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Effect of Predaceous Mite Release Timing on Persea Mite (Acari:Tetranychidae) Populations in Avocado Orchards

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Abstract.

The persea mite, *Oligonychus perseae* Tuttle, Baker, & Abbatiello, is a major pest of avocados, *Persea americana* var. *drymifolia* Blake (Lauraceae) in San Luis Obispo, Ventura, Santa Barbara, and San Diego Counties of California. Two species of phytoseiids that specialize on spider mites, *Galendromus helveolus* and *G. annectens,* have been reared in California for control of persea mite. To determine a critical month to initiate releases of these preda-ceous mites for controlling persea mite, releases of 150 mites per tree (rate of 15,000 per acre) were made once during the third week of each of the five months of March through July at two sites, Camarillo and Somis, in Ventura County in 1996. Another treatment was the release of 5,000 mites each month from March through July (rate of 25,000 per acre). In Camarillo, the releases of predaceous mites every month from March until July and releases in April and May were most effective in reducing persea mite populations. The March, June, and July releases were less effective on most sample dates. However, all six treatments significantly reduced persea mite numbers when compared with the control in August and September. In Somis, the patterns of *O. perseae* populations among treatments were different than in Camarillo. April and May releases were not effective in Somis, whereas the March release resulted in significantly lower populations compared with the releases every month and the control on some dates. The different results at the two sites indicate location can be important in determining effectiveness of the predaceous mites. Although G. *helveolus* and *G. annectens* showed potential as effective biological control agents of persea mite when released in the appropriate months, effectiveness in Somis may have been limited by the inability of G. *annectens* to establish high populations within the orchard.

KEYWORDS *Oligonychus perseae, Galendromus helveolus, Galendromus annectens,* avocados

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The persea mite, *Oligonychus perseae* Turtle, Baker, & Abbatiello, is a major pest of avocados, *Persea americana* var. *drymifolia* Blake (Lauraceae) in San Luis Obispo, Ventura, Santa Barbara, and San Diego Counties of California. As with other tetranychid mites, it damages leaves by extracting chlorophyll from leaf tissue. Leaves attacked by mites show numerous distinctive patchy scars, especially prominent along veins, and may drop prematurely. Although it has yet to be shown conclusively, severe mite infestations may result in reduced tree health, vigor, and fruit yields.

Non chemical methods for mite control are needed to prevent upsets in the natural enemy-pest balance and potential secondary pest outbreaks in avocado orchards. A native phytoseiid mite, *Euseius hibisci,* is common in avocado orchards and is a generalist predator, but it appears to be too large to invade persea mite nests. There is some evidence that it feeds on and suppresses persea mite populations (Phillips, unpublished). Two smaller species of phytoseiids that specialize on spider mites, *Galendromus helveolus* and G. *annectens,* were imported into California for control of persea mite. Although G. *annectens* has long been established in California orchards, a more aggressive individual was imported from Venezuela for rearing commercially. Unlike *E. hibisci,* both *Galendromous* species can enter persea mite nests and feed on the mites. These mites were eventually reared in insectaries and became commercially available to growers for release into avocado orchards, but a well defined, effectively timed release program has not been identified.

The timing of predaceous mite releases may be critical for persea mite control. Early establishment of predaceous mite populations may be important in preventing large population increases. However, if releases are timed too early, when too few prey are present, or when pollen, an alternative food for some predaceous mites, is absent, the predaceous mites may be unable to establish their populations. In such a situation, later releases just before persea mite populations increase may prove more effective, provided these populations have not already reached their peak. Subsequent to our studies, in comparative studies of releases of six different phytoseiid mites Hoddle et al. (1999) determined a relative effectiveness in predator mites and showed that *Neoseiulus californicus* was similar to G. *helveolus* in effectivenss in *O. perseae* suppression. Kerguelen and Hoddle (1999) have also compared the effectiveness of two species of phytoseiid mites relative to an oil spray and found a positive effect from predator releases.

In this study conducted in 1996, the objective was to determine a critical month to initiate releases of G. *helveolus* and G. *annectens* for persea mite control in avocado orchards. Single monthly releases are also compared with multiple releases to determine an effective release strategy.

Materials and Methods

Study Sites. Two commercial avocado orchards, located in Camarillo and Somis, Ventura County, were selected for the trial from March to September 1996. Sites were located one mile apart in a coastal, cool climate approximately 15 miles from the Pacific Ocean. Trees at both sites were spaced 20 feet apart. Trees in the Camarillo orchard were 22 years old, 25 feet tall, with a nearly closed canopy. Trees in the Somis orchard were approximately six year old and were ten feet tall. Meteorological data were collected from March through July 1996 at evapotranspiration stations within one mile of each site.

Predaceous Mites. *Galendromus helveolus* and G. *annectens* were obtained from a commercial insectary (Biotactics Inc, Riverside, CA). Mites were shipped weekly in plastic vials containing 150 mites (75 *G. helveolus* and 75 G. *annectens)* in corn grit.

Predaceous Mite Treatments and Releases. Seven treatments were applied at the Camarillo and Somis sites. Five of the treatments were releases of 15,000 predaceous mites per acre in each of the five months of March through July. Releases were made on 21 March, 26 April, 24 May, 27 June, and 25 July. A sixth treatment was the release of 5,000 mites per acre every month, beginning in March and ending in July, for a total of 25,000 mites per acre by the end of the experiment (the five releases treatment). An untreated control was also included as a seventh treatment. The treatments were made at an equivalent of 5,000 mites per acre per release by releasing 50 *G. helveolus* and *G. annectens* (50% mix of the two species) per tree on each often trees per treatment. Trees were randomly assigned treatments. Mites were released into the south or southwest quadrant of each release tree by first misting the foliage with water in a pre-marked ten foot by ten foot area of the tree canopy. Mites were then sprinkled along with the bulk carrier of corn grit onto the wetted foliage.

One pre-treatment sample was made on 11 March at both sites, followed by bi-monthly samples post release as each release was made. Samples consisted of four leaves from the release quadrant (one meter by one meter), and two leaves each from either side of the release quadrant, for a total of eight leaves per tree. Only older leaves, which have higher mite populations, were sampled. Leaves were removed from trees and placed in ziplock bags. Bags were kept and chilled in coolers and transported to the laboratory, where *O. perseae, G. helveolus,* and *G. annectens* on leaves were identified and counted under a microscope.

Mite counts per tree (from the eight leaves) were square root transformed, and the transformed variables among three to seven treatments (depending on date) were analyzed using one-way analysis of variance (ANOVA), followed by the Tukey test ($P<0.05$). Homogeneity of variances was checked using Cochran's C Test. In cases where variances were unequal, the Kruskal-Wallis test was used. Effects of site and release months (^treatments) were analyzed using two-way ANOVA. Because data from consecutive dates were not independent, data from each date were analyzed separately. Analyses were performed using Statgraphics (Manugistics, Inc., Rockville, MD).

Results

Meteorological Differences between Sites. Maximum and minimum daily temperatures and relative humidities near the Camarillo and Somis sites during the study period are shown in Fig. 1. Maximum temperatures at the Camarillo site were generally lower than at Somis, especially from June through July. However, minimum temperatures at Camraillo were generally higher than at Somis throughout the season, but especially from March through May. Relative humidities at Camraillo were lower than those at Somis from March through May, and for a short period from late June through early July.

Effects of Predaceous Mite Releases on *Oligonychus perseae* Populations. *O. perseae* populations among the six predaceous mite releases and the control in Camarillo and Somis are seen in Figs. 2A and 2B, respectively. Results of multiple comparisons tests are shown in Table 1. In Camarillo, the five releases treatment, the 26 April release, and the 24 May release were most effective in significantly reducing persea mite populations. This was especially clear in late July and August, when persea mite populations in the control trees were highest (Fig. 2A, Table 1). The 21 March, 27

June, and 25 July releases were less effective than the 26 April and 24 May releases. However, all six treatments were effective when compared with the control on August 7, 22, and September 5 (Table 1).

In Somis (Fig. 2B, Table 1), the patterns of *O. perseae* populations were different than in Camarillo. Analyses using a two-way ANOVA consistently showed a significant site treatment interaction, indicating the among treatment effects differed between sites (e.g., 5 April: site x treatment: F=6.79; df=2.54; P<0.0023; 5 June: site x treatment: F=7.29; df=4.90; P<0.0001; 17 July: site x treatment: F=4.09; df=5.108; P<0.0019). Whereas the five, April, and May releases were effective in Camarillo, these releases were generally ineffective in Somis. Also in contrast to Camarillo, the 21 March release resulted in the lowest persea mite populations on 3 July (Fig. 2B, Table 1). Persea mite populations in all treatments and the control in Somis nearly vanished by 5 August, whereas populations were still high at this time in Camarillo.

Effects of Releases on *Galendromus helveolus* Populations. In Camarillo, populations of *G. helveolus* in all release trees were higher than in the control (Fig. 3 A and Table 2). Highest populations of *G. helveolus* during peak persea mite abundance in August (Fig. 2 A) were established with the five releases treatment, followed by the April and May releases. The March, June, and July releases also resulted in some mite establishment during peak persea mite abundance, but at significantly lower levels in some cases than the April and May releases (Table 2).

As in Camarillo, *G. helveolus* populations in Somis were highest during peak persea mite abundance (Fig. 2B) in the five releases treatment, followed by the April and May releases (Fig. 3B). The March, June, and July releases in Somis (Fig. 3B) yielded similar results as in Camarillo (Fig. 3 A). Highest populations of *G. helveolus* in Somis occurred after persea mite populations peaked and declined (Fig. 2B). Similar to *O. persea,* analyses with two-way ANOVA indicated there were significant interactions between site and treatment effects on *G. helveolus* (19 June: site x treatment: F=5.36; df=4.90; P<0.0001; 17 July: F=7.57; df=5.108; P<0.0001; 5 August: F=6.38; df=6.126; P< 0.0001).

Effects of Releases on *Galendromus annectens* Populations. In Camarillo, populations of *G. annectens* in August were highest in June and July release treatments, along with the control (Fig. 4A, Table 3). However, no clear patterns of abundance were evident. In Somis, *G. annectens* populations were nearly absent, except on 5 and 19 June (Fig. 4B), and no significant differences among any treatments were detected on any date (P>0.05). The populations at Somis were significantly lower than at Camarillo on 20 June (site: F=17.02; df=4.90; P<0.0001; treatment: F=1.88; df=4.90; P=0.1216; site x treatment: F=1.38; df=4.90; P=0.2473). There was a significant site x treatment interaction on 7 June (F=2.66; df=4.90; P=0.0379). Despite being released in equal numbers, the numbers of G. ann*ectens* (Figs 4A and 4B) recovered from leaves were lower than *G. helveolus* at both sites (Figs. 3A and 3B).

Discussion

The results indicate that appropriately timed releases of *G. helveolus* and *G. annectens* can significantly reduce *O. perseae* populations. In particular, five consecutive monthly releases from March to July (25,000 mites/acre) or single releases in April and May

(15,000 mites per acre) seem to be most effective in reducing populations. Releases in March may be ineffective because persea mite populations during this month are insufficient to sustain predator populations. Releases in June and July seem to be too late, perhaps because warmer temperatures during these months allow the persea mites to develop and reproduce at a much faster rate than in previous months. Because of the elevated rate of increase, the predators may be unable to bring populations down as effectively as in April and May. Higher mortality caused by heat or the lack of pollen during June and July may also be important factors.

Our results indicate effectiveness of predaceous mite releases differed greatly between our two sites. Perhaps this was related to the low numbers of *G. annectens* at Somis as this was a major difference between this site and Camarillo where the releases were more successful. This suggests low survivorship of *G. annectens* at Somis, which may have resulted in less predation of the persea mites. If so, *G. helveolus* in combination with *G. annectens* may be more effective in controlling persea mite than *G. annectens* is by itself. *G. annectens* also seemed less suited for releases into the avocado trees than *G. helveolus* in Camarillo, where the numbers of *G. helveolus* recovered from trees were also higher than those of *G. annectens.* In addition to differential predator establishment, the presence of some persistent ecological disturbance, as evidenced by the sudden disappearance of persea mites in August, may have skewed the results from Somis. Tree size differences between sites may also have contributed significantly in providing differences in habitat for the two species of predaceous mites.

References

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Kerguelen, V. and M.S. Hoddle. 1999. Biological control of *Oligonychus perseae* (Acari: Tetranychidae) on avocado: 11. Evaluating the efficacy of *Galendromous helveolus* and *Neoseiulus californicus* (Acari: Phytoseiidae). Int. J. Acarol. 25(3): 221-229.

Table 1. Results of analysis of variance (F-values, ANOVA) and Tukey tests and Kruskall-Wallis (K-W) tests comparing effects of predaceous mite release dates on *Oligonychus perseae* populations in Camarillo and Somis, California, in 1996. Different letters within rows (sample dates) indicate significant differences for release dates. Numbers within parentheses are absolute rankings (l=lowest density to 7=highest density) for that date. Ranks for non significant differences are not shown.

Camarillo

	Release Date – 1996								
Sample Date	3/21	4/26	5/24	6/27	7/25	5 Releases	Control	F (or K-W[b])	P
Mar 11[a]	a(5)	a(3)	a(1)	act)	a(4)	a(2)	a(6)	43.31[b]	<0.0001
April 3	a(2)	—	—	—	—	a(1)	a(3)	7.91[b]	0.0192
17	ns	—	—	—	—	ns	ns	1.45	0.2518
May 8	ns	ns	—	—	—	ns	ns	2.71	0.0595
22	ns	ns	—	—	—	ns	ns	6.22[b]	0.1012
June 7	a(5)	ab(2)	ab(3)	—	—	b(1)	a(4)	5.25	0.0015
20	a(5)	bc(2)	a(4)	—	—	c(1)	ab(3)	8.26	<0.0001
July 5	a(6)	b(1)	b(2)	ab(5)	—	ab(3)	ab(4)	3.30	0.0112
19	ab(3)	ab(2)	abc(4)	bc(5)	—	a(1)	c(6)	7.49	<0.0001
Aug 7	ab(4)	d(2)	a(3)	b(6)	ab(5)	d(1)	c(7)	42.99	0.0001
22	a(4)	b(2)	b(3)	a(5)	a(6)	b(1)	c(7)	39.23	<0.0001
Sep 5	ac(5)	b(2)	b(3)	ab(4)	c(6)	b(1)	d(7)	24.28	<0.0001

Somis

	Release Date – 1996								
Sample Date	3/21	4/26	5/24	6/27	7/25	5 Releases	Control	F	P
Mar 11[a]	ns	ns	ns	ns	ns	ns	ns	0.28	0.9437
April 5	ab(2)	—	—	—	—	b(3)	a(l)	4.12	0.0274
19	NA[c]	—	—	—	—	NA[c]	NA[c]	—	—
May 3	a(1)	bc(3)	—	—	—	c (4)	ab(2)	7.13	0.0007
20	a(2)	b (4)	—	—	—	ab(3)	a(1)	4.89	0.0059
June 5	a(1)	ab(4)	ab(3)	—	—	b (5)	ab(2)	5.46	0.0011
19	a(1)	a (2)	a(3)	—	—	b (5)	a (4)	8.22	<0.0001
July 3	a(1)	a (2)	ab(3)	b(6)	—	ab(4)	b(5)	5.25	0.0005
17	a(6)	d (1)	abc(4)	ab(5)	—	cd(2)	bcd(3)	4.84	0.0010
Aug 5	a(4.5)[d]	a(4.5)[d]	a(1.5)[d]	a(1.5)[d]	b(7)	a(3)	a(6)	5.95	0.0001
20	ns	ns	ns	ns	ns	ns	ns	0.86	0.5324
Sep 4	ns	ns	ns	ns	ns	ns	ns	1.71	0.1336

ns = nonsignificant.
[a] Pre-treatment counts.
[b] Variances unequal, Kruskall-Wallis test.
[c] Data not available or incomplete for analyses.

[d] Tied ranks.

Table 2. Results of analysis of variance (F-values, ANOVA) and Tukey tests comparing effects of predaceous mite release dates on *Galendromus helveolus* establishment in Camarillo and Somis, California, in 1996. Different letters within rows (sample dates) indicate significant differences for release dates. Numbers within parentheses are absolute rankings (1=lowest density to 7=highest density) for that date. Ranks for non significant differences are not shown.

Camarillo									
	Release Date – 1996								
Sample Date	3/21	4/26	5/24	6/27	7/25	5 Releases	Control	F	P
Mar 11[a, b]	—	—	—	—	—	—	—	—	—
April 3	a(3)	—	—	—	—	ab(2)	b(1)	4.35	0.0230
17	ns	—	—	—	—	ns	ns	1.00	0.3811
May 8	a(2)[c]	b(4)	—	—	—	a(2)[c]	a(2)[c]	6.00	0.0020
22	ns	ns	—	—	—	ns	ns	3.20	0.0349
June 7	ns	ns	ns	—	—	ns	ns	3.63	0.0119
20	a(2)	a(3)	ab(4)	—	—	b(5)	a(1)	8.84	<0.0001
July 5	ab(4)	b(5)	ab(3)	a(2)	—	b(6)	a(1)	6.22	0.0001
19	ab(3)	bc(5)	bc(4)	a(2)	—	c(6)	a(1)	13.42	<0.0001
Aug 7	ab(7)	cd(6)	bc(5)	a(2)	a(3)	d(7)	a(1)	21.42	<0.0001
22	ab(4)	b(5)	b(7)	a(2)	a(3)	b(6)	a(1)	8.14	<0.0001
Sep 5	ab(5)	a(3)	bd(6)	c(2)	ab(4)	d(7)	c(1)	9.24	<0.0001
Somis									
	Release Date – 1996								
Sample Date	3/21	4/26	5/24	6/27	7/25	5 Releases	Control	F	P
Mar 11[a, b]	—	—	—	—	—	—	—	—	—
April 5	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—
May 3	a(1.5)[c]	b(4)	—	—	—	ab(3)	a(1.5)[c]	4.80	0.0065
20	ns	ns	—	—	—	ns	ns	2.25	0.0992
June 5	ns	ns	ns	—	—	ns	ns	2.34	0.0691
19	ns	ns	ns	—	—	ns	ns	2.28	0.0758
July 3	a(1.5)[c]	b(5)	ab(4)	ab(3)	—	b(6)	a(1.5)[c]	4.57	0.0015
17	a(2)[c]	d(5)	b(4)	a (2)[c]	—	b(6)	a(2)[c]	11.82	0.0001
Aug 5	be(5)	c(7)	a(2)[c]	ab(4)	a (2)[c]	bc(6)	a(2)[c]	9.39	<0.0001
20	a(1.5)	c(6)	bc(5)	a (3)	ab(4)	c(7)	a(1.5)[c]	16.45	<0.0001
Sep 4	a (3)	b(5)	b (6)	a (2)	a (4)	b(7)	a(1)	16.12	<0.0001

ns = nonsignificant.

[a] Pre-treatment counts.
[b] All zero counts.
[c] Tied ranks.

Table 3. Results of analysis of variance (F-values, ANOVA) and Tukey tests comparing effects of predaceous mite release dates on *Galendromus annectens* establishment in Camarillo and Somis, California, in 1996. Different letters within rows (sample dates) indicate significant differences for release dates. Numbers within parentheses are absolute rankings (1=lowest density to 7=highest density) for that date. Ranks for non significant differences are not shown. There were no significant differences at Somis on any date.

	Camarillo Release Date – 1996								
Sample Date	3/21	4/26	5/24	6/27	7/25	5 Releases	Control	F	P
Mar 11[a, b]	ns	ns	ns	ns	ns	ns	ns	1.21	0.3127
April 3	a(3)	—	—	—	—	ab(2)	b(1)	10.54	0.0004
17	a(1)	—	—	—	—	b(3)	ab(2)	4.34	0.0231
May 8	ns	—	—	—	ns	ns	ns	1.18	0.3321
22	ns	ns	—	—	—	ns	ns	1.58	0.2101
June 7	a(5)	ab(2)	a(4)	—	—	ab(3)	b(l)	4.32	0.0049
20	ns	ns	ns	—	—	ns	ns	1.91	0.1259
July 5	a(1)	a(2)	ab(3)	ab(4)		b(6)	ab(5)	3.45	0.0088
19	ns	ns	ns	ns	—	ns	ns	2.20	0.0680
Aug 7	a(3)	a(2)	a(1)	a(4)	b(7)	a(6)	a(5)	7.15	0.0001
22	abc(4)	a(1)	ab(3)	c(7)	c(6)	ab(2)	bc(5)	10.12	0.0001
Sep 5	ab(4)	a(1)	a(2)	ab(5)	b(7)	a(3)	b(6)	5.74	<0.0001

ns = nonsignificant.
[a] Pre-treatment counts.

Figure 1. Climatic data from test sites in Camarillo and Somis, Ventura County.

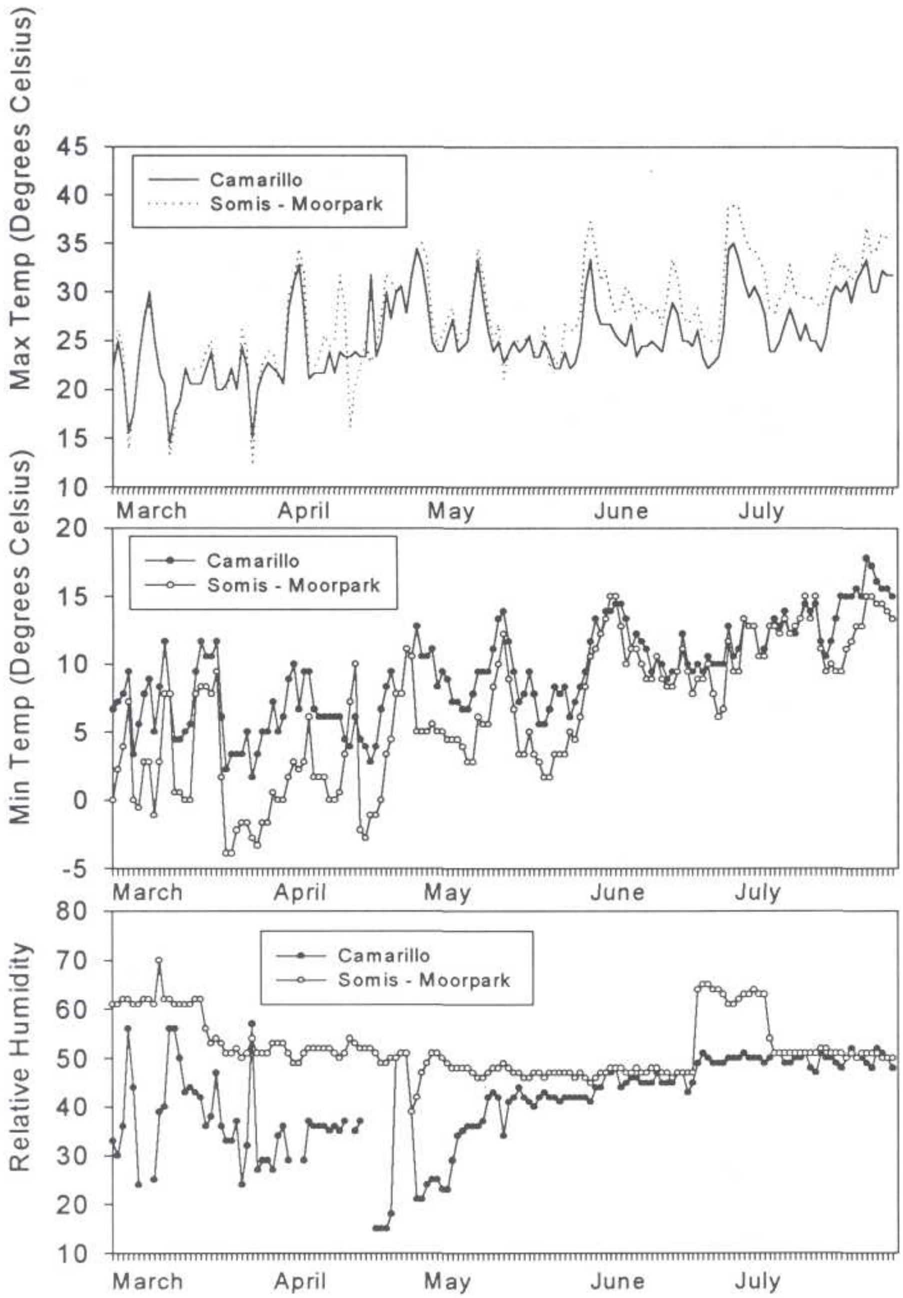

Figure 2. Persea mite levels at two release sites, Camarillo (A) and Somis (B).

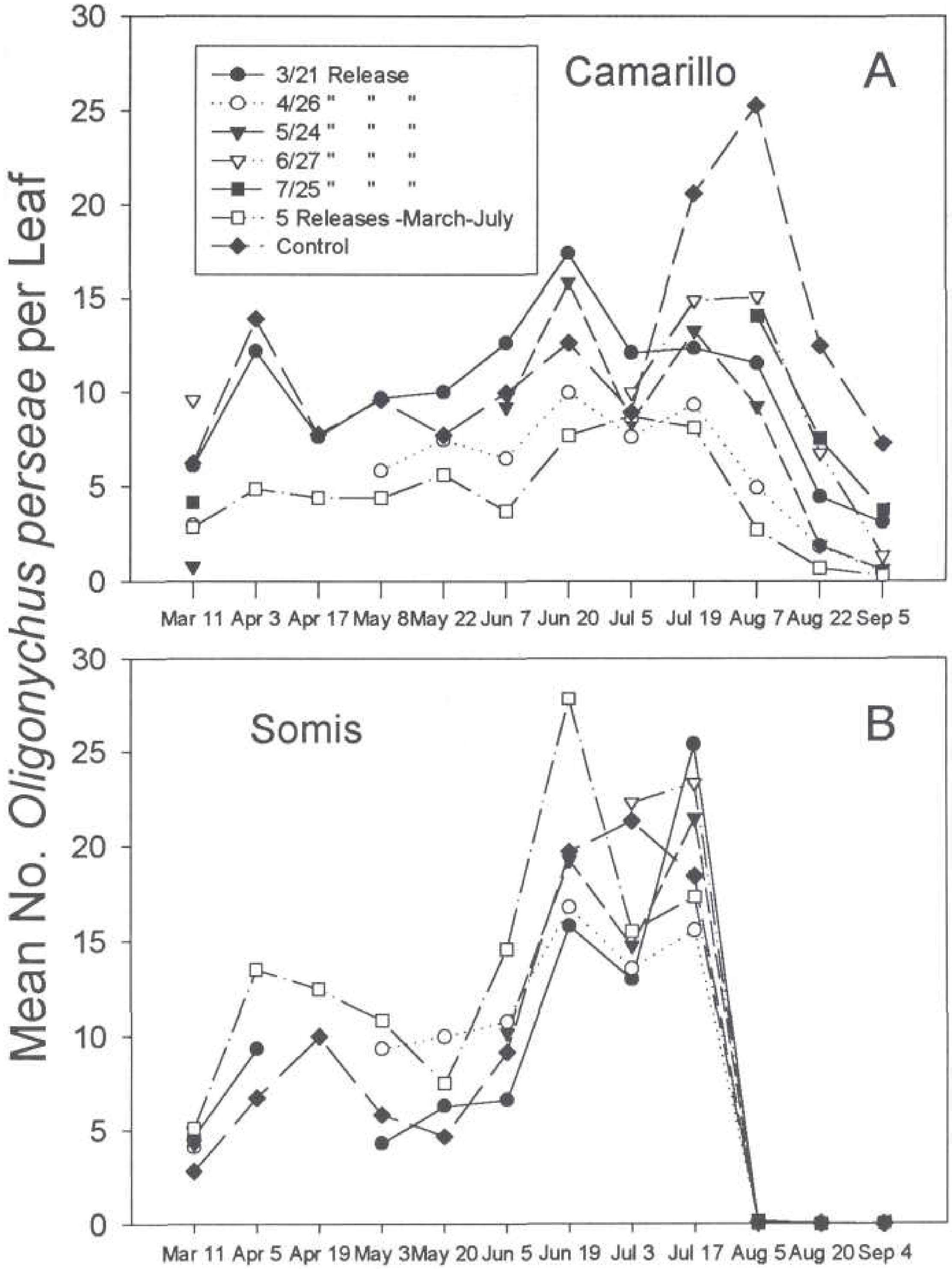

Figure 3. Levels of the predaceous mite *Galendromaus helveolus* at Camarillo (A) and Somis (B).

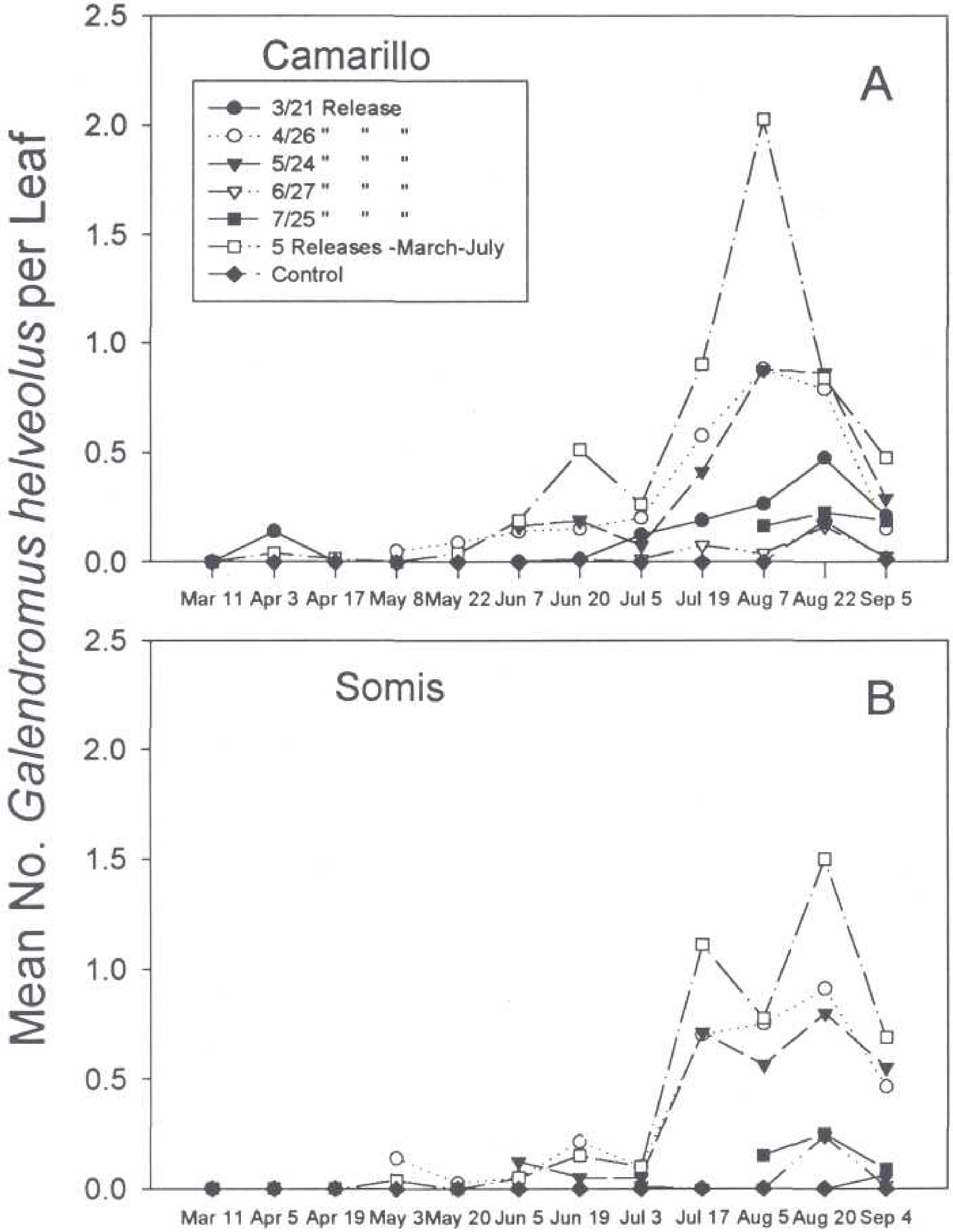

Figure 4. Levels of the predaceous mite *Galendromaus annectens* at Camarillo (A) and Somis (B).