime or sulfur was applied either alone or in mixture to protect several agricultural and horticultural crops from insect destruction. Additionally, chemically reactive hydrated lime and sulfur were being applied along with tobacco, wood ash, linseed oil, soap and cow dung as paints or washes to fruit trees and grapevines to protect them from insect and disease damage (Caldwell *et al.* 2013). Moreover, in the studies conducted, the limestone compounds and its derivatives have been introduced as an herbicide, insecticide and fungicide (Fierascu *et al.* 2020).

Meanwhile, common pistachio psylla is one of the most imperative 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 inorganic compounds have been used on the rate of oviposition and hatching rate of common pistachio psylla eggs.

2. Materials and Methods

2.1. The location of the purchased inorganic stones

The location and conditions of the purchased inorganic stones have been shown in table 1.

Table 1. The location and region of inorganic stones mine.

Region	Cultivar	Geographical coordinates
Hamadan, Iran	Subarkose	34°51'30.8"N 48°24'28.2"E
Esfahan, Iran	calcite	33°28'52.1"N 50°41'36.4"E
Fars, Iran	Biomicrite	29°44'51.1"N 53°24'11.8"E
Khorasan Razavi, Iran	granite	36°10'30.1"N 59°36'00.5"E
Obe, Afghanistan	coarse crystal sparitic limestone	34°21'28.7"N 63°29'43.6"E
Natanz, Esfahan, Iran	monzogabbro	33°31'27.3"N 51°50'37.8"E
Kerman, Iran	fine crystal sparitic limestone	29°28'18.8"N 57°29'53.1"E
Fars, Iran	monzodiorite	29°26'44.4"N 54°07'29.2"E
Yazd, Iran	oomicrite	31°35'13.0"N 53°40'38.0"E
Birjand, South Khorasan, Iran	pelsparite	32°48'13.7"N 59°17'21.9"E

2.2. Light microscopy observations

Light microscope (Olympus BH 2) at 10x magnification at room temperature was used to evaluate the profile of inorganic stone with respect to the size and morphological characteristics.

2.3. The location and conditions of the experimenting area

The first-year experiment was performed in Sharafabad, Kerman, Iran and the second year experiment was performed in Nazdikabad, Kerman, Iran. In this study, orchards were selected that were on the economic threshold in terms of the 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 (Table 2).

Table 2. The location and conditions of the experimenting area

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

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

In the garden tested, we have used the compounds of subarkose, calcite, biomicrite, granite, coarse crystal sparitic limestone, monzogabbro, fine crystal sparitic limestone, monzodiorite, oomicrite and pelsparite. The stones were ground and turned into a powder. Inorganic powder with 3 concentrations: 5, 25 and 50 g/l was mixed with water as a suspension. A garden with some psylla infestation and a large number of adult insects was selected. Numerous homogeneous trees were selected and their leaves were marked in 4 geographical directions with colorful ribbons. The leaves were selected so that there were at least 4 leaves at the bottom of next year's cluster. For this purpose, leaves having 3 and 5 leaflets were selected. In the next step, the surface of the marked leaves was thoroughly cleaned with cotton and water to be completely clean in terms of the presence of nymphs and psylla eggs.

The suspensions prepared by spraying (3 ml puff by a hand sprinkler model GM313) 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 pistachio psylla without any cover and after 7 days, all treated leaves were collected and transferred to the laboratory. In the research laboratory, with a binocular, the number of eggs on each leaflet was counted and recorded.

2.5. Second year (repeating the experiment of the previous year). In the second year, the treatments of monzogabbro, granite, calcite and biomicrite being meaningfully different from other pesticides in the first year, were selected and repeated at a concentration of 50 g/l. The procedure was similar to that of the previous year.

2.6. The effect of biomicrite on the hatching rate of pistachio psylla eggs in the second year. As a result of the special effect of biomicrite 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 g/l was prepared as a suspension. In the first step, a number of leaves were marked with colored ribbons. Then, the surface of the leaves was thoroughly cleaned with water and cotton. Cleaned leaves were exposed to common pistachio psylla without any cover for oviposition. After 3 days, the surface and the bottom of the cleaned leaves containing psylla eggs were sprayed with 3 ml puff of biomicrite 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 some of the leaflets used as controls. Some of the 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.

2.7. Data analysis. With the aim of confirming the basic hypotheses, the data were first tested using Bartlett's test for natural distribution and homogeneity of variance (Köhler et al., 2002). All statistical analyzes using software Statplus (version 4.9, 2007) took place. The first step is to calculate the mean, then find out the difference between the means in this case the differences between indicated and secondly the significant differences between the level of five percent. To compare data obtained from studies using ANOVA-One-Way was performed using Fisher LSD test.

3. Results

3.1. Profile of inorganic stone. To ensure the purchased stones, the cross section was prepared by a light microscope. The profile of inorganic stone was evaluated for determining the average size and morphological characteristics.

(1) Subarkose: This section has 75% semicircular quartz, 20% feldspar and 5% crushed stone (Fig. 1).
(2) Calcite: This section is formed from the transformation of limestone. Its main mineral is calcite (Fig. 2).
(3) Biomicrite: This section has a microcrystalline background with calcified fossil fragments (Fig. 3).
(4) Granite: This section contains 40% quartz, 30% orthoclase, plagioclase and hornblende and pyroxene (Fig. 4).
(5) Coarse crystal sparitic limestone: This section is a large crystalline calcite (Fig. 5).
(6) Monzogabbro: This section contains 80% plagioclase, pyroxene and opaque mineral. Also, many parts of the cross section have been chlorinated (Fig. 6).
(7) Fine crystal sparitic limestone: This section is a large crystalline calcite that precipitates between grains after precipitation of calcium carbonate saturated fluids (Fig. 7).
(8) Monzodiorite: This section contains 70% plagioclases, 10% pyroxene, 5% hornblende, 5% biotite (Fig. 8).
(9) Oomicrite: This section has non-skeletal grains of spherical or elliptical calcium carbonate with a size of less than 2 mm (Fig. 9).
(10) Pelsparite: This section contains non-skeletal grains of calcium carbonate, all or part of which are composed of micrites and do not have any recognizable internal structure. Sparite is usually in the form of cavity filling cement (Fig. 10).

3.2. The effect of several inorganic compounds on the oviposition rate of common pistachio psylla in the first year. The results have indicated that the effect of different treatments on the reduction of oviposition rate at a concentration of 5, 25 and 50 g/l was significant compared to that of the control (Fig. 11). The results show that the lowest oviposition rate was related to calcite, biomicrite, granite and monzogabbro treatments with a concentration of 50 g/l ($P\leq 0.0001$, $df_{t,e} = 10, 11$, $F = 32.05$) and the highest oviposition rate of common pistachio psylla on each leaf was related to biomicrite and pelsparite treatment with a concentration of 5 g/l ($P\leq 0.001$, $df_{t,e} = 10, 11$, $F = 53.56$). Moreover, no significant difference was observed in some treatments like between the treatments of Subarkose, Calcite, Granite, Monzogabbro, Fine crystal sparitic limestone, Monzodiorite and Oomicrite compared to control at the concentration of 5 g/l ($P\leq 0.01$, $df_{t,e} = 10, 11$, $F = 29.12$).

The effect of monzogabbro, granite, calcite and biomicrite treatments at the concentration of 50 g/l on the oviposition rate of common pistachio psylla in the second year

The results of monzogabbro, granite, calcite and biomicrite treatment on oviposition rate in the second year showed that the oviposition rate of the treated leaves with Granite and Calcite experience a significant decrease in oviposition rate compared to that of the control, while the treated leaves with monzogabbro and biomicrite compared to that of the control was not statistically significant, (Fig. 12) ($P\geq 0.01$, $df_{t,e} = 4, 5$, $F = 35.21$).

3.3. The effect of Biomicrite at a concentration of 50 g/l on the hatching rate of pistachio psylla eggs in the second year. The results of this study show that the biomicrite used in this part of the experiment could not make any changes in the process of egg hatching (Fig. 13) ($P\geq 0.07$, $df_{t,e} = 2, 3$, $F = 21.03$).

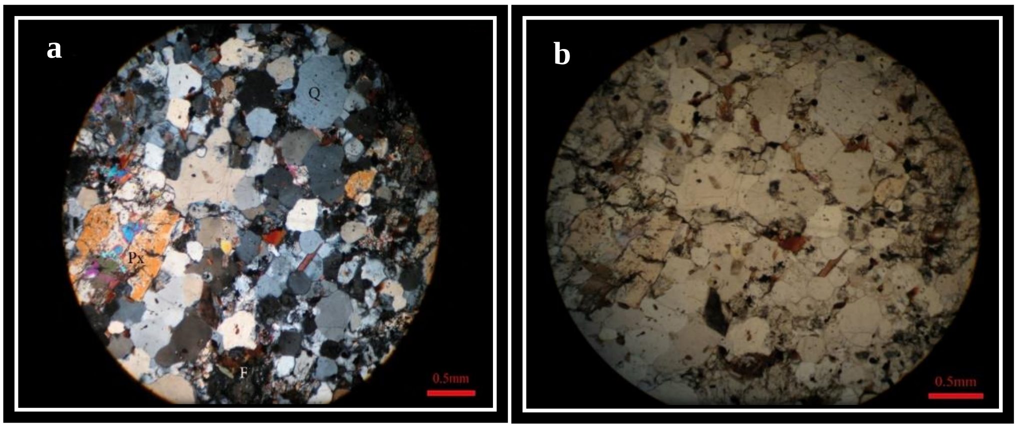

Fig 1 The profile of Subarkose. The quartz grains are marked with Q, feldspar with F, and pyroxene with Px. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

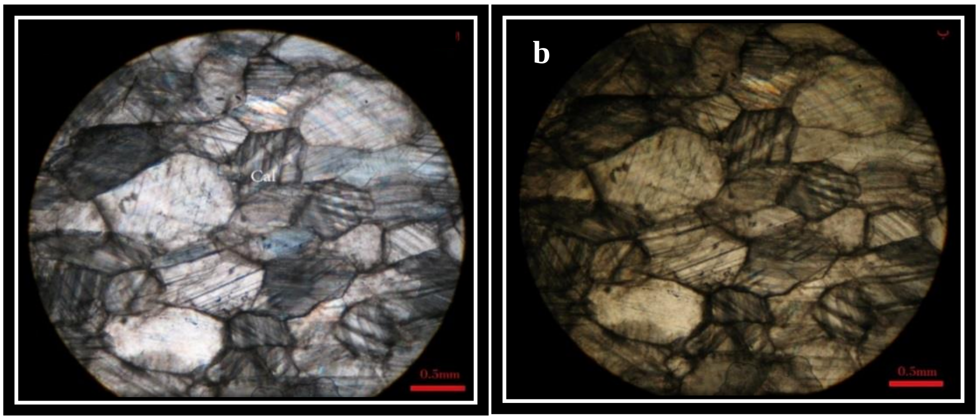

Fig 2 The profile of Calcite. Calcite grains are marked with Cal. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

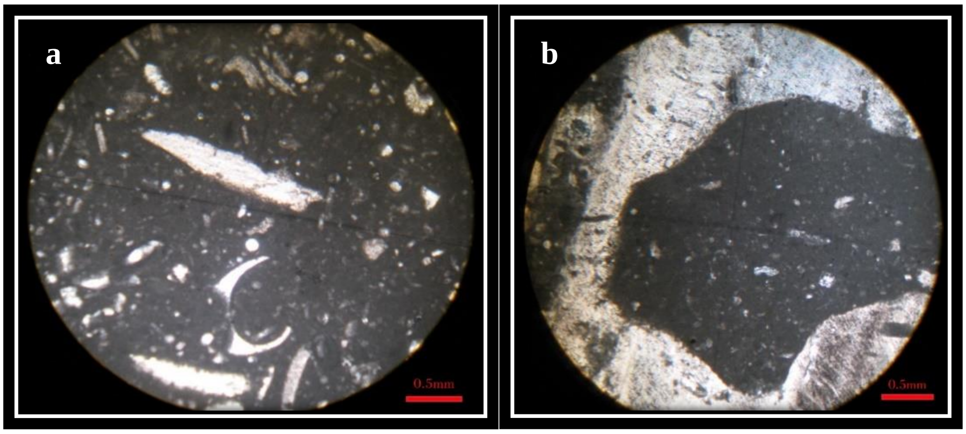

Fig 3 The profile of Biomicrite. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

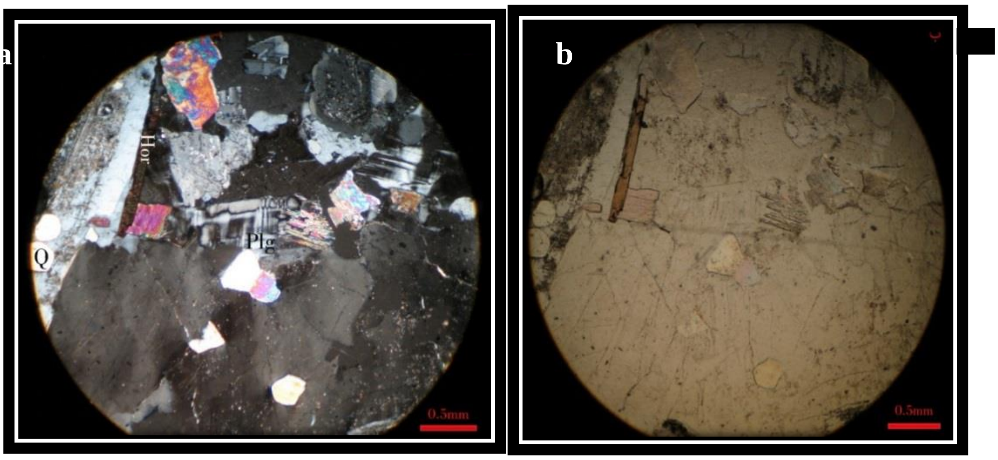

Fig 4 The profile of granite. The quartz grains are marked with Q, plagioclase with plg, and hornblende with Hor. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

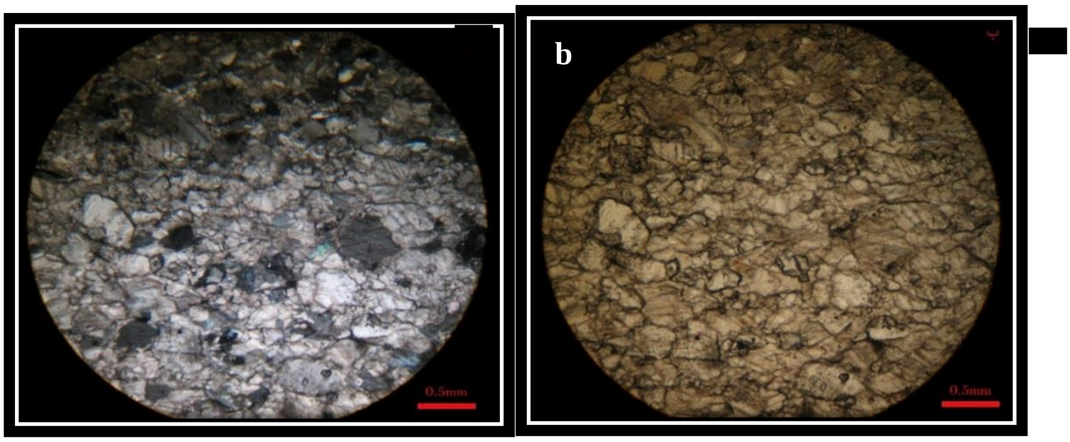

Fig 5 The profile of coarse crystal sparitic limestone. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

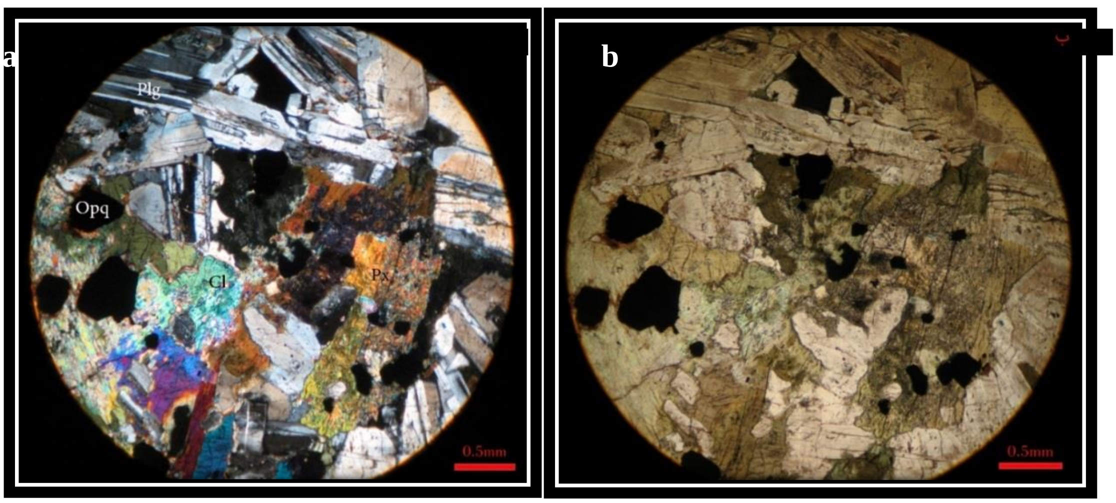

Fig 6 The profile of monzogabbro. The opaque are marked with Opq, plagioclase with Plg, and chlorination with Cl. a: The sample image in Xpl light, and b: the sample image in ppl light. The scale bar for all is 0.5 mm.

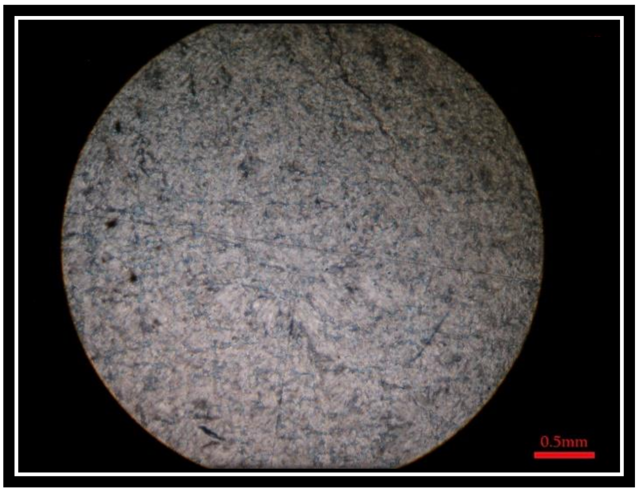

Fig 7 The profile of fine crystal sparitic limestone. The scale bar for all is 0.5 mm.

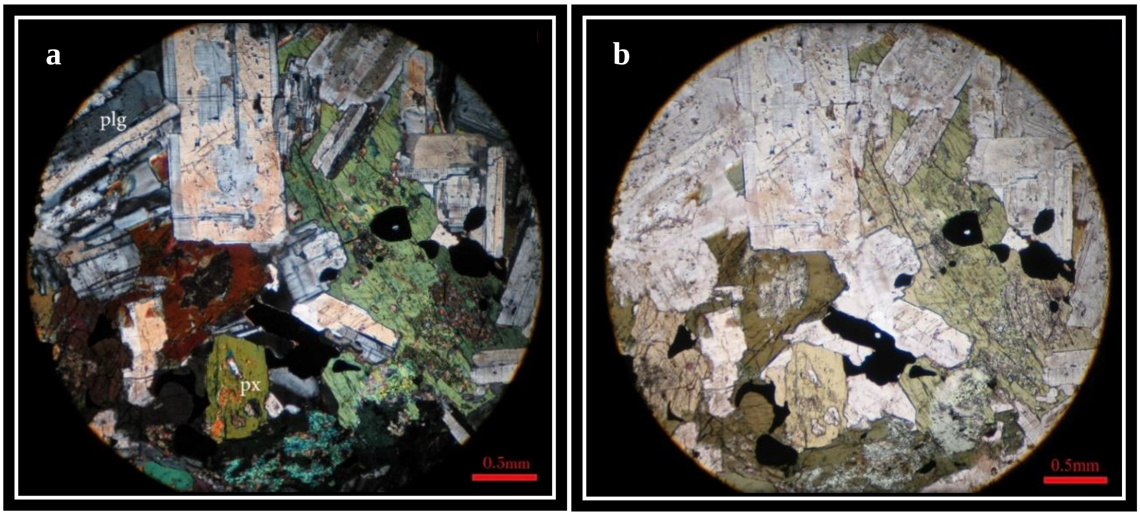

Fig 8 The profile of monzodiorite. Pyroxene are detected in plagioclases grains (plg). a: The sample image in Xpl light, b: the sample image in ppl light. The scale bar for all is 0.5 mm.

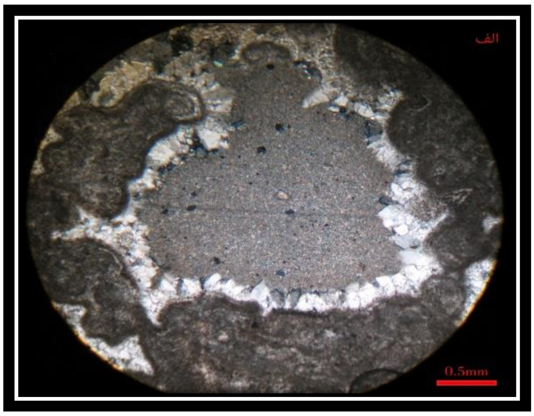

Fig 9 The profile of oomicrite. The scale bar for all is 0.5 mm.

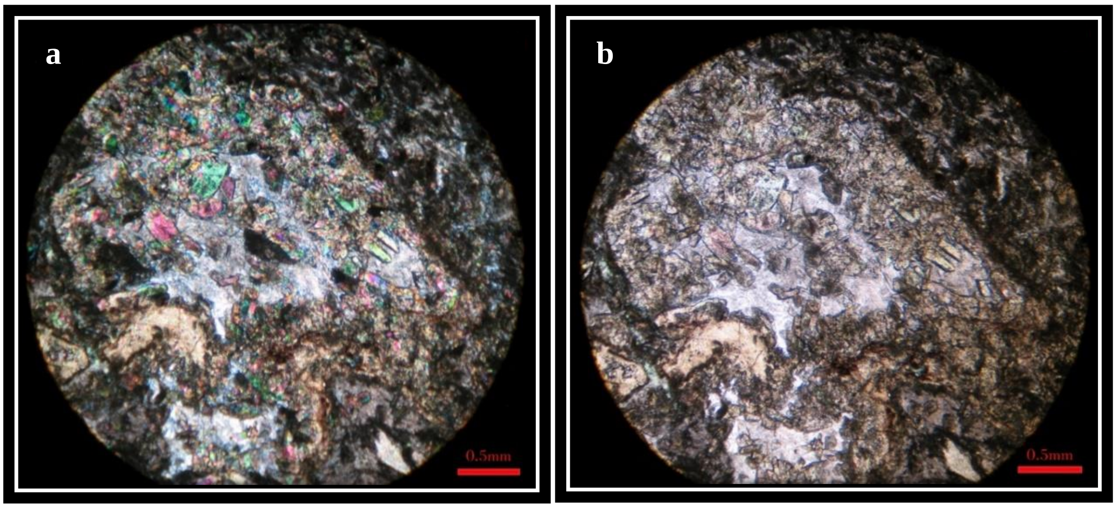

Fig 10 The profile of pelsparite. a: The sample image in Xpl light, b: the sample image in ppl light. The scale bar for all is 0.5 mm.

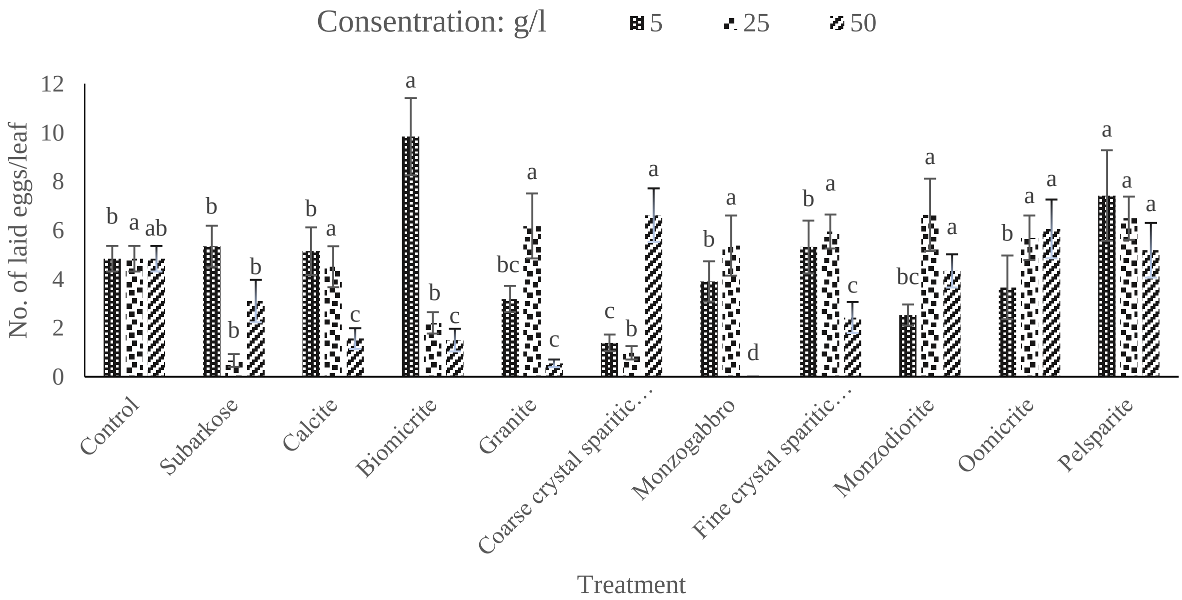

Fig 11 The effect of several inorganic compounds at concentrations of 5, 25 and 50 g/l on the oviposition rate of common pistachio psylla in the first year

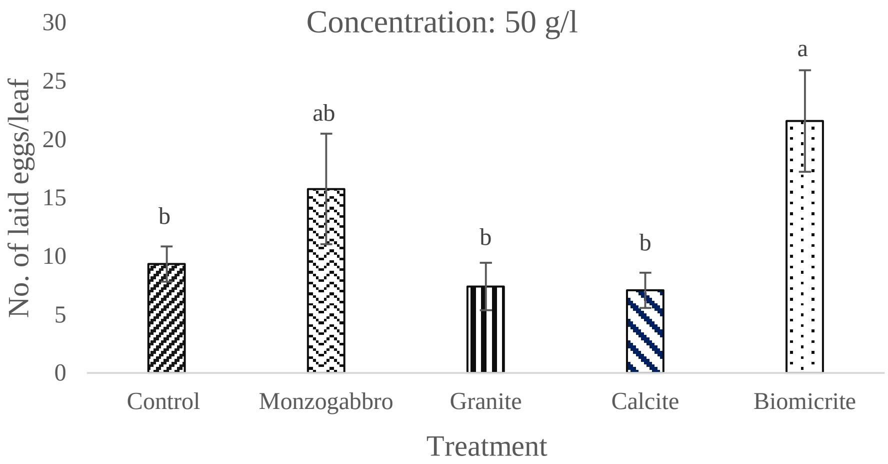

Fig 12 The effect of monzogabbro, granite, calcite and biomicrite treatments at the concentration of 50 g/l on the oviposition rate of common pistachio psylla in the second year

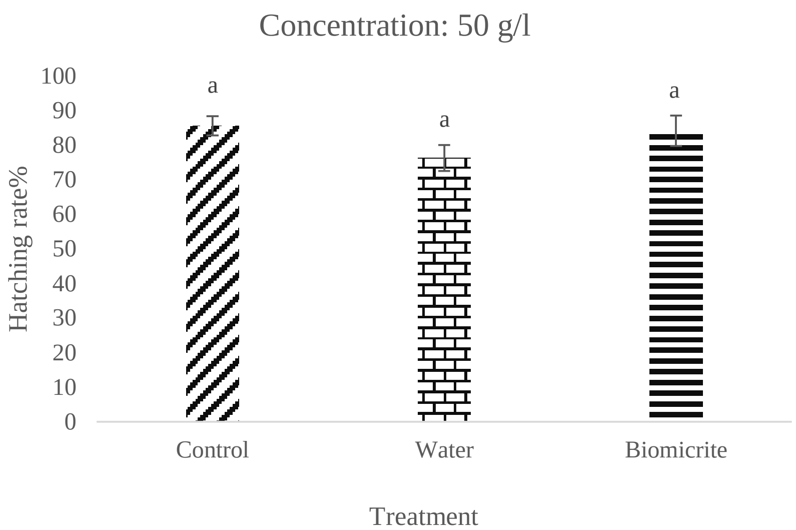

Fig 13 The effect of biomicrite at the concentration of 50 g/l on the hatching rate of pistachio psylla eggs in the second year

4. Discussion

This is the time that necessitates the proper use of pesticides to protect our environment and eventually health hazards associated with it. Alternative pest control strategies such as IPM including natural pesticides and biocontrol is very diverse (Valizadeh *et al.*, 2013). Inorganic compounds can be investigated as alternatives for chemical pesticides. The results in the first year have shown one of the compounds that had the lowest oviposition rate is related to monzogabbro treatment with a concentration of 50 g/l. Monzogabbro a coarse-grained igneous rock consisting of essential plagioclase feldspar, orthoclase feldspar, and pyroxene, with or without biotite. Plagioclase of labradorite composition is the dominant feldspar, making up 60–90% of the total feldspar. The presence of orthoclase feldspar distinguishes this rock from a gabbro (Nevalainen et al., 2014). 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 (Almeida *et al.*, 2009; Toledo and Reis, 2018; Godoy *et al.*, 2018). Toledo and Reis (2018) reported 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. Panahandeh (2019) has reported that potassium silicate, in the presence of CADENCE GOLD (an additive compound containing humectant, three non-ionic surfactants and wetting agents) significantly reduced the oviposition rate of pistachio psylla.

The next compounds with the lowest oviposition rate were Calcite, Biomicrite, Granite and Fine crystal sparitic limestone with a concentration of 50 g/l. Moreover, in the second year, the highest decrease of oviposition rate belonged to Calcite and Granite when compared to Biomicrite but have shown no significant comparing to the control.

Calcite ($CaCO_3$) is among the most abundant minerals on earth, counting for more than 4% of the earth's crust. The consumption of this compound is not considered a danger to the environment. Calcite also contains fertilizers such as calcium and carbonate ions, which increases the plant's resistance to insects (Ricci *et al.*, 2013). Kumara *et al.* (2019) reported nano calcite (NC) is used as an environmental friendly foliar fertilizer to increase the yield of many crops around the world. It was found that the application of nano calcite foliar fertilizer has helpful effects on yield, growth, seed quality and insect resistivity of Rice (*Oryza sativa* L.). So, higher concentrations of nano calcite greatly reduce the pest damages to the crop.

Hua *et al.* (2015) have also reported that the application of nano calcium carbonate can increase plant protection against insect pests. They have also mentioned that nano calcium carbonate is a good alternative for chemical pesticides as it is a safe, human and environmentally friendly material.

The effect of different concentrations on oviposition was quite evident in this study. In the treatment of subarkose, calcite, biomicrite and pelsparite, the oviposition rate decreased with increasing concentration. Results of the present study are consistent with results of Sheibani *et al*. (2016) that investigated the effect of different concentrations of kaolin particle film on common pistachio psyllid and reported that the oviposition and nymph population of this pest decreases with increasing concentration of kaolin particle film. The reduction of oviposition due to kaolin could be attributed to the repellency effect of kaolin.

Likewise, in this study it was found that using Biomicrite and Pelsparite at the concentration of 5 g/l, increases oviposition rate; this concentration is not recommended to be used to control the pest. Rohani and Sami (2012) reported urea and zinc-urea treatments increased the density of common 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 (Katsoyannos and Papadopoulos, 2004).

The leaves treatment with Biomicrite failed to change the process of egg hatching. Panahandeh (2019) reported that fertilizer compounds with inorganic origins including potassium silicate, ammonium sulfate, di-potassium phosphate, potassium sulfate, potassium nitrate, calcium nitrate, manganese sulfate, iron sulfate, zinc 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 damages exposed by external factors. Even compounds that absorb moisture do not have a negative effect on the hatching rate of eggs (Panahandeh, 2019).

5. Conclusion

Chemical pesticides are contributing in current agriculture to fulfil the need of raising population. They are very toxic in nature and pose acute risks to human health and the environment. In addition, it can eliminate natural enemies and pest resistance to chemical toxins. Recent studies have reported a significant effect of inorganic compounds on pest control. Most of these compounds are safe for natural enemies, and their environmental hazards are far less than chemical pesticides. In the present study, it was attempted to investigate the insecticidal effects of inorganic compounds on common pistachio psylla. This pest is one of the most dangerous and important pests of pistachios in the world. The results indicated that the inorganic compounds Calcite, Biomicrite, Granite and Monzogabbro are able to significantly reduce the oviposition of common psylla pests. In this study, the effect of Biomicrite on egg hatching rate was investigated, and the results showed that this compound has no effect on reducing egg hatching rate. So, it is suggested that additional research be done to determine how inorganic compounds affect pests. It is moreover recommended to conduct further detailed studies to study the effect of such compounds on the most important enemies of common pistachio psylla.

Acknowledgments

The authors would like to thank the Shahid Bahonar University of Kerman, Iran for supporting the research.

Disclosure statement

No potential conflict of interest was reported by the authors.

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جلد 13، شماره3، سال 1400، (67-54)

تاثیر سنگ‌های معدنی مختلف روی میزان تخم‌ریزی و تفریخ تخم‌های پسیل معمولی پسته(*Agonoscena pistaciae* **Burkhhardt & Lauterer (Hem.: Psyllidae)** در شرایط باغی

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چکیده

پسیل معمولی پسته یکی از آفات مهم و اقتصادی در باغات پسته جهان است. در حال حاضر کنترل شیمیایی، روش اصلی کنترل این آفت به شمار می‌رود. استفاده بیش از حد از حشره‌کش‌های شیمیایی منجر به ایجاد جمعیت مقاوم پسیل پسته و ایجاد خطرات زیست‌محیطی شده است. به نظر می‌رسد استفاده از ترکیبات معدنی به‌عنوان حشره‌کش، یکی از راه‌های کاهش میزان باقیمانده سموم خطرناک در محصولات کشاورزی است. در این تحقیق اثرات حشره‌کشی 10 نوع سنگ معدنی (حاوی کانی‌های ساب‌آرکوز، کلسیت، بیومیکریت، گرانیت، آهک اسپارایتی درشت‌بلور، آهک اسپارایتی ریزبلور، مونزوگابرو، مونزودیوریت، اُاُمیکریت و پل‌اسپاریت) روی تخم‌ریزی و تفریخ تخم این حشره بررسی شد. نتایج نشان داد که برگ‌های تیمار شده با کانی مونزوگابرو (0/00±00)، گرانیت (0/54±0/01)، بیومیکریت (1/50±0/21)، و کلسیت (1/56±0/17) در غلظت 50 گرم در لیتر، بیشترین کاهش در میزان تخم‌ریزی آفت در آزمایش سال اول را داشتند. نتایج آزمایش سال دوم نشان داد برگ‌های تیمار شده با بیومیکریت، افزایش قابل توجهی در میزان تخم‌ریزی در مقایسه با کلسیت، گرانیت و شاهد داشت. این تحقیق همچنین نشان داد که تیمار بیومیکریت تاثیری در روند تفریخ تخم نداشته است. بنابراین براساس نتایج این تحقیق، مونزوگابرو، گرانیت و کلسیت می‌توانند جهت کنترل پسیل پسته در باغات پسته استفاده گردند.

واژه‌های کلیدی: پسیل معمولی پسته، ترکیبات معدنی، تخم‌ریزی، تفریخ تخم

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تاریخ دریافت مقاله:1400/7/18 - تاریخ پذیرش مقاله:1400/9/20