Turkish Journal of Agriculture - Food Science and Technology, 12(s1): 2082-2088, 2024
DOI: https://doi.org/10.24925/turjaf.v12is1.2082-2088.7078

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effects of Some Insecticides on *Agonoscena pistaciae* Burckhardt & Lauterer (Hemiptera: Psyllidae)

Adnan Tusun[1,a,*], Çağlar Kalkan[1,b], Serdar Satar[1,c]

[1] *Department of Plant Protection, Faculty of Agriculture, Cukurova University, Balcalı, Adana 01330, Türkiye*
[*] *Corresponding author*

ARTICLE INFO

Research Article

Received : 20.08.2024
Accepted : 29.10.2024

Keywords:
Agonoscena pistaciae
Biological activity
Chemical control
Spirotetramat
Insecticides

ABSTRACT

Chemical control is the most common method used to control *Agonoscena pistaciae* Burckhardt & Lauterer (Hemiptera: Psyllidae). This study compared the application of the five most widely used insecticides in the management of *A. pistaciae* which has resulted in significant yield losses, in Siirt (Kurtalan) and Şanlıurfa (Birecik) in 2023. Active ingredients spinetoram, lambda-cyhalothrin, deltamethrin, sulfoxaflor, and spirotetramat were examined in the study. The study was designed with four replications, and its characters were formed by the insecticides registered concentration and the control. The plots measured 3 x 3 = 9 trees. Nymph and adult counts were conducted from the middle trees before, as well as 7, 14, and 21 days after application following the application of the spray. The Henderson-Tilton formula was used to analyze the counting data for nymph or adult counts in each plot of leaf samples. All registered active ingredients effected the *A. pistaciae* above %80 all count days. Among the active ingredients the biological efficacy of spirotetramat was the highest compared to other insecticides. These active ingredients can be used to control *A. pistaciae*, with consideration given to the pest's potential resistance to insecticides and the impact of the ingredients on natural enemies.

[a] *adnantusun@gmail.com* *https://orcid.org/0000-0003-4492-120X*
[b] *ckalkan@cu.edu.tr* *https://orcid.org/0000-0003-3915-4827*
[c] *hserhat@cu.edu.tr* *https://orcid.org/0000-0003-0449-205X*

Introduction

Pistachio psyllid, *Agonoscena pistaciae* Burckhardt & Lauterer (Hemiptera: Psyllidae) is one of the most important pests in pistachio-growing regions in Türkiye. For half a century, *A. pistaciae* has been causing great economic losses in pistachio orchards in the world. The pistachio psyllid is found in many pistachio-growing areas around the borders of Türkiye, including Armenia, Iraq, Turkmenistan, and Iran, as well as in Mediterranean regions such as Greece and Syria (Burckhardt & Lauterer, 1989, Burckhardt & Lauterer, 1993, Mart et al., 1995; Lauterer et al., 1998). According to Tokmakoğlu (1973), *A. pistaciae* was detected for the first time in Türkiye by *A. targionii* Licth in pistachio orchards in Gaziantep province. Additionally, in previous studies, many researchers identified the psyllid species as *A. succincta* Heeg. (Çelik, 1975; Klimaszewski & Lodos, 1977; Günaydın, 1978). Burckhardt & Önuçar (1993) reported that the species found in pistachio fields in the Southeastern Anatolia Region was *A. pistaciae*, not *A. targionii* or *A. succincta*. Both nymphs and adults of the pistachio psyllid are harmful by sucking leaf sap. They also produce large amounts of honeydew, leading to the formation of sooty mold. By feeding directly on tree leaves, *A. pistaciae* causes the trees to lose vitality, become stunted, bud drop, leaf shedding, and yield decrease (Samih et al., 2005). Therefore, the control of *A. pistaciae* is very important.

While it has been reported that psyllids are difficult to control using only pesticides, it has been reported that as a result of chemical control, psyllids develop morphological, physiological, and behavioral changes and are active throughout most of the year (Horton, 1999). For years, farmers have been unconsciously spraying pesticides against this pest, which is important in pistachio fields in Türkiye. As a result of this, negativities such as residue on the plant, destruction of natural enemies, negative effects on the environment and human health, as well as resistance to the pest in a short time, occur, and as a result of these, the control becomes more complex. In addition, some of these pesticides have been reported to use biological control agents used to control the pistachio psyllid by negatively affecting their populations, which can then emerge more easily and more intensely with the pressure of a natural enemy that does not remain above the pest (Mehrnejad, 2003). *Psyllaephagus pistaciae* Ferrière

(Hymenoptera: Encyrtidae) and *Oenopia conglobata* (Linnaeaus) (Coleoptera: Coccinellidae) have been reported to be the main biological control agents for pistachio psyllid (Mehrnejad, 2001; Bolu, 2004). It has been reported that among natural enemies, especially *O. conglobata*, can be seen on pistachio psyllid populations all year round, that both adult and larval stages can predator, and that it can feed on all stages of the pest, and that this predator has a better potential in biological control than other predators and parasitoids (Bolu, 2004). However, natural enemies alone cannot keep the *A. pistaciae* population below the economic damage threshold. Therefore, the use of chemical control becomes inevitable. Active ingredients used within the scope of integrated control should also have low negative effects on the natural enemies of *A. pistaciae*.

Some studies are on the detection, population development, and control of *A. pistaciae* on pistachio trees in Türkiye. Most of these studies (Tokmakoğlu, 1973; Günaydın, 1978; Çelik, 1981; Bolu & Kornoşor, 1995; Mart et al., 1995; Kaplan & Çınar, 2000; Şimşek & Bolu, 2017; Kaplan & Çiftçi, 2020; Özgen et al., 2022) are in the Southeastern Anatolia Region. The aim of this study was to determine whether the insecticides used in the control of *A. pistaciae* in field conditions continue to be effective in field conditions.

Material and Method

Insecticides

The insecticides used in the trial were determined as a result of interviews with consultants and producers working in the region. In the interviews, it was found that spirotetramat was the most widely used insecticide, with other active ingredients being used less frequently. To assess the differences in effectiveness, other active ingredients were favored for comparison against spirotetramat, which has been in use for is more commonly applied (Table 1).

Experimental Design

While selecting the pistachio orchards where the trials will be established, it was paid attention that the age, variety, and planting intervals of the trees were homogeneous. Biological efficacy trials were conducted according to the method of the Ministry of Agriculture of the Republic of Türkiye. The trials were carried out in 4 different locations in Arslanlı and Bağlarbaşı neighborhoods in Birecik district of Şanlıurfa province and Yunuslar and Avcılar neighborhoods in Kurtalan district of Siirt province, where the pest is above the economic damage threshold of 20-30 nymphs per compound leaf. The trials were established in Birecik district on 07.05.2023 and in Kurtalan district on 03.06.2023. The trials were carried out according to the randomize blocks design with 3x3=9 trees as one plot. In addition, a control plot without spraying was established. The number of replications was set as 4. Information about the insecticides used in the study is given in Table 1. For the counts, 10 old and 10 young compound leaf samples were taken from the trees in the middle of each plot on 10 labelled shoots. Counts were made once in the field before application. After the spraying, counts were made four times on days 3, 7, 14 and 21. The count results were evaluated according to the Henderson-Tilton formula based on the number of live insects counted in each plot in leaf samples.

Data Analysis

The effect rates of insecticides tested under field conditions on *A. pistaciae* populations were calculated using the Henderson-Tilton formula (1955).

$$\text{Corrected \%} = \left(1 - \frac{\text{n in CBT} \times \text{n in TAT}}{\text{n in CAT} * \text{n in TBT}}\right) * 100$$

CBT : Control before treatment
CAT : Control after treatment
TAT : Treated after treatment
TBT : Treated before treatment
*n : Insect population

The normality of the data obtained from the experiment on the effects of different pesticide applications on *A. pistaciae* and the Henderson-Tilton corrected data was checked with the Shapiro Wilk test. The homogeneity of the data was checked with the Levene's test. Since the data showed normal and homogeneity distribution, one-way ANOVA was applied to detect differences between the applications and Henderson-Tilton data. Tukey HSD test was used in multiple comparison tests to detect the difference between means of treatments. (IBM SPSS 20.0 Statistical package; SPSS Inc., Armonk, NY). General Linear Model (GLM) analysis was applied to the data to assess the effects of weeks, treatments, and their interactions (GLM, Univariate; α=0.05).

Results

The results of the trials conducted in 4 different locations in Şanlıurfa and Siirt are given in Tables 2, 3, 4, and 5. In the trial conducted in Arslanlı neighborhood of Birecik district of Şanlıurfa, 3 days after the application (daa), the most effective active ingredients were determined to be spirotetramat with 93.46% effectiveness and deltamethrin with 92.96% effectiveness ($F_{4, 15}$=11.54; $P < 0.001$; Table 2).

Table 1. Information on insecticides used in the studies.

Company	Trade name	Active ingredient	Formulation type	Concentration
Corteva	Delegate 250 WG	%25 Spinetoram	WG	30 g/100 lt
Koruma	Kung-fu 5 EC	50 g/l Lambda-cyhalothrin	EC	20 ml /100 lt
Bayer	Decis 2.5 EC	25 g/l Deltamethrin	EC	30 ml /100 lt
Corteva	Transform 500 WG	%50 Sulfoxaflor	WG	15 g/100 lt
Bayer	Movento SC 100	100 g/l Spirotetramat	SC	100 ml/100 lt

Table 2. Results of the biological activity trial established in the Arslanlı neighborhood of Şanlıurfa/Birecik district.

Active ingredient	R	Live individuals					Henderson-Tilton Efficacy (%)			
		BA	3 DAA	7 DAA	14 DAA	21 DAA	3 DAA	7 DAA	14 DAA	21 DAA
Spinetoram	1	1220	125	101	56	88	90.17	93.01	96.48	95.03
	2	1093	79	89	81	103	93.28	92.89	93.84	92.88
	3	517	112	101	93	141	80.29	83.61	85.88	79.81
	4	794	104	87	79	87	87.62	90.19	91.83	91.54
	Mean	906	105±2.77	94.5±2.2	77.25±2.25	104.75±3.41	87.84 ba[a]	89.92 bc	92.01 bc	89.91 bc
Lambda-cyhalothrin	1	1341	259	241	207	211	81.48	84.84	88.15	89.15
	2	1081	191	182	197	208	83.57	85.30	84.86	85.45
	3	1127	218	231	180	194	82.40	82.80	87.47	87.26
	4	1042	225	199	162	172	79.58	82.89	87.23	87.26
	Mean	1147.75	223.25±3.84	213.25±3.65	186.5±3.72	196.25±3.76	81.76 b	83.96 d	86.93 d	87.28 c
Deltamethrin	1	1313	51	48	37	50	96.27	96.92	97.84	97.37
	2	1172	99	81	71	96	92.15	93.96	94.97	93.81
	3	1018	89	79	68	77	92.04	93.49	94.76	94.40
	4	1009	92	59	37	82	91.38	94.76	96.99	93.73
	Mean	1128	82.75±1.12	66.75±0.76	53.25±0.76	76.25±0.86	92.96 a	94.78 ab	96.14 ba	94.83 ab
Sulfoxaflor	1	981	153	131	121	125	85.04	88.73	90.53	91.21
	2	1091	149	140	135	142	87.30	88.79	89.72	90.16
	3	1037	155	151	133	138	86.40	87.78	89.93	90.15
	4	1108	162	156	122	147	86.18	87.39	90.96	89.76
	Mean	1054.25	154.75±2.46	144.5±2.35	127.75±2.26	138 ±2.31	86.23 b	88.17 cd	90.29 cd	90.32 bc
Spirotetramat	1	871	64	41	28	28	92.95	96.03	97.53	97.78
	2	967	84	39	27	21	91.92	96.48	97.68	98.36
	3	981	55	37	27	23	94.90	96.83	97.84	98.26
	4	1007	63	29	22	17	94.08	97.42	98.21	98.70
	Mean	956.5	66.5±0.65	36.5±0.29	26±0.15	22.25± 0.19	93.46 a	96.69 a	97.81 a	98.28 a
Control	1	751	783	890	978	1089	0.00	0.00	0.00	0.00
	2	951	1023	1089	1145	1258	0.00	0.00	0.00	0.00
	3	981	1078	1169	1250	1325	0.00	0.00	0.00	0.00
	4	850	899	949	1035	1101	0.00	0.00	0.00	0.00
	Mean[a]	883.25	945.75 a	1024.25 a	1102 a	1193.25 a				

R: Replication; BA: Before App.; [a]means followed by different letters in the same column are significantly different according to Tukey HSD tests (P<0.001)

Table 3. Results of the biological activity trial established in the Bağlarbaşı neighborhood of Şanlıurfa/Birecik district.

Active ingredient	R	Live individuals					Henderson-Tilton Efficacy (%)			
		BA	3 DAA	7 DAA	14 DAA	21 DAA	3 DAA	7 DAA	14 DAA	21DAA
Spinetoram	1	1346	256	201	81	151	81.43	86.33	94.88	91.22
	2	989	69	55	88	117	93.29	94.92	92.31	91.11
	3	1213	198	133	113	149	84.87	90.86	92.98	91.68
	4	1411	238	178	142	111	84.03	88.62	91.68	93.92
	Mean	1239.75	190.25±2.17	141.75±1.23	106±0.79	132±1.31	85.90 c[a]	90.18 b	92.96 b	91.98 b
Lambda-cyhalothrin	1	851	166	140	135	127	80.95	84.94	86.50	88.32
	2	1123	147	154	128	181	87.42	87.48	90.15	87.89
	3	1284	221	187	161	152	84.04	87.85	90.55	91.98
	4	1349	187	190	158	182	86.87	87.30	90.32	89.57
	Mean	1151.75	180.25±3.34	167.75±3.91	145.5±3.54	160.5±3.82	84.82 c	86.89 b	89.38 c	89.44 b
Deltamethrin	1	1250	58	45	34	43	95.47	96.70	97.69	97.31
	2	1078	71	65	58	65	93.67	94.50	95.35	95.47
	3	1207	82	72	51	62	93.70	95.02	96.82	96.52
	4	1155	87	75	31	45	92.87	94.14	97.78	96.99
	Mean	1172.5	74.5±0.39	64.25±0.21	43.5±0.13	53.75±0.74	93.93 ab	95.09 a	96.91 a	96.57 a
Sulfoxaflor	1	894	123	111	101	127	86.56	88.63	90.39	88.88
	2	982	107	99	85	109	89.53	90.80	92.52	91.66
	3	1018	118	108	121	132	89.25	91.15	91.04	91.22
	4	964	138	127	110	118	86.45	88.12	90.57	90.53
	Mean	964.5	121.5±1.11	111.25±1.55	104.25±1.01	121.5±1.21	87.95 bc	89.67 b	91.13 bc	90.57 b
Spirotetramat	1	1278	55	45	33	35	95.80	96.78	97.80	97.86
	2	1078	78	64	56	56	93.04	94.58	95.51	96.10
	3	1353	69	46	28	29	95.27	97.16	98.44	98.55
	4	1289	59	42	34	17	95.67	97.06	97.82	98.98
	Mean	1249.5	65.25±0.45	49.25±0.57	37.75±0.33	34.25±0.15	94.94 a	96.40 a	97.39 a	97.87 a
Control	1	792	811	865	931	1012	0.00	0.00	0.00	0.00
	2	818	851	896	947	1089	0.00	0.00	0.00	0.00
	3	789	851	946	1047	1165	0.00	0.00	0.00	0.00
	4	891	941	988	1078	1152	0.00	0.00	0.00	0.00
	Mean	822.5	863.5	923.75	1000.75	1104.5				

R: Replication; BA: BA: Before App; [a]means followed by different letters in the same column are significantly different according to Tukey HSD tests (P<0.001)

Table 4. Results of the biological activity trial established in the Yunuslar neighborhood of Siirt/Kurtalan district.

Active ingredient	R	Live individuals					Henderson-Tilton Efficacy (%)			
		BA	3 DAA	7 DAA	14 DAA	21 DAA	3 DAA	7 DAA	14 DAA	21 DAA
Spinetoram	1	954	112	91	82	96	88.64	91.10	92.24	91.39
	2	857	90	86	74	101	89.65	90.62	92.26	89.89
	3	893	95	89	94	123	89.60	90.85	90.78	88.34
	4	1009	97	91	87	94	90.85	91.68	92.38	92.24
	Mean	928.25	98.5±0.23	89.25±0.6	84.25±0.8	103.5±0.93	89.69 b[a]	91.06 b	91.92 bc	90.46 b
Lambda-cyhalothrin	1	1171	184	155	143	161	84.80	87.65	88.97	88.23
	2	1001	134	126	103	134	86.81	88.24	90.77	88.52
	3	988	167	161	164	162	83.47	85.04	85.47	86.12
	4	931	169	141	111	121	82.72	86.02	89.47	89.17
	Mean	1022.75	163.5±1.46	145.75±1.89	130.25±1.56	144.5±1.68	84.45 c	86.74 c	88.67 d	88.01 b
Deltamethrin	1	979	71	57	58	34	92.98	94.57	94.65	97.03
	2	897	56	55	46	48	93.85	94.27	95.40	95.41
	3	1008	78	67	69	75	92.43	93.90	94.01	93.70
	4	1093	84	82	85	89	92.68	93.08	93.13	93.22
	Mean	994.25	72.25±0.45	65.25±0.21	64.5±0.32	61.5±0.36	92.99 a	93.95 a	94.30 ab	94.84 a
Sulfoxaflor	1	1071	120	125	110	145	89.16	89.11	90.73	88.41
	2	1093	115	123	89	131	89.63	89.48	92.70	89.72
	3	921	89	95	95	110	90.55	90.53	90.97	89.89
	4	847	97	86	87	114	89.10	90.63	90.93	88.79
	Mean	983	105.25±1.23	107.25±1.67	95.25±1.79	125±1.91	89.61 b	89.94 b	91.33 cd	89.20 b
Spirotetramat	1	1102	61	57	51	66	94.64	95.17	95.82	94.87
	2	1037	74	66	45	47	92.97	94.05	96.11	96.11
	3	1055	59	59	46	51	94.53	94.87	96.18	95.91
	4	1123	64	65	36	55	94.58	94.66	97.17	95.92
	Mean	1079.25	64.5±0.68	61.75±0.29	44.5±0.13	54.75±0.45	94.18 a	94.69 a	96.32 a	95.70 a
Control	1	1218	1259	1305	1349	1423	0.00	0.00	0.00	0.00
	2	1128	1145	1207	1258	1315	0.00	0.00	0.00	0.00
	3	1098	1123	1196	1254	1297	0.00	0.00	0.00	0.00
	4	1067	1121	1156	1208	1281	0.00	0.00	0.00	0.00
	Mean	1127.75	1162	1216	1267.25	1329				

R: Replication; BA: BA: Before App; [a]means followed by different letters in the same column are significantly different according to Tukey HSD tests (P<0.001)

In the counts made 21 days after the application, spirotetramat showed a high effect with 98.28% and was statistically separated from other active ingredients ($F_{4,15}$=6.975; P = 0.002; Table 2). In the trial conducted in the Bağlarbaşı neighborhood of Birecik district of Şanlıurfa, an effect of over 90% was observed in deltamethrin and spirotetramat applications 3 days after the application. Spirotetramat was in a different group compared to other applications ($F_{4,15}$=10.34; P<0.001; Table 3). 21 days after the application, an effect of over 90% was calculated for deltamethrin, spinetoram, sulfoxaflor, and spirotetramat applications. Spirotetramat and deltamethrin were statistically separated from other active ingredients ($F_{4,15}$=31.00; P<0.001; Table 3).

In Siirt, another province where the trials were conducted, in the Yunuslar neighborhood of Kurtalan district, the effectiveness rates for lambda-cyhalothrin, sulfoxaflor, spinetoram, deltamethrin, and spirotetramat were determined as 84.45, 89.61, 89.69, 92.99 and 94.18%, respectively, 3 days after the application (Table 4). Again, spirotetramat and deltamethrin were in a statistically separate group ($F_{4,15}$=50.93; P<0.001; Table 4). In the counts made 21 days after the application, an effect of over 90% was observed in spinetoram, deltamethrin, and spirotetramat applications. In the trial conducted in the Avcılar neighborhood of Kurtalan, it was determined that spinetoram, deltamethrin, and spirotetramat had an effect of over 90% 3 days after the application, and spirotetramat was statistically in a separate group ($F_{4,15}$=16.29; P<0.001; Table 5). After 21 days of application, active ingredients except lambda-cyhalothrin showed an effect of over 90%. Spirotetramat, deltamethrin, and spinetoram were statistically separated from the others ($F_{4,15}$=30.07; P<0.001; Table 5).

As a result of the General Linear Model analysis, treatments, counts, and their interactions were found to be statistically significant at all experimental locations (Table 6).

Discussion

Insecticides are the most important component of current control methods to reduce the damage of *A. pistaciae*. In the biological effectiveness trials conducted in Şanlıurfa and Siirt provinces in the Southeastern Anatolia Region of Türkiye, it was revealed that the insecticides registered for *A. pistaciae* and included in the trial were highly effective on the nymphs of this pest and could be used in pest control. Among the insecticides used in the trials, spirotetramat, which is among the Tetronic and Tetramic Acid Derivatives according to the IRAC MoA classification and has ambimobile systemic properties, was determined to be highly toxic to *A. pistaciae*. In their study, Gheibi & Taheri (2017) determined that after spirotetramat was administered with irrigation water, the highest mortality occurred on the 20th day in nymphs (99.44%) and on the 30th day in adults (98.23%). As can be seen from this study, spirotetramat is quite successful in the control against *A. pistaciae*. Spirotetramat may be safer than other active ingredients for *O. conglobata*, which is an important predator of *A. pistaciae* in the pistachio ecosystem, and its use in integrated pest management can be recommended to maintain the natural balance (Bemani et al., 2018).

Table 5. Results of the biological activity trial established in the Avcılar neighborhood of Siirt/Kurtalan district.

Active ingredient	R	Live individuals					Henderson-Tilton Efficacy (%)			
		BA	3 DAA	7 DAA	14 DAA	21 DAA	3 DAA	7 DAA	14 DAA	21 DAA
Spinetoram	1	1126	91	92	76	101	92.10	92.20	93.67	92.53
	2	1030	86	81	67	69	91.96	92.78	94.23	94.31
	3	1091	95	92	96	84	92.01	92.91	92.92	93.99
	4	1165	79	85	82	88	93.27	93.24	93.66	93.45
	Mean	1103 a[a]	87.75±0.63	87.5±0.60	80.25±0.57	85.5±0.74	92.33 ab	92.78 a	93.62 ab	93.57 a
Lambda-cyhalothrin	1	856	178	189	152	167	79.67	78.92	83.36	83.76
	2	981	142	138	132	133	86.06	87.09	88.06	88.48
	3	1021	129	146	141	155	88.41	87.97	88.89	88.15
	4	941	145	146	134	148	84.70	85.63	87.17	86.36
	Mean	949.75	148.5±1.60	154.75±1.52	139.75±1.23	150.75±1.49	84.71 c	84.91 b	86.87 b	86.69 b
Deltamethrin	1	1055	65	65	57	55	93.98	94.12	94.94	95.66
	2	1002	71	68	63	70	93.18	93.77	94.42	94.07
	3	1104	85	72	42	53	92.94	94.52	96.94	96.25
	4	1265	91	82	63	89	92.86	94.00	95.51	93.90
	Mean	1106.5	78±0.45	71.75±0.45	56.25±0.29	66.75±0.79	93.24 ab	94.10 a	95.45 a	94.97 a
Sulfoxaflor	1	939	105	94	94	101	89.07	90.44	90.62	91.05
	2	981	113	119	103	116	88.91	88.87	90.68	89.95
	3	893	99	95	95	101	89.83	91.05	91.44	91.17
	4	796	88	85	73	90	89.02	90.11	91.74	90.19
	Mean	902.25	101.25±1.24	98.25±1.13	91.25±1.56	102 ±1.89	89.21 b	90.12 a	91.12 b	90.59 b
Spirotetramat	1	1067	76	71	71	87	93.03	93.65	93.76	93.21
	2	955	64	61	59	65	93.55	94.14	94.52	94.22
	3	1099	63	63	71	71	94.74	95.18	94.80	94.96
	4	917	75	68	69	55	91.88	93.13	93.22	94.80
	Mean	1009.5	69.5±0.56	65.75±0.91	67.5±0.21	69.5±0.58	93.30 a	94.02 a	94.08 a	94.30 a
Control	1	1238	1266	1297	1321	1487	0.00	0.00	0.00	0.00
	2	1095	1137	1193	1234	1289	0.00	0.00	0.00	0.00
	3	1079	1176	1283	1341	1382	0.00	0.00	0.00	0.00
	4	1163	1171	1256	1291	1341	0.00	0.00	0.00	0.00
	Mean	1143.75	1187.5	1257.25	1296.75	1374.75				

R: Replication; BA: BA: Before App; [a]means followed by different letters in the same column are significantly different according to Tukey HSD tests (P<0.001)

Table 6. The results of the General Linear Model (GLM) analysis to determine the effects of deltamethrin, lambda cyhalothrin, spirotetramat, spinetoram and sulfoxaflor applications and different periods on the density of *Agonoscena pistaciae*.

Location	Source of variation	df	Mean square	F value	P value
Şanlırfa/Birecik/Arslanlı	Applications	5	1866634.50	251.30	<0.001
	Weeks	4	2655699.41	357.54	<0.001
	Applications*Weeks	20	176633.96	23.78	<0.001
Şanlırfa/Birecik/Bağlarbaşı	Applications	5	1341831.95	284.10	<0.001
	Weeks	4	3472363.89	735.19	<0.001
	Applications*Weeks	20	211138.61	44.70	<0.001
Siirt/Kurtalan/Yunuslar	Applications	5	2988459.48	1442.86	<0.001
	Weeks	4	2608938.01	1259.62	<0.001
	Applications*Weeks	20	145853.54	70.42	<0.001
Siirt/Kurtalan/Avcılar	Applications	5	3171514.37	1644.74	<0.001
	Weeks	4	2663944.59	1381.52	<0.001
	Applications*Weeks	20	160117.68	83.04	<0.001

The studies carried out to date on the biological effects of pesticides on natural enemies show the great importance of this problem. The study conducted by Mohammadkhani et al. (2021), reported that the results showed lower side effects of spirotetramat than thiamethoxam, lambda-cyhalothrin, and acetamiprid on *O. conglobata*. Although the effect of spirotetramat on natural enemies was not evaluated in this study, it is predicted that its side effects may be low according to previous studies. In this study, all active ingredients used in the results of biological efficacy trials against pistachio psyllid can be used in chemical control. However, when implementing these applications, the presence of natural enemies should also be taken into consideration. In weekly observations to be made in pistachio orchards starting from April-May, if an average of 20-30 nymphs are seen in 100 compound leaves of the pest with a licensed plant protection product success in its struggle (Mart et al., 1995). In the study conducted by Hassani et al. (2009) in Iran, they stated that the damage threshold of pistachio psylla depends on many variables such as temperature, humidity, precipitation. Farmers spray in spring even though there are no pests in nature. These unnecessary practices disrupt the natural balance and cause extra costs to producers in economic terms. Therefore, in the control against pests, it is necessary not to control before reaching the economic damage threshold. In addition to all these, it is recommended to reduce the use of chemicals in the control against pests and to use environmentally friendly chemicals if they are to be used. Because there are natural enemies in nature that put pressure on pests. Özgen et al. (2022) reported that the larvae or adults of *O. conlobata* were highly effective on *A. pistaciae* when 100 were released per tree, and the *A. pistaciae* population remained below the economic damage threshold. In order to protect natural enemies that can be successful like this and are found in Türkiye's natural fauna, it is important to use pesticides that have side effects on natural enemies.

In conclusion, it was determined that the licensed insecticides used in the study were still effective in controlling *A. pistaciae*. Among insecticides, spirotetramat can be recommended for use as it is both more effective and has a lower impact on natural enemies. In order to prevent or slow down the development of resistance in the pest, active ingredients in different groups according to the IRAC MoA classification should be preferred in sequential sprayings.

Declarations

Acknowledgment

No support was provided for this study

Funding

No financial support was received for this study.

Declaration of Competing Interests

The authors declare they have no financial interests.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Adnan Tusun, Çağlar Kalkan, and Serdar Satar. The first draft of the manuscript was written by Adnan Tusun, Çağlar Kalkan, and Serdar Satar, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

References

Bemani, M., Moravvej, G., Izadi, H., & Sadeghi-Namaghi, H. (2018). Variation in insecticidal susceptibility of *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Aphalaridae), and its coccinellid predator, *Oenopia conglobata* L.(Coleoptera: Coccinellidae). *Journal of the Kansas Entomological Society*, *91*(2), 110-118. https://doi.org/10.2317/0022-8567-91.2.110

Bolu, H. (2004). Güneydoğu Anadolu Bölgesi antepfıstığı alanlarında bulunan avcı Coccinellidae türleri, yayılış alanları ve zararlı *Agonoscena pistaciae*'nın populasyon değişimi üzerine etkileri. *Plant Protection Bulletin*, *44*(1-4), 69-77.

Bolu, H., & Kornoşor, S. (1995). Şanlıurfa ilinde iki farklı antepfıstığı çeşidinde *Agonoscena pistaciae* Burckhardt and Lauterer (Homoptera: Psyllidae)'nin populasyon değişimi. *GAP Bölgesi Bitki Koruma Sorunları ve Çözüm Önerileri Sempozyumu*, 27-29.

Burckhardt, D., & Lauterer, P. (1989). Systematics and biology of the Rhinocolinae (Homoptera: Psylloidea). *Journal of Natural History*, *23*(3), 643-712. https://doi.org/10.1080/00222938900770371

Burckhardt, D., & Lauterer, P. (1993). The jumping plant-lice of Iran (Homoptera, Psylloidea). *Revue Suisse de Zoologie*, *100*(4), 829-898.

Burckhardt, D. & Önuçar, A. (1993). A Reviem of Turkish Jumping Plant-lice (Homoptera, Psylloidea). *Revue Suisse De Zoologie*, *100*(3): 547-574.

Çelik, M. Y. (1975). Gaziantep İlinde Antep fıstığının Zararlıları ve Bunların Faydalı Böcekleri Üzerinde Çalışmalar. *Tarım ve Orman Bakanlığı Zirai Mücadele ve Zirai Karantina Genel Müdürlüğü, Zirai Mücadele Araştırma Yıllığı*, *9*: 43-44.

Çelik, M. Y. (1981). Investigation on the description, biology, host plants and natural enemies of the important harmful species of Psyllidae family on the pistachio trees in Gaziantep and its surrounding area. *T.C. Tarım ve Orman Bakanlığı, Araştırma Eserleri Serisi*, 51, 108 pp.

Gheibi, M., & Taheri, Y. (2017). Effect of flupyradifurone, spirotetramat and thiacloprid insecticides on common pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer (Hem.: Psyllidae). *IAU Entomological Research Journal*, *8*(4), 255-270.

Günaydın, T. (1978). Güneydoğu Anadolu Bölgesinde Antepfıstıklarında Zarar Yapan Böcek Türleri, Tanınmaları, Yayılışları ve Ekonomik Önemleri Üzerinde Araştırmalar (*Basılmamış Uzmanlık tezi. E. Ü. Zir. Fak. Bit. Kor. Böl.*), 106 pp.

Hassani, M. R., Nouri-Ganbalani, G., Izadi, H., Shojai, M., & Basirat, M. (2009). Economic injury level of the psyllid, *Agonoscena pistaciae*, on pistachio, *Pistacia vera* cv. *Ohadi*. *Journal of Insect Science*, *9*(1), 40. https://doi.org/10.1673/031.009.4001

Henderson, C. F. & Tilton, E. W. (1955). Tests with acaricides against the brown wheat mite. *Journal of Economic Entomology*, *48*(2), 157-161. https://doi.org/10.1093/jee/48.2.157

Horton, D.R., (1999). Monitoring of pear psylla for pest management decisions and research. *Integrated Pest Management Reviews*, 4(1), 1–20. https://doi.org/10.1023/A:1009602513263

IBM Corp. Released (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

Kaplan, C., & Çınar, M. (2000). Şanlıurfa ilinde *Agonoscena pistaciae* Burk and Laut (Hom: Psyllidae)'nin populasyon değişimi ve bazı doğal düşmanları (Hemiptera: Anthocoridae, Miridae ve Lygaeidae). *Türkiye IV. Entomoloji Kongresi*, 12-15.

Kaplan, C., & Çiftçi, M. C. (2020). Siirt İlinde Antepfıstığı Psillidi [*Agonoscena pistaciae* Burck. and Laut.)(Hemiptera: Aphalaridae)]'nın Yayılışı ve Populasyon Dinamiğinin Belirlenmesi. *ISPEC Journal of Agricultural Sciences*, *4*(2), 186-200. https://doi.org/10.46291/ISPECJASvol4iss2pp51-65

Klimaszewski, S. M., & Lodos, N. (1977). New information about jumping plant lice of Türkiye (Homoptera: Psylloidea). *Ege Üniversitesi Ziraat Fakültesi Dergisi*, *14*, 1-9.

Lauterer, P., Broumas, T., Drosopoulos, S., Souliotis, C., & Tsourgianni, A. (1998). Species of the genus *Agonoscena* (Homoptera, Psyllidae), pests on *Pistacia* and first record of *A. pistaciae* in Greece. *Annales de l'Institut Phytopathologique Benaki*, *18*(2), 123-128.

Mart C., Erkilic L., Uygun N. & Altin M. (1995). Species and pest control methods used in Pistachio orchards of Türkiye. *Acta Horticulturae*, *419*(1), 379-386. https://doi.org/10.17660/ActaHortic.1995.419.63

Mehrnejad, M. R. (2001). The current status of pistachio pests in Iran. *Cahiers Options Me´ diterrane´ ennes*, *56*, 315–322.

Mehrnejad, M. R. (2003). Pistachio Psylla and Other Major Psyllids of Iran. *Publication of the Agricultural Research and Education Organization*, Tehran, 116 pp.

Mohammadkhani, E., Gheibi, M., & Basirat, M. (2021). Lethal and sub-lethal effects of spirotetramat, thiamethoxam, lambda-cyhalothrin and acetamiprid insecticides, on the biological parameters of *Oenopia conglobata contaminata* Menetries (Col.: Coccinellidae). *Pistachio and Health Journal*. *4*(1), 66-85.

Özgen, İ., Mamay, M., & Yanık, E. (2022). Release of the lady beetle (*Oenopia conglobata* L.) to control the common pistachio psylla. *Biological Control*, *171*, 104940. https://doi.org/10.1016/j.biocontrol.2022.104940

Samih M.A., Alizadeh A. & Saberi Riseh R. (2005). Pistachio Pests and Diseases in Iran and their IPM. *Organization of Jihad-e-University*, Tehran, 301 pp.

Şimşek, A., & Bolu, H. (2017). Diyarbakır İli antepfıstığı *Pistacia vera* L. bahçelerindeki zararlı böcek faunasının belirlenmesi. *Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *6*(2), 43-58.

Tokmakoğlu, C. (1973). The studies on some features of biology and control methods of *Aganoscena targionii* Licht. *Plant Protection Bulletin*, 13(2), 67-72.