

Technical Report

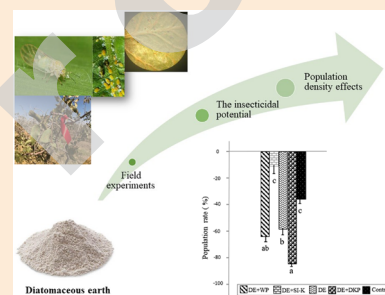
Diatomaceous earth foliar spraying along with adjuvants in pistachio orchards associated with the common pistachio psylla, *Agonoscena pistaciae*

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The common pistachio psylla, *Agonoscena pistaciae*, is a serious global pest menacing pistachio orchards. Considering the dangers of using excessive chemical pesticides, it seems that using natural insecticides such as diatomaceous earth is a suitable way to lower the residual amount of highly hazardous pesticides. In this study, the effects of diatomaceous earth with different additives, including dipotassium hydrogen phosphate, polyurethane glue as a wood adhesive, and potassium silicate, were investigated in several concentrations over two years in orchard conditions. Although all treatments showed significant effects, the most effective treatments were (diatomaceous earth+dipotassium hydrogen phosphate) and (diatomaceous earth+polyurethane glue). Therefore, the use of diatomaceous earth combined with the additive materials mentioned can potentially be a safe method for the integrated management of the common pistachio psylla.



Keywords: diatomaceous earth, common pistachio psylla, inorganic fertilizer, population density.

Introduction

The pistachio, *Pistacia vera* L., is an essential economic horticultural product currently cultivated across the Americas, Europe, Asia, Africa, and Oceania. Presently, the United States, Iran, and Turkey are the three major pistachio producers, supplying about 92% of the global pistachio demand.¹⁾ The common pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Aphalaridae), is one of the most destructive pistachio tree pests due to its widespread distribution in all pistachio-producing regions of Iran.²⁾ Various pesticides are used to control the common pistachio psylla. Chemical pesticide application has an adverse effect on natural enemies and the environment and is considered to be one factor influencing the development of pest resistance.³⁻⁵⁾ Therefore, it is necessary to use alternative meth-

ods for control of this pest. Several studies have demonstrated the satisfactory function of diatomaceous earth as a natural insecticide and recommend its use for the protection of stored products.^{6,7)} Ebadollahi and Sadeghi studied the toxicity of kaolin and diatomaceous earth (Sayan[®]) against *Spodoptera exigua*.⁸⁾ The results showed that kaolin and diatomaceous earth can be considered suitable alternatives to chemical pesticides in the management of *S. exigua*. Three improved diatomaceous earth products (DEs), InsectoSec[®], Diatomeenerde Probe-A, and Fossil Shield[®] 90.0, were tested against *Sitophilus zeamais* Motschulsky (Coleoptera: Dryophthoridae) and *Tribolium castaneum* (Coleoptera: Tenebrionidae) in the laboratory, and the results demonstrated that all formulations reduced the progeny emergence compared to the control.⁹⁾ Marubayashi *et al.* showed that application of the insecticide with adjuvants, combined with the use of different nozzles, changed the droplet spectrum and risk of drift.¹⁰⁾ Evidence has shown that different inorganic fertilizers have reduced the population of the common pistachio psylla.¹¹⁾ Rouhani *et al.* evaluated the effect of micronutrients, including zinc, nitrogen, and calcium, on the population density of *A. pistaciae*.¹²⁾ Their results showed that calcium is the most effective in reducing the population density of the pest. Foliar application of potassium silicate can be recommended as a control agent for the red mite *Oligonychus ilicis* McGregor

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(Trombidiformes: Tetranychidae) on coffee. This compound is not considered a danger to the environment.¹³ Camata *et al.* evaluated the effect of potassium silicate on pest resistance and postharvest longevity of the chrysanthemum.¹⁴ This work demonstrated that leaf application of potassium silicate reduced the incidence of cercosporiosis and thrips in chrysanthemum leaves. Generally, despite the extensive research on various compounds, including synthetic insecticides, plant essential oils, and inorganic compounds already introduced in the agricultural industry, none of the common compounds has been able to satisfactorily control the common pistachio psyllid. The unsatisfactory effect of repeated spraying against this pest causes severe resistance to this pest and reduces the quality of the product in terms of consumer health.¹⁵ In this study, we investigated the effect of diatomaceous earth with additive compounds on the population growth of *A. pistaciae* in pistachio orchards. Also, it is expected that using diatomaceous earth in a new and practical way as a natural insecticide with different additives, some of which are used as nutrients for trees, will be effective in reducing the population density of the pest.

Materials and methods

1. Study site

Investigation was conducted during 2017 and 2018 in a pistachio garden (1764 m above sea level) (30°14'38"N, 57°7'22"E) at Shahid-Bahonar University in Kerman, Iran.

In this garden, before the start of the research, no insecticide or composition had been used during the winter or spring to control pistachio pests. The trees in the garden were the Ohadi variety.

2. Insecticides

Treatments included: (diatomaceous earth), (diatomaceous earth+dipotassium hydrogen phosphate), (diatomaceous earth+potassium silicate), and (diatomaceous earth+poly urethane glue) (Table 1).

3. Field tests

3.1. Foliar spraying

In all of the experiments, various high-consumption and low-consumption DEs, along with additive materials, were evaluated over the course of two years. The two concentrations of diatomaceous earth were 0.5% and 1%, and 0.2% additive materials were used in a gasoline-powered sprayer (KAWAGOE26c.c). Purified water was used for the preparation of all treatments and

the control. In the pistachio garden, four rows were considered separately for different treatments, and one row was considered the control. Ten trees in each row were randomly selected and exposed to spray treatments.

3.2. Sampling

Sampling was done three and twelve days after the first spraying. Three leaves from each treated tree (a total of thirty leaves after each treatment) were taken and transferred to the laboratory. The *A. pistaciae* nymphs on the underside of the leaves were counted before and after spraying.

3.3. Population growth formula

The following formula was used to calculate the percentage of nymph population growth:

$$\text{The percentage of nymph population growth} = \frac{B - A}{A} \times 100,$$

where

A = the number of nymphs before spraying, and

B = the number of nymphs after spraying.

4. Statistical analysis

With the aim of confirming the basic hypotheses, the data were first examined using Bartlett's test for natural distribution and homogeneity of variance.¹⁶ For statistical comparison of the mean data, the data were subjected to a one-way analysis of variance (ANOVA) followed by a Fisher least significant difference (LSD) method ($p \leq 0.05$). All statistical analyses were performed using StatPlus software (version 4.9, 2007).

Results

1. First-year results

The effects of the 0.5% diatomaceous earth with additives on the population growth rate of *A. pistaciae* nymphs in the first year are shown in Fig. 1-a. This figure shows the consequences 3 days after foliar spraying with 0.5% diatomaceous earth and a 0.2% additive. Although none of the treatments had a significant effect on population density after three days, treatment with (diatomaceous earth) and (diatomaceous earth+dipotassium hydrogen phosphate) at the same concentrations (0.5%) resulted in the greatest reduction in population growth rate after twelve days, as shown in Fig. 1-b ($p \leq 0.005$; $df_{t,e} = 4, 5$; $F = 35.27$). In addition, the results demonstrated that the effects of the mentioned treatments can be increased by increasing the concentrations, as according to the data given in Fig. 2-a and -b, the greatest effects of 1% concentrations were related to (diatomaceous earth+dipotassium hydrogen phosphate) and (diatomaceous earth+polyurethane

Table 1. The diatomaceous earth, inorganic compounds, and sprayer used in the study.

Common name	Commercial name	Company
Diatomaceous earth	CELITE	World Mineral
Potassium silicate	LOPOT 1986	PQ Corporation
Polyurethane glue	TYTAN	Nojan Gostar Arya
Dipotassium hydrogen phosphate	PRIMA	Omnisal GmbH
Gasoline-powered sprayer	—	KAWAGOE 26c.c

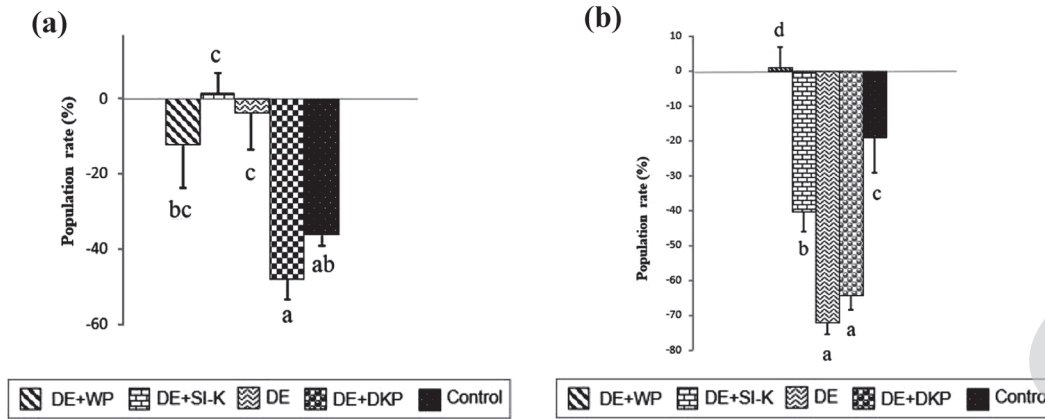


Fig. 1. The effect of 0.5% diatomaceous earth with additives on the population growth of *Agonoscena pistaciae* nymphs 3 days (a) and 12 days (b) after spraying in first-year experiments. DE: diatomaceous earth; WP: polyurethane glue; Si-K: potassium silicate; DKP: dipotassium hydrogen phosphate. Different letters show significant differences ($p \leq 0.005$).

glue), and this controlling process was increased after twelve days ($p \leq 0.000$; $df_{t_e} = 4, 5$; $F = 23.62$) (Fig. 2-a and -b). There were no significant differences between diatomaceous earth treatments after twelve days.

2. Second-year results

During the second year, the experiment was repeated with the same concentrations and time records of the population growth rate. The three days post-treatment outcome with the 0.5% concentration revealed that all diatomaceous-based treatments decreased the population growth rate significantly. There were no significant differences between the (diatomaceous earth+dipotassium hydrogen phosphate) and (diatomaceous earth+potassium silicate) treatments, as both of them reduced the population growth rate significantly more than the treatments with (diatomaceous earth) and (diatomaceous earth+polyurethane glue) ($p \leq 0.01$; $df_{t_e} = 4, 5$; $F = 36.51$) (Fig. 3-a). Contrary to the

great effect of (diatomaceous earth+potassium silicate) three days post-treatment, it was not able to keep the leaves clean after twelve days and had increased the population rate compared to the other diatomaceous earth-based treatments. In addition, there was no significant difference from the control treatment. In this section, (diatomaceous earth) and (diatomaceous earth+polyurethane glue) had the most outstanding effect on the pest as compared to other treatments ($p \leq 0.01$; $df_{t_e} = 4, 5$; $F = 39.18$) (Fig. 3-b). When the concentration was increased to 1.0%, all diatomaceous earth-based treatments showed a strong effect on the population rate; (diatomaceous earth+polyurethane glue) and (diatomaceous earth+potassium silicate) had the highest effect, and there were significant differences between (diatomaceous earth+polyurethane glue) with (diatomaceous earth) and (diatomaceous earth+dipotassium hydrogen phosphate) ($p \leq 0.0002$; $df_{t_e} = 4, 5$; $F = 27.83$) (Fig. 4-a). Figure 4-b shows the effects of 1.0% concentration treatments, which were record-

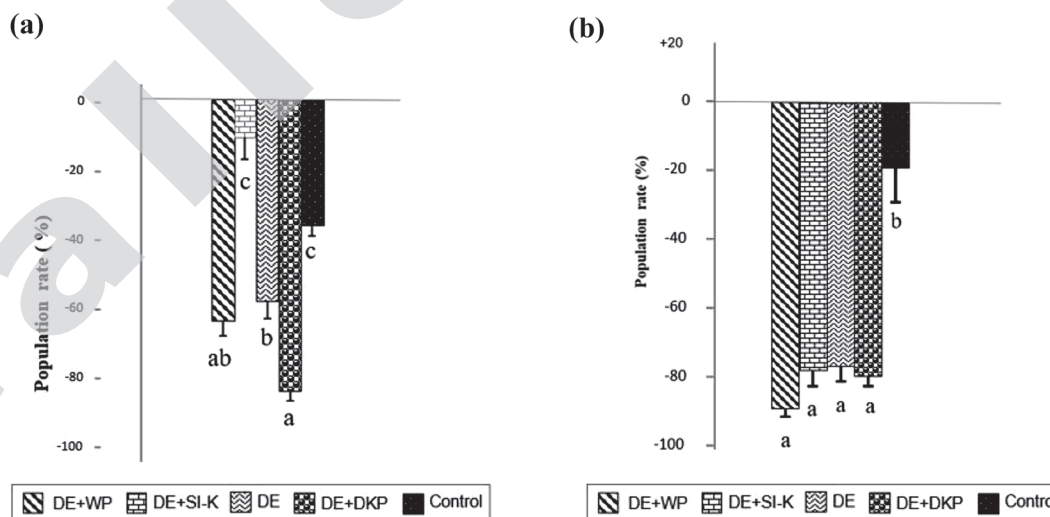


Fig. 2. The effect of 1.0% diatomaceous earth with additives on the population growth of *Agonoscena pistaciae* nymphs 3 days (a) and 12 days (b) after spraying in first-year experiments. DE: diatomaceous earth; WP: polyurethane glue; Si-K: potassium silicate; DKP: dipotassium hydrogen phosphate. Different letters show significant differences ($p \leq 0.0001$).

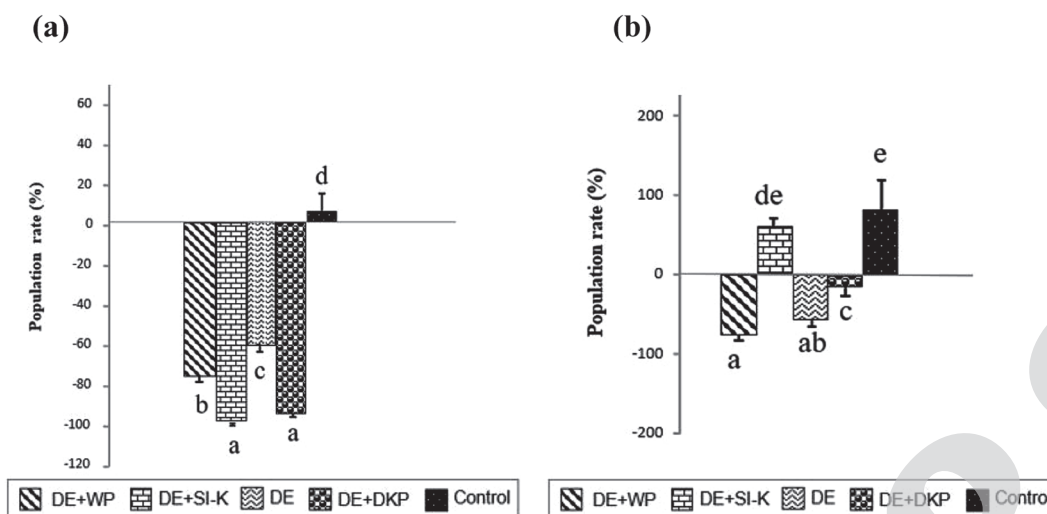


Fig. 3. The effect of 0.5% diatomaceous earth with additives on the population growth of *Agonoscena pistaciae* nymphs 3 days (a) and 12 days (b) after spraying in second-year experiments. DE: diatomaceous earth; WP: polyurethane glue; Si-K: potassium silicate; DKP: dipotassium hydrogen phosphate. Different letters show significant differences ($p \leq 0.01$).

ed twelve days post-treatment. The highest population growth rate was observed with (diatomaceous earth+potassium silicate) treatment as compared to the other diatomaceous earth-based treatments. It should be noted that there was no significant difference between leaves treated with (diatomaceous earth+potassium silicate) and the control. The other diatomaceous earth-based treatments, including (diatomaceous earth+poly urethane), (diatomaceous earth+dipotassium hydrogen phosphate), and (diatomaceous earth), had the greatest reducing effect on the population growth of *A. pistaciae* nymphs as compared to the control ($p \leq 0.0002$; $df_e = 4, 5$; $F = 40.26$) (Fig. 4-b).

Discussion

The use of pesticides in the agriculture industry is excessive, and

approximately 85% of pesticide production worldwide has been applied to the chemical control of various pests.¹⁷ The pesticides used in agriculture are a key issue in human health, especially for those working in the field.¹⁸ Over the years, the prolonged use of chemical pesticides has made the common pistachio psylla resistant to many pesticides, while these pesticides have had a destructive effect on natural enemies.¹⁹ Recent studies have shown the significant effect of using diatomaceous earth and inorganic fertilizers for pest control. Most of these compounds are safe for natural enemies, and their environmental hazards are lower than those of other chemical pesticides.²⁰ Our study showed that although some of the treatments, including (diatomaceous earth+dipotassium hydrogen phosphate), had a great and consistent effect on the population growth rate of the com-

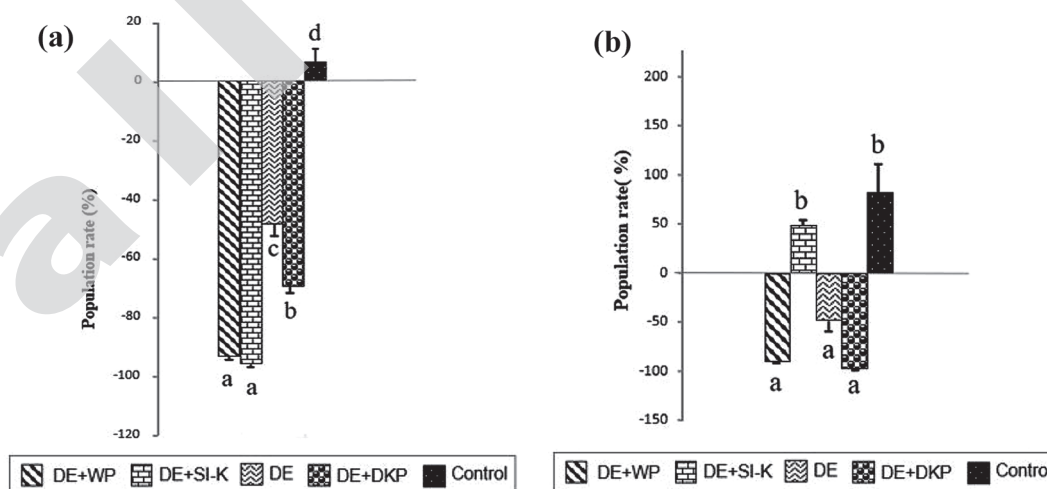


Fig. 4. The effect of 1.0% diatomaceous earth with additives on the population growth of *Agonoscena pistaciae* nymphs 3 days (a) and 12 days (b) after spraying in second-year experiments. DE: diatomaceous earth; WP: polyurethane glue; Si-K: potassium silicate; DKP: dipotassium hydrogen phosphate. Different letters show significant differences ($p \leq 0.0002$).

mon pistachio psylla, depending on various factors, the tested treatments could have a different effect on the mentioned pest. The existing field research showed that the effects of inorganic insecticides can be variable due to disparate environmental conditions and some other unknown factors.²¹⁾ It was observed that the effect of diatomaceous earth-based treatments, including (diatomaceous earth), (diatomaceous earth+dipotassium hydrogen phosphate), and (diatomaceous earth+polyurethane glue), at twelve days post-treatment was greater than that at three days post-treatment. It should be noted that the mentioned positive time correlation was not the case with (diatomaceous earth+potassium silicate). Moreover, we found that the effects of diatomaceous earth can be greatly increased by increasing the concentration. Mahdavian *et al.* reported that the effects of some botanical compounds increased with increasing concentrations.²²⁾ According to both two-year experiments, the diatomaceous earth-based treatments that were mixed with additives clearly reduced the population growth rate more than treatment with diatomaceous earth alone. Therefore, the results demonstrated that the foliar fertilizer dipotassium hydrogen phosphate is probably the best additive when using diatomaceous earth against the common pistachio psylla. Wang *et al.* showed that some adjuvants like organosilicon and polymeric components can increase the effect of pesticides foliar spraying.²³⁾ Diatomaceous earth causes insects to dry out and die by absorbing the oils and fats from the cuticle of their exoskeleton. Diatomaceous earth has sharp edges that are abrasive, speeding up the process. It remains effective as long as it is kept dry and undisturbed.²⁴⁾ Polyurethane glue was used to make diatomaceous earth more stable on leaves and to increase its durability. Desai *et al.* reported on polyurethane as a wood adhesive that is able to bond two woods and some other materials.²⁵⁾ The effect of the DKP content and the water to binder ratio on setting time, fluidity, compressive strength, and drying shrinkage has been reported.²⁶⁾

Conclusion

In the present study, we investigated the insecticidal effects of diatomaceous earth with some additive materials on the common pistachio psylla. The special materials were added to the tank at the beginning of the spraying process, and it was observed that diatomaceous earth as a natural insecticide can decrease the population growth rate of *A. pistaciae* nymphs. In addition, dipotassium hydrogen phosphate and polyurethane glue can greatly increase the effect of diatomaceous earth and increase the efficiency of the foliar spraying. Further research on the factors that affect the effectiveness of diatomaceous earth in pest control is recommended. Studying the effect of diatomaceous earth with additives on the most important natural enemies of the common pistachio psylla is also recommended.

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