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Short paper

Influence of insecticide application timing on the field efficacy of chemical treatments against *Agonoscena pistaciae* (Hemiptera: Psyllidae)

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Abstract: The pistachio psyllid, *Agonoscena pistaciae* Burckhardt & Lauterer, is one of the most destructive pests of pistachio trees in Iran. This study evaluated the efficacy of five chemical compounds including abamectin (EC 1.8%), acetamiprid (SP 20%), hexaflumuron (EC 10%), hexaflumuron (EC 10%) + abamectin (EC 1.8%), and thiamethoxam (SC 24%) at concentrations of 0.6 ml/L, 0.25 g/L, 0.7 ml/L, 0.5 + 0.3 ml/L, and 0.4 ml/L, respectively. The insecticides were applied at two different timings: early control (second week of May) and late control (fourth week of June) in two pistachio orchards in Isfahan Province, Iran. Nymphal mortality was recorded one day before spraying and at 3, 7, 14, and 21 days post-treatment. In both application times, thiamethoxam and abamectin exhibited the highest and lowest insecticidal efficacy, respectively. The early control was more efficient than the late control in all treatments. Therefore, early application of thiamethoxam is recommended for optimal chemical control of pistachio psyllid.

Keywords: Chemical control, Early control, Late control, Pistachio psyllid, Thiamethoxam

Introduction

The pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Psyllidae), is a major destructive pest of pistachio trees, *Pistacia vera* L., in Iran (Hassani *et al.*, 2009). Both nymphs and adults damage trees by feeding on plant sap, which weakens the trees, causes brown leaf spots, premature leaf and bud drop, reduces kernel weight, and increases blank and non-split nuts. These effects ultimately lead to significant declines in yield and quality (Tusun *et al.*, 2024). According to FAO (2023), the United States was the global leader in pistachio production in 2023, yielding 675,850 tonnes. Iran, which possessed a larger cultivated area of 273,881 hectares (compared to 186,967 hectares in the U.S.), ranked second with an output of 307,866 tonnes. As pistachio represents a high-value crop, effective and timely pest control is

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critical. However, farmers often apply control measures haphazardly, including poorly timed interventions. Although chemical control remains one of the most effective strategies against *A. pistaciae* (Mehrnejad, 2010), the efficacy of insecticides heavily depends on application timing.

The pistachio psyllid requires multiple annual insecticide applications for effective control because it can complete up to 6 generations per year (Hassani *et al.*, 2010; Mehrnejad, 2010). While adopting economic injury levels (EIL) can reduce pesticide use, determining accurate EIL thresholds is complex. Key challenges include the pest's unique feeding behavior, its multi-generational life cycle, varying cultivar susceptibility, and economic factors like input costs and market values. Field surveys indicate that approximately 95% of Iranian pistachio growers implement their first pesticide application during spring (March-June) following initial monitoring (Hosseininaveh & Abbasi, 2019).

To date, multiple classes of insecticides, including neonicotinoids and insect growth regulators (IGRs), have been registered in Iran for controlling psyllids and other pistachio pests (PPO, 2025). Several laboratory and field studies have documented the efficacy of various insecticides against *A. pistaciae* (Amirzade *et al.*, 2014; Rouhani *et al.*, 2019; Tusun *et al.*, 2024). Given the pest's significant economic impact, Iranian farmers routinely use various insecticides to control *A. pistaciae*. Therefore, although abamectin is not registered for this pest, it was selected for this study because local growers commonly apply it. Since the optimal timing of insecticide application is crucial for successful pest control (Tang *et al*., 2010), this study aims to assess the field performance of five insecticides applied at two distinct timings for pistachio psyllid management.

Materials and Methods

In this study, the efficacy of five chemical compounds, including Abamectin (Vertimec® EC 1.8%), Acetamiprid (Mospilan® SP 20%), Hexaflumuron (Consult® EC 10%), Hexaflumuron (Consult® EC 10%) + Abamectin (Vertimec® EC 1.8%), and Thiamethoxam (Memory® SC 24%) was evaluated against pistachio psylla nymphs under field conditions. The tested concentrations were 0.6 ml/L, 0.25 g/L, 0.7 ml/L, 0.5 + 0.3 ml/L, and 0.4 ml/L, respectively. The insecticides were selected based on consultations with local agricultural advisors and producers in the study region. The experiment was conducted in two pistachio orchards located in Rahimabad village (32°46′N, 51°91′E, 1534 m) and Hosseinabad village (32°35′N, 52°16′E, 1572 m) in Isfahan province, Iran. The orchards consisted of 13-year-old Ahmadaghaei variety trees, which were uniformly managed for irrigation, fertilization, planting intervals, and crop load in accordance with regional standards. Chemical applications were timed for early (second week of May, Rahimabad) and late control (fourth week of June, Hosseinabad) in 2022. A randomized complete block design with five replications was employed. Insecticides were applied using a 20-L backpack engine-powered sprayer with a single-nozzle lance, and the sprayer was thoroughly cleaned between treatments. A water-only treatment served as the control. For sampling, five central trees per treatment were selected, and five compound leaves were collected from each tree at mid-canopy height from various directions. Nymphs of *A. pistaciae* on both leaf surfaces were counted and recorded. The economic injury threshold for this pest is reported as 20–30 nymphs per compound leaf (Tusun *et al.*, 2024). Samples were transported to the laboratory in ventilated containers (11 × 10 × 4 cm), and live insects were counted under a stereomicroscope (20× magnification). Psyllid nymph populations were recorded one day before and 3, 7, 14, and 21 days after spraying (Mahdavian *et al.*, 2021), without differentiation between nymphal stages. Efficacy was calculated using the Henderson-Tilton formula (1955). Normality of the data was assessed with the Kolmogorov-Smirnov test. Statistical comparisons were performed using one-way ANOVA (to assess differences in insecticide

efficacy among treatments on a given sampling day) and an independent-samples t-test (to compare early and late control applications). Where ANOVA results were significant, means were separated using Tukey's HSD test at $P < 0.05$. The data were analyzed using IBM SPSS Statistics v.22.0 (IBM Corp., 2013).

Results and Discussion

Table 1 presents the mean percent efficacy of abamectin, acetamiprid, hexaflumuron, hexaflumuron + abamectin, and thiamethoxam at 3, 7, 14, and 21 days post-application during mid-May (early control period). Among the tested insecticides, thiamethoxam exhibited the highest efficacy. The lethality of this insecticide was about 60% for up to 21 days after spraying, which was significantly higher than that of acetamiprid and abamectin. Abamectin showed the lowest insecticidal activity, and its combination with hexaflumuron did not significantly enhance hexaflumuron's toxicity. Notably, all insecticides (except abamectin) exceeded 70% efficacy against *A. pistaciae* for up to one week after spraying (Table 1).

During late control of psyllids, thiamethoxam and abamectin still exhibited the highest and lowest insecticidal efficacy, respectively; However, this difference was not statistically significant by 21 days post-treatment (Table 2). Furthermore, no significant differential efficacy was observed between the two neonicotinoids (thiamethoxam and acetamiprid) at any post-treatment interval. In contrast, when these insecticides were applied in mid-May (early-season control), their efficacy showed significant differences at 7, 14, and 21 days post-treatment (Table 1). The early control was more efficient than the late control in all treatments. This difference was particularly pronounced (statistically significant) at 3, 7, and 14 days post-treatment (Tables 1 and 2).

This study investigated temporal management strategies of pistachio psyllid control and their impact on the efficacy of recommended and commonly used insecticides. Our findings demonstrate that insecticide application timing significantly influences *A. pistaciae* control efficacy. Similarly, Abdolahi-Ezzatabadi *et al.* (2023) reported that temporal management knowledge for pistachio pests (including *A. pistaciae*) does not enhance pistachio yield but increases pesticide productivity and reduces application rate (0.477 l/ha/year). Indeed, optimizing application timing and the resulting increase in insecticide efficacy not only reduces spraying costs but also diminishes ecotoxicological impacts by reducing application volume or frequency (Abdolahi-Ezzatabadi *et al.*, 2023).

Table 1 Efficiency of insecticides on nymphal stage of *Agonoscena pistaciae* at different days after spraying in Rahimabad village (middle May-early control).

Insecticides	%Efficiency (± SE) [1]			
	3 DAT[2]	7 DAT	14 DAT	21 DAT
Abamectin	54.89 ± 1.74 c*	43.06 ± 3.30 c*	40.59 ± 6.04 c	22.78 ± 3.95 c
Acetamiprid	83.60 ± 2.74 ab*	74.82 ± 1.86 b*	55.15 ± 3.28 bc*	38.24 ± 5.86 bc
Hexaflumuron	76.24 ± 4.98 b*	82.63 ± 0.94 ab*	65.31 ± 2.79 ab*	51.10 ± 3.90 ab*
Hexaflumuron + Abamectin	81.20 ± 1.80 ab*	79.72 ± 1.25 ab*	60.35 ± 4.03 ab*	41.28 ± 6.29 abc
Thiamethoxam	90.97 ± 0.52 a*	84.85 ± 3.05 a*	75.44 ± 4.73 a*	59.97 ± 3.73 a*
F	23.922	67.887	8.873	8.294
df	4, 20	4, 20	4, 20	4, 20
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[1] Means followed by different letters within each column are significantly different ($P < 0.05$, Tukey's test).
[2] Days after treatment (DAT).
*Means marked with an asterisk indicate a significant difference between early and late controls at 5% level (using t-student test).

Table 2 Efficiency of insecticides on nymphal stage of *Agonoscena pistaciae* at different days after spraying in Hosseinabad village (late June-late season).

Insecticides	%Efficiency (± SE)[1]			
	3 DAT[2]	7 DAT	14 DAT	21 DAT
Abamectin	33.27 ± 2.84 b*	30.68 ± 1.84 d*	23.18 ± 5.36 b	19.12 ± 2.03 a
Acetamiprid	49.62 ± 4.93 ab*	54.28 ± 2.54 ab*	35.16 ± 5.15 ab*	24.28 ± 4.64 a
Hexaflumuron	40.53 ± 2.54 b*	49.48 ± 1.30 bc*	38.85 ± 3.56 ab*	28.19 ± 3.58 a*
Hexaflumuron + Abamectin	45.84 ± 3.82 ab*	40.59 ± 3.87 cd*	33.22 ± 2.98 ab*	25.83 ± 3.07 a
Thiamethoxam	58.72 ± 5.57 a*	61.42 ± 2.91 a*	50.23 ± 3.17 a*	32.08 ± 4.22 a*
F	5.413	20.516	5.514	1.748
df	4, 20	4, 20	4, 20	4, 20
P	< 0.004	< 0.0001	< 0.004	= 0.179

[1] Means followed by different letters within each column are significantly different ($P < 0.05$, Tukey's test).
[2] Days after treatment (DAT).
*Means marked with an asterisk indicate a significant difference between early and late controls at 5% level (using t-student test).

Saour (2005) demonstrated that teflubenzuron (IGR) and thiacloprid (neonicotinoid) provided effective control of pistachio psyllid *Agonoscena targionii* Lichtenstein damage when applied early in the season. In contrast, mid-season kaolin-based coatings (when psyllid population pressure peaked) effectively reduced nymphal damage. Chemical control of psyllids is challenging under elevated temperatures because of their extended seasonal activity period, during which they undergo significant morphological, physiological, and behavioral adaptations (Saour, 2005). Furthermore, the diminished efficacy of late applications observed in the present study may be attributed to increases in pest populations and generational overlap during warmer months (Srinivasa Rao *et al.*, 2022).

Abamectin (avermectin class) demonstrated consistently poor efficacy against *A. pistaciae* at both application timings across all evaluation periods (Tables 1 and 2). This limited performance likely results from abamectin's poor systemic activity and its mode of action. Abamectin exerts its effects by activating glutamate-gated chloride channels, leading to rapid paralysis in target insects (Wolstenholme & Rogers, 2005). In contrast, three effective insecticides were evaluated: thiamethoxam, acetamiprid (a neonicotinoid), and hexaflumuron (an IGR). These compounds have systemic activity with both contact and stomach effects. Neonicotinoids target nicotinic acetylcholine receptors, while hexaflumuron inhibits chitin formation and disrupts insect molting (Tunaz & Uygun, 2004; Simon-Delso *et al.*, 2015). Tang *et al.* (2021) reported that thiamethoxam and acetamiprid exhibited high toxicity, whereas pyriproxyfen and buprofezin (IGRs) showed moderate toxicity against the Asian citrus psyllid, *Diaphorina citri* Kuwayama. Similarly, Bemani *et al.* (2018) compared the insecticide susceptibility of different populations of the pistachio psyllid and its predator (*Oenopia conglobata* L.) in Iran, finding that both insects were more sensitive to acetamiprid than to spirotetramat or hexaflumuron.

In the present study, field trials in Isfahan pistachio orchards (2022) revealed that application timing significantly alters insecticide efficacy against *A. pistaciae*. Specifically, early-season (mid-May) treatments with thiamethoxam achieved 90.97% nymphal mortality at 3 days post-treatment, whereas late-season (late-June) applications of the same insecticide yielded only 58.72%. Nevertheless, in pistachio orchards, early, mid, and late seasons are all critical periods for appropriate management due to the multivoltine life cycle and feeding behavior of this pest (Mehrnejad, 2013). Given the consistently low efficacy of abamectin across both application timings, it is recommended that growers exclude this

insecticide from psyllid management programs. Substituting more effective alternatives (thiamethoxam, acetamiprid, and hexaflumuron) will prevent unnecessary costs and minimize the risk of insecticide resistance.

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Conflict of Interest

The authors declare no conflict of interest.

Author's Contributions

Mehran Rezaei: Conceptualization, methodology, formal analysis, investigation, draft preparation, final review and edit, and project administration. Fatemeh Graily-Moradi: formal analysis, draft preparation, and final review and edit. Mohammad Ali Mirhosseini: formal analysis, draft preparation, and final review and edit.

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بررسی تأثیر زمان‌بندی کاربرد حشره‌کش‌ها بر کارایی کنترل شیمیایی پسیل پسته *Agonoscena pistaciae* (Hemiptera: Psyllidae) در شرایط مزرعه

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چکیده: پسیل پسته، *Agonoscena pistaciae* Burckhardt & Lauterer، یکی از مخرب‌ترین آفات درختان پسته در ایران است. در این مطالعه کارایی پنج حشره‌کش شامل آبامکتین (EC 1.8%)، استامی‌پراید (SP 20%)، هگزافلومورون (EC 10%)، هگزافلومورون (EC 10%) + آبامکتین (EC 1.8%) و تیامتوکسام (SC 24%) به‌ترتیب در غلظت‌های ۰/۶ میلی‌لیتر بر لیتر، ۰/۲۵ گرم بر لیتر، ۰/۷ میلی‌لیتر بر لیتر، ۰/۵ + ۰/۳ میلی‌لیتر بر لیتر و ۰/۴ میلی‌لیتر ارزیابی شد. حشره‌کش‌ها در دو زمان کنترل زودهنگام (هفته دوم اردیبهشت) و کنترل دیرهنگام (هفته چهارم خرداد)، در دو باغ پسته در استان اصفهان استفاده شد. میزان تلفات پوره‌های پسیل یک روز قبل از سمپاشی و در روزهای سوم، هفتم، چهاردهم و بیست و یکم پس از تیمار ثبت شدند. در هر دو زمان کنترل، به‌ترتیب بیشترین و کم‌ترین اثر حشره‌کشی مربوط به تیامتوکسام و آبامکتین بود. هم‌چنین کاربرد زود هنگام این حشره‌کش‌ها مؤثرتر از کاربرد دیرهنگام آن‌ها در تمامی تیمارها بود. بنابراین می‌توان کاربرد زودهنگام تیامتوکسام را به‌عنوان یک حشره‌کش مؤثر برای کنترل شیمیایی پسیل پسته پیشنهاد نمود.

واژگان کلیدی: کنترل شیمیایی، کنترل زودهنگام، کنترل دیرهنگام، پسیل پسته، تیامتوکسام