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Proceeding Paper

Investigating the Efficacy of Potassium Silicate and Potassium Sulfate against the Pistachio Psyllid (*Agonoscena pistaciae*) under Field Conditions †

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Abstract: Pistachio (*Pistachio vera* L.) is an economically valuable crop, and Iran is among the biggest producers and consumers of this product in the world. The pistachio psyllid (*Agonoscena pistaciae*) is one of the most destructive pests of this crop, resulting in severe damage in terms of yield and quality. Therefore, pistachios are subjected to multiple sprayings with various pesticides during the growing season. As pistachio nuts are exported and largely consumed freshly in Iran, investigating zero-pollution strategies such as applying environmentally safe and non-chemical pesticides to control this pest is essential. In this research, the efficacy of potassium silicate and potassium sulfate against *A. pistaciae* was investigated in a pistachio orchard and compared with some common pesticides, i.e., acetamiprid, imidacloprid, and thiamethoxam. The pistachios were sprayed with commercial formulations of each pesticide using their recommended dosage, and with water (control), using a complete randomized block design (CRBD) with three replicates. Populations of *A. pistaciae* nymphs were evaluated 1 day before and 1, 3, 7, 14, and 21 days following sprayings, by randomly collecting 60 leaves from each treatment. The results showed that all pesticides reached their maximum efficacies (>85%) 3 days after spraying, and no significant differences were observed between the compounds ($p = 0.15$). Over time, however, the efficacy of pesticides decreased dramatically, and potassium silicate (37.97%) and acetamiprid (14.58%) showed the highest and lowest efficacies, respectively ($p < 0.01$). Our results suggest acceptable efficacies of potassium silicate and potassium sulfate as environmentally safe compounds against the pistachio psyllid compared to common chemical pesticides.

Keywords: pistachio; *Agonoscena pistaciae*; pesticides; potassium silicate; potassium sulfate

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1. Introduction

Pistachio (*Pistachio vera* L.) is a tree native to Central Asia, producing edible seeds rich in fatty acids, protein, minerals, and vitamins, which are widely consumed throughout the world [1]. Iran is among the most eminent producers and exporters of this economically valuable crop [2] with a production of 337,815 tons and a harvested area of 12,181 ha in 2019 [3] (FAOSTAT 2019).

The common pistachio psyllid, *Agonoscena pistaciae* Burckhardt and Lauterer (Hem.: Psyllidae) is a destructive insect pest of pistachio trees that causes serious damage to this crop in all pistachio-producing regions of Iran [4,5]. Adults and nymphs of this pest suck leaf sap and produce large amounts of white powder from dried honeydew. Direct feeding of the pest causes reduced plant growth, defoliation, stunting, falling of fruit buds, and poor yield [6].

Chemical control is the main approach adopted by farmers to control *A. psitaciae*, and as a result, vast amounts of chemical pesticides, i.e., acetamiprid, imidacloprid, and thiamethoxam, are used annually against this insect pest [7–9]. Excessive application of these pesticides has led to adverse effects on the health and sustainability of agroecosystems, and to the potential dietary exposure risk for the consumers of pistachio nuts [10,11]. In this regard, investigating zero-pollution approaches through the utilization of environmentally safe and non-chemical pesticides seems crucial.

Potassium silicate (K_2SiO_3) is a naturally occurring compound and is the potassium salt of silicic acid. In formulation, this compound is readily absorbed by plants and provides suppression of mites, whiteflies, and other insects. It is approved for use on crops, fruits, nuts, turf, and ornamentals [12,13]. Potassium silicate is not expected to have adverse effects on humans or the environment [12]. Potassium sulfate (K_2SO_4) is also a water-soluble inorganic compound that is used as a fertilizer and insecticide, and is also reported to improve the resistance of plants against sucking pests [14].

In this research, a field trial was conducted to evaluate the efficacy of two non-chemical environmentally safe pesticides—potassium silicate and potassium sulfate—against populations of the pistachio psyllid. Furthermore, these effects were compared with the conventional chemical pesticides acetamiprid, imidacloprid, and thiamethoxam.

2. Materials and Methods

Field experiments were performed in 1.5 ha pistachio orchard with 11-year-old pistachio trees of Badami-Sefid cultivar located in Roshtkhar, Razavi Khorasan Province, Iran (longitude: 59°13′22″ E; latitude: 34°42′12″ N; altitude: 1145 m). The experimental layout was a complete randomized block design (CRBD) with three replicates, and 10 trees in each block. Treatments consisted of sprayings with recommended dosages of commercial formulations of acetamiprid (Mospilan®; 20% SP; 0.7 g/L; Arman Sabz Adineh Co., Tehran, Iran), imidacloprid (Confidor®; 35% SC; 0.4 g/L; Samiran Co., Tehran, Iran), thiamethoxam (Actara®; 25% WG; 0.4 g/L; Syngenta Co., Basel, Switzerland), potassium silicate (2 g/L; Barafshan Co., Tehran, Iran), potassium sulfate (4 g/L; Héliopotasse Co., Mulhouse, France), and water (control). Sprayings were conducted on 1 August 2020, based on common regional practices, by using a calibrated backpack sprayer (Sam Kubota KF-2202, Japan). Between each plot, one row of pistachio trees was left unsprayed to avoid cross-contamination. All other agricultural practices were conducted under identical conditions in all plots.

Populations of *A. pistaciae* nymphs were evaluated 1 day before and 1, 3, 7, 14, and 21 days following sprayings by randomly collecting 60 leaves from each treatment. Leaves were collected from all sides of the trees at a height of 1.5 m, placed in plastic bags, and transferred to the laboratory in a cold chamber (4 °C). In the laboratory, nymph populations were calculated under a binocular stereomicroscope.

Effectiveness percentages of each pesticide were calculated and corrected according to the control plots based on the Henderson–Tilton formula (Equation (1)).

$$\text{Effectiveness } (\%) = \left[\left(1 - \frac{T_a \times C_b}{T_b \times C_a} \right) \times 100 \right] \quad (1)$$

where T_a and C_a are the number of nymphs in treated and control plots, respectively, after pesticide treatment, and T_b and C_b are the number of nymphs in treated and control plots, respectively, before pesticide treatment.

Data were analyzed using one-way ANOVA, and means were compared using Tukey's HSD method ($p < 0.05$). All data were analyzed using the SAS software version 9.4 (SAS Institute, Cary, NC, USA).

3. Results and Discussion

The results show that initially, at day 1, potassium sulfate (82.95 ± 1.33%), thiamethoxam (80.89 ± 3.35%), and imidacloprid (79.21 ± 5.38%) had the highest efficacies on *A. pistaciae* nymph populations, while potassium silicate (69.99 ± 2.07%) and acetamiprid (60.68 ± 4.52%) had the lowest efficacies ($p < 0.01$) (Figure 1).

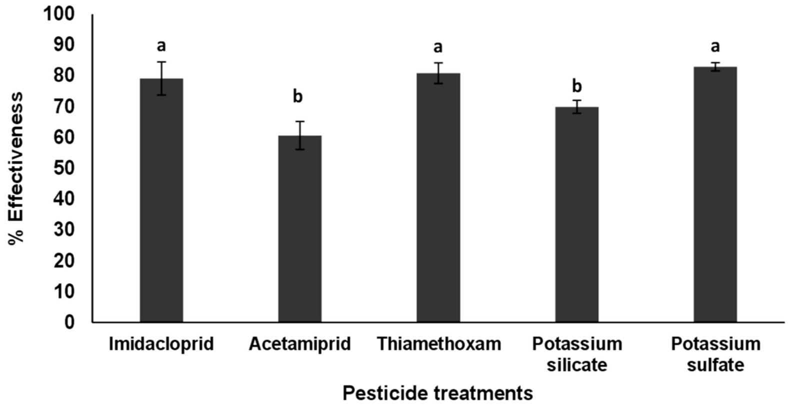

Figure 1. Average effectiveness (%) of pesticides on *A. pistaciae* nymph populations 1 day after sprayings. Error bars represent standard deviations of triplicates. Columns with different letters show a significant difference (Tukey's HSD, $p < 0.01$).

The highest efficacies of all pesticides (>85%) were achieved after 3 days with no significant difference between the treatments ($p > 0.05$) (Figure 2).

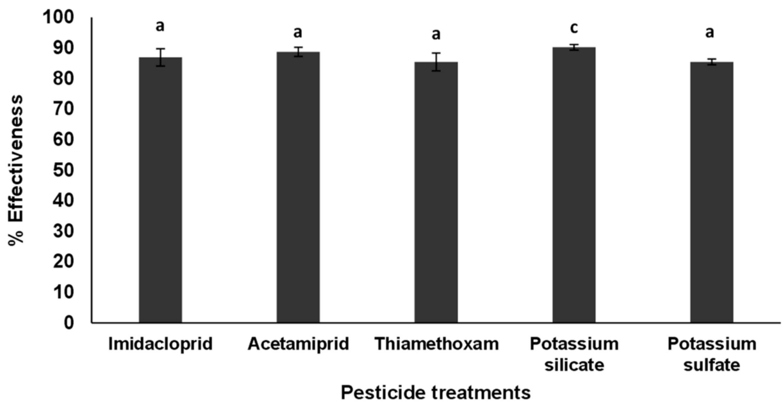

Figure 2. Average effectiveness (%) of pesticides on *A. pistaciae* nymph populations 3 days after sprayings. Error bars represent standard deviations of triplicates. Columns with different letters show a significant difference (Tukey's HSD, $p < 0.01$).

The efficacies of the pesticides, however, decreased from days 7–21 (Figures 3–5). At day 21, potassium silicate showed the highest efficacy (37.97 ± 1.37%) ($p < 0.01$), followed by imidacloprid (24.39 ± 0.88), potassium sulfate (22.97 ± 0.88), and thiamethoxam (19.98 ± 0.26). The lowest efficacy at day 21 belonged to acetamiprid (14.58 ± 2.82) ($p < 0.01$).

Based on our results, the non-chemical pesticides potassium silicate and potassium sulfate showed acceptable initial efficacy against *A. pistaciae* nymph populations compared to the other chemical compounds. Furthermore, even after 21 days, potassium silicate showed the highest control, which reveals its long-lasting effectiveness against *A. pistaciae* nymphs. Potassium silicate, alone or in combination with different pesticides, has been shown to have acceptable efficacy against various pests [15,16]. Powders containing silicon (Si) are known to destroy the lipid surface layer of insects such as *Tribolium castaneum* (Coleoptera: Tenebrionidae) [17]. Furthermore, potassium silicate and other compounds with Si are known to be influential in inducing physical and physiological resistance against pests in plants [18]. Potassium has also been used as a fertilizer and an insecticide, and can enhance plant resistance against insect pests [14].

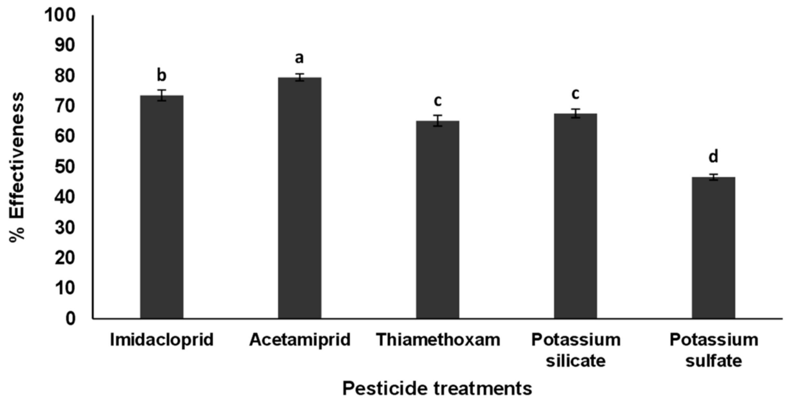

Figure 3. Average effectiveness (%) of pesticides on *A. pistaciae* nymph populations 7 days after sprayings. Error bars represent standard deviations of triplicates. Columns with different letters show a significant difference (Tukey's HSD, $p < 0.01$).

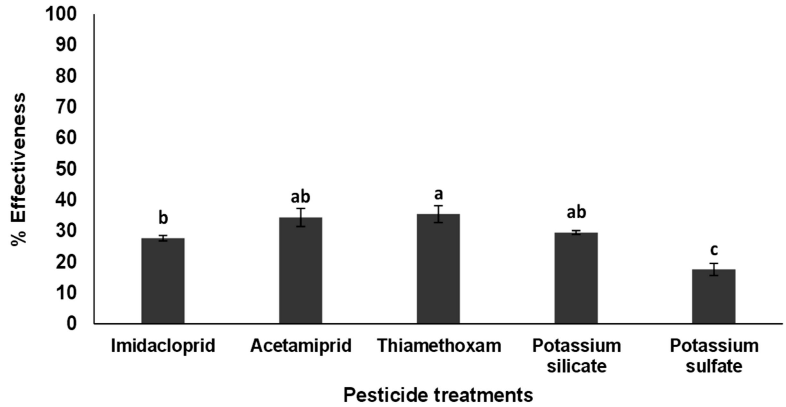

Figure 4. Average effectiveness (%) of pesticides on *A. pistaciae* nymph populations 14 days after sprayings. Error bars represent standard deviations of triplicates. Columns with different letters show a significant difference (Tukey's HSD, $p < 0.01$).

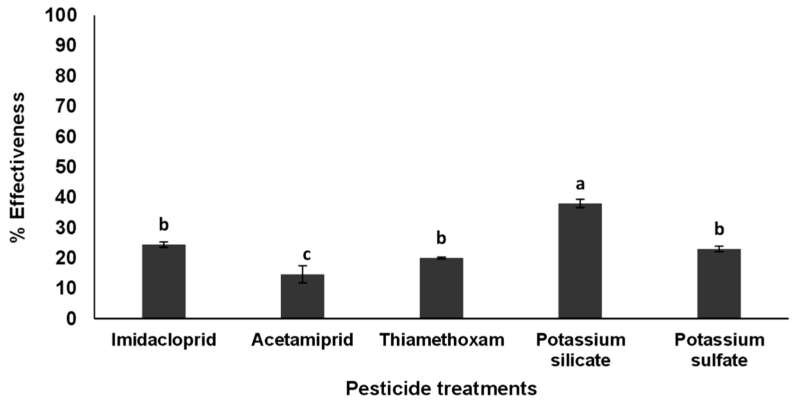

Figure 5. Average effectiveness (%) of pesticides on *A. pistaciae* nymph populations 21 days after sprayings. Error bars represent standard deviations of triplicates. Columns with different letters show a significant difference (Tukey's HSD, $p < 0.01$).

4. Conclusions

The results of our study reveal statistically equal, or even higher, effectiveness and durability of potassium silicate and potassium sulfate against the nymph populations of *A. pistaciae* in pistachio orchards, compared to common chemical insecticides. Therefore, the application of these environmentally safe compounds is suggested as an approach towards adopting zero-pollution solutions for controlling insect pests.

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Conflicts of Interest: The authors declare no conflict of interest.

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