Seasonal Population Fluctuations of *Serangium parcesetosum* (Coleoptera: Coccinellidae), a Predator of Citrus Whitefly, *Dialeurodes citri* (Homoptera: Aleyrodidae) in Turkey's Eastern Mediterranean Citrus Groves

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Environ. Entomol. 32(5): 1105–1114 (2003)

ABSTRACT We conducted investigations on seasonal population fluctuations of *Serangium parcesetosum* Sicard and citrus whitefly, *Dialeurodes citri* (Ashmead), in the East Mediterranean citrus orchards in Turkey from 1992 to 1995. *Serangium parcesetosum* and *D. citri* were sampled in two mandarin orchards at 2- to 3-wk intervals. Sooty-mold growth on honeydew excreted by the citrus whitefly on sampled trees also was evaluated as an indirect measure of the predator's success. *Serangium parcesetosum* controlled *D. citri* populations effectively and prevented them from causing sooty-mold growth in the citrus groves in all 4 yr. It also fed and reproduced on brown soft scale, *Coccus hesperidum* L., another citrus pest, as an alternate host when *D. citri* populations were lower, and contributed to biological control, along with two other predators of coccoids, *Chilocorus bipustulatus* (L.) and *Exochomus quadripustulatus* L.

KEY WORDS *Serangium parcesetosum*, citrus whitefly, *Dialeurodes citri*, *Coccus hesperidum*, biological control

IN TURKEY, CITRUS IS GROWN mostly along the Mediterranean and the Aegean Sea, and partially in the East Black Sea regions. The largest citrus production area is the East Mediterranean region with ≈70% of the country's total citrus production (Anonymous 1999). One of the main problems encountered in citrus production in the region is control of injurious insects and mites.

The citrus pests could be kept under control by integrated pest control (integrated pest management) approaches based on biological control. Mainly naturally occurring and released biological control agents have been employed in the integrated pest management programs, including the cottony cushion scale, *Icerya purchasi* Maskel and citrus mealybug, *Planococcus citri* (Risso), are controlled by the exotic predatory ladybird beetles *Rodolia cardinalis* (Mulsant) and *Cryptolaemus montrouzieri* Muls., and by the encyrtid wasp, *Leptomastix dactylopii* How., respectively, in addition to indigenous natural enemies. California red scale, *Aonidiella aurantii* (Maskell), the soft scales, *Coccus hesperidum* L. and *C. pseudomagnoliarum* Kuwana, and other coccids can be controlled usually by summer oil applications to reduce the disruption of natural enemies. The citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), can be managed by specific acaricide applications when necessary.

Among the citrus pests, the citrus whitefly (CW), *Dialeurodes citri* (Ashmead), has become a major pest recently, replacing the another pest whitefly, *Parabemisia myricae* (Kuwana), which was suppressed successfully by a specific introduced parasitoid, *Eretmocerus debachi* Rose and Rosen (Uygun et al. 1994). High populations of CW retard tree and fruit development by extraction of large amounts of plant sap. Loss of fruit quality also results because of sooty-mold growth on leaves covered with honeydew excreted by the pest (Ebeling 1959, Lodos 1982). Although many natural enemies of CW are recorded in the citrus-growing areas of Turkey, none of them are capable of suppressing CW populations (Zoral 1974, Soylu 1980, Ulu 1984). Therefore, summer oil applications are needed to prevent the pest's damage.

The predacious lady beetle *Serangium parcesetosum* Sicard, found first in India, was introduced into the Caucasian Black Sea coast of Georgia in 1974 and to the south of France and Corsica from the nation of Georgia in 1985 for biological control of CW (Antadze and Timofeeva 1975, Timofeeva and Nyuhan 1978, Malausa et al. 1988). The beetle also was found in the East Black Sea coast of Turkey and introduced into the East Mediterranean region of the country in 1990 (Yigit 1992a). The predator became established and

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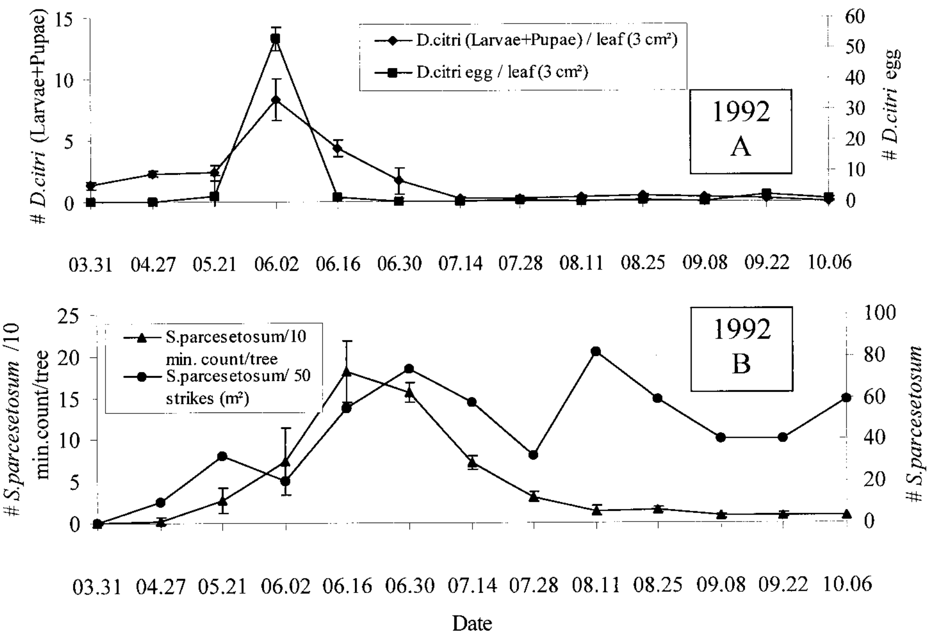

Fig. 1. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* (B) in the first orchard in 1992 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

dispersed throughout the citrus-growing areas infested by CW (Yigit et al. 1994).

Serangium parcesetosum also has been reported as a promising biological control agent against some other whitefly species such as the citrus blackfly, *Aleurocanthus woglumi* Ashby; the sweetpotato whitefly, *Bemisia tabaci* Genn.; and the silverleaf whitefly, *B. argentifolii* Bellows and Perring (Kuchanwar et al. 1982, Kapadia and Puri 1989, Legaspi et al. 1996, Ellis et al. 2001, Legaspi et al. 2001). Within the same genus, *Serangium paonicum* Chapin has been recorded as a predator of the white peach scale, *Pseudaulacaspis pentagona* (Targioni) in Japan (Yasuda 1981).

In this article, we present the results of studies on seasonal population fluctuations of *S. parcesetosum* and CW in the East Mediterranean citrus orchards in Turkey from 1992 to 1995.

Materials and Methods

Studies were conducted in Dortyol, Hatay province, in two 11-yr-old untreated "Satsuma" mandarin orchards containing 400 trees heavily infested by CW. *Serangium parcesetosum* adults reared in the laboratory (Yigit 1992b) were released at the rate of 15 adults per tree in May 1991, on 10 trees randomly selected in the first orchard. The predator was released in a second orchard by the same method in May 1992. After the predator's establishment in both orchards, its activity was observed from 1992 to 1995.

A group of 10 sample trees was selected in each orchard to observe population fluctuations of CW and its predator, *S. parcesetosum.* Samplings were performed to estimate the populations of the pest and the predator from the beginning of April to mid October at 2–3 wk intervals.

Citrus Whitefly Sampling. Last-stage larvae and pupae were counted on the leaves during the adult-emergence period in the spring. On young leaves, the eggs, larvae, and pupae were counted. These counts also were made for successive generations of CW. We randomly sampled 10 leaves from among the bottom five leaves on 1-yr-old shoots from all around each tree (100 leaves for each orchard) and brought them to the lab in an ice box at 7–10°C. The larvae, pupae, and eggs were counted under a stereomicroscope, on three 1-cm^2 areas on the underside of the leaf along the main vein.

Brown soft scale, *C. hesperidum* L., which was a common pest only in the first orchard, also was counted in 1993–1995 on the same 10 sample leaves per tree used for CW by the same methods mentioned above.

***Serangium parcesetosum* Sampling.** *Serangium parcesetosum* was sampled on the same dates and 10 sample trees marked for CW counting in the two orchards. We slowly walked around the periphery of each tree for 10 min. The larvae, pupae, and adult *S. parcesetosum* on the leaves and twigs at observer's height (1.5–2 m) were recorded (McMurtry et al. 1969).

A strike technique (Steiner 1962, Horsburg and Asquith 1968) also was used to count *S. parcesetosum* and *Clitostethus arcuatus* (Rossi) (an indigenous lady beetle predator of CW) on unmarked trees in the orchards: one branch of each tree was struck three times, which is called one strike, by a plastic-covered stick, and adults and larvae of *S. parcesetosum* and *C. arcuatus* that fell on a collapsible tray (1 m^2 of white

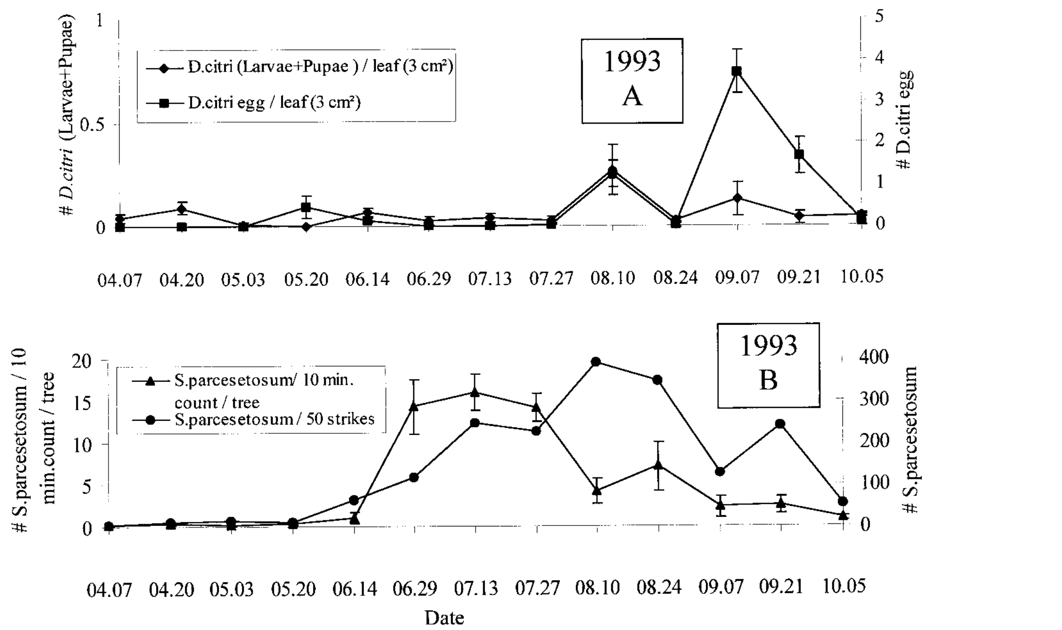

Fig. 2. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* (B) in the first orchard in 1993 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

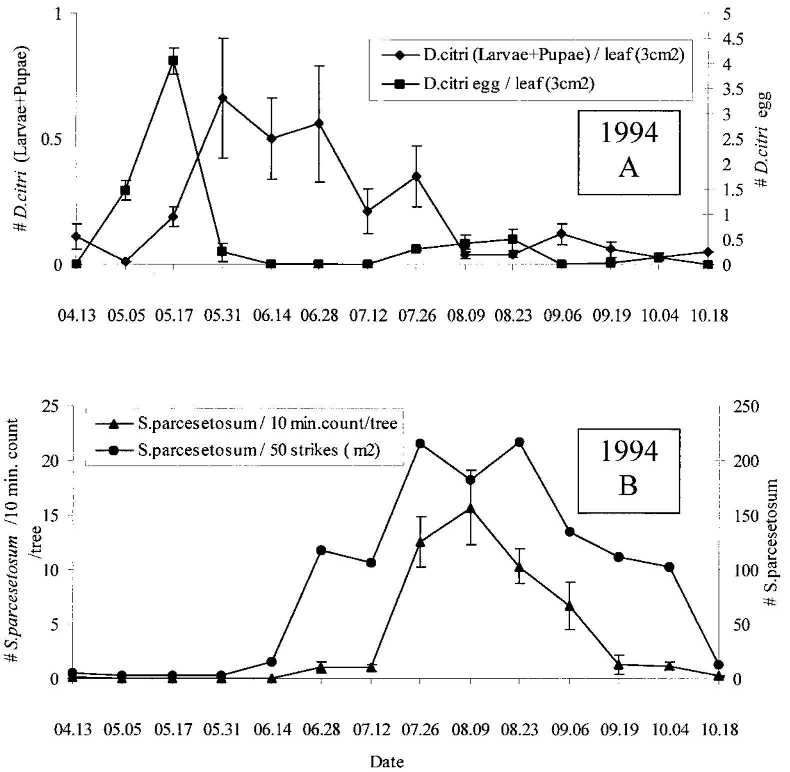

Fig. 3. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* (B) in the first orchard in 1994 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

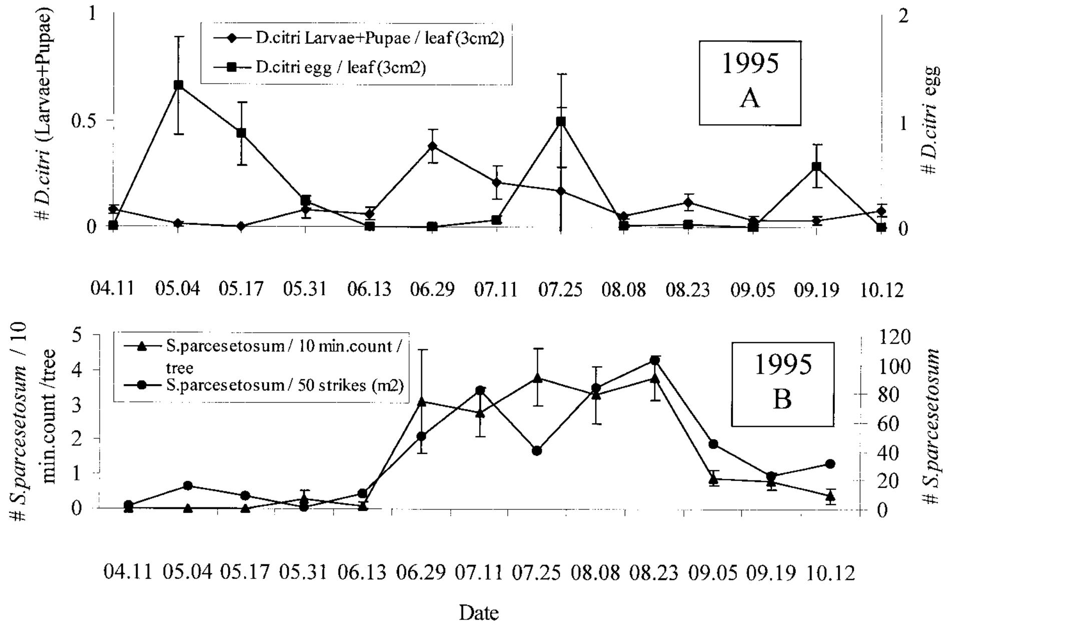

Fig. 4. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* (B) in the first orchard in 1995 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

cloth) were recorded. A total of 50 strikes (one or two strikes per tree) were made in each orchard. After recording, all predators that fell on the tray were released in the same trees.

Population levels of CW and *S. parcesetosum* were compared in the two orchards by *t*-test ($P < 0.05$) to evaluate the relationships among the predators, CW and the brown soft scale in 1993–1995.

Sooty-mold growth on honeydew excreted by the CW on sampled trees was scored according to the rating scale developed by Ulu (1984) as an indirect measure of the predator's success at the end of the

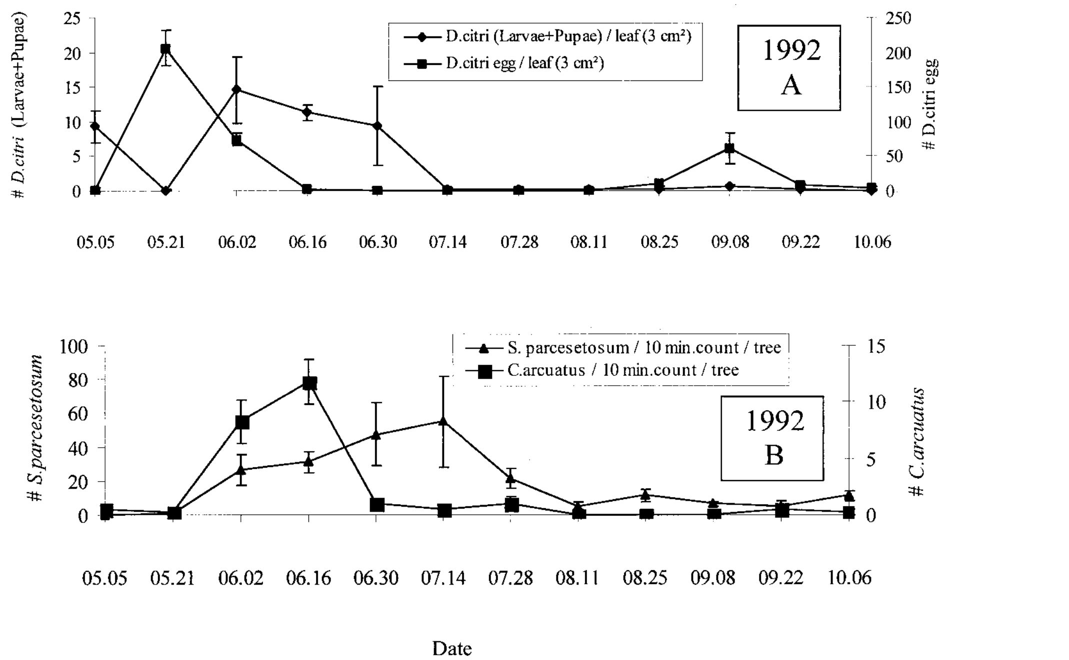

Fig. 5. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* and *C. arcuatus* (B) in the second orchard in 1992 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

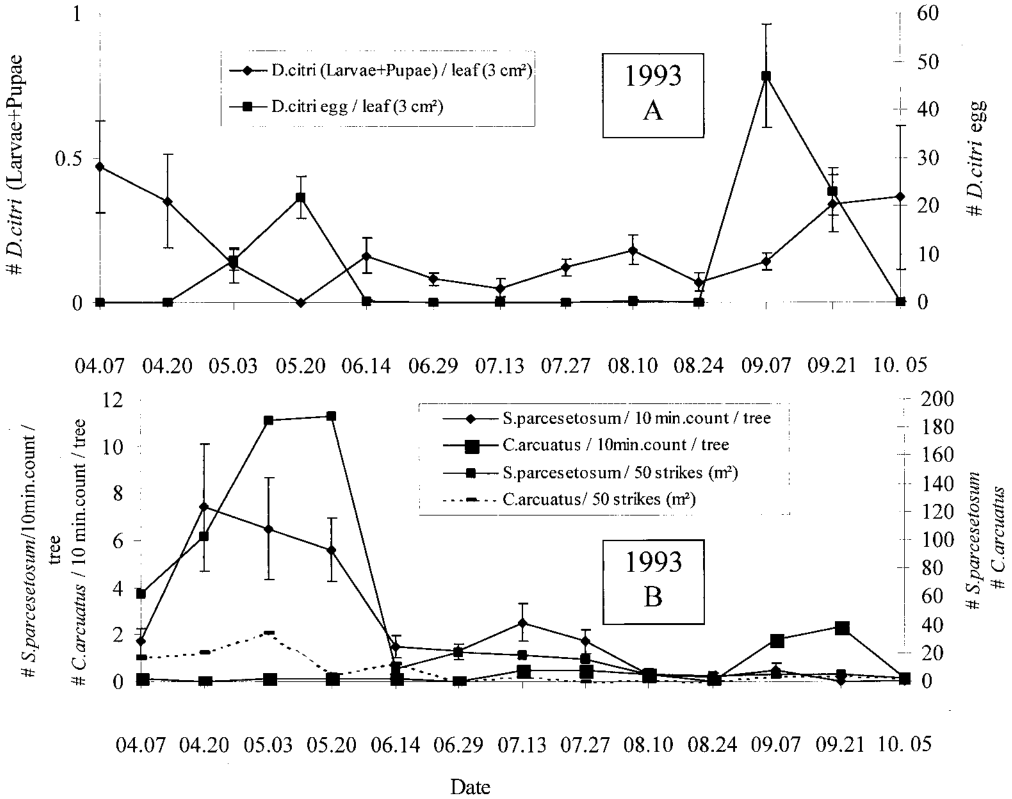

Fig. 6. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* and *C. arcuatus* (B) in the second orchard in 1993 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

season in October 1992. The scale ranges from 0 to 4: 0, clean; 1, little (+) mold growth only on inside leaves; 2, medium (+ +) more mold growth (<25%) only on inside leaves; 3, dense (+ + +) 25–50% of the leaves with mold growth; 4, very dense (+ + + +) 50–100% of the leaves with mold growth.

Three orchards were chosen with no *S. parcesetosum* activity or insecticide spray against the CW to compare the success of *S. parcesetosum* in the first year of the study (30 June 1992). The citrus whitefly density (larvae and pupae) was recorded for 10 leaves taken on four sides of five trees chosen randomly in each orchard. Additionally, five trees in the orchards were evaluated for sooty-mold growth by the same rating scale mentioned above.

The CW density differences among the orchards in which *S. parcesetosum* was released relative to those in which beetles were not released were analyzed using the analysis of variance procedure, and Duncan multiple range test ($P < 0.05$) was used to compare significantly different means (McKenzie et al. 1995). The sooty-mold growth differences among orchards with and without *S. parcesetosum* releases also were analyzed using a nonparametric statistical test (Kruskal-Wallis test) and Tukey's multiple comparison test was applied to compare the mean ranks (Winks 2002).

Results

The CW populations (larvae and pupae) in the two orchards were reduced by *S. parcesetosum* predation and continued at low levels during the growing season in all 4 yr of the study (Figs. 1–8). The highest CW density in the first orchard was 8.32 larvae and pupae per leaf sample (3 cm^2) at the beginning of the 1992 season. The CW population appears to have been suppressed by *S. parcesetosum* before the end of the season and remained at low levels (maximum of 0.66 larvae and pupae per leaf (3 cm^2)) in 1992 through 1995.

In the second orchard, in which *S. parcesetosum* was first released in 1992, pest pressure was highest at the beginning of the 1992 season, with 14.55 larvae and pupae per leaf sample (3 cm^2). Following the 1992 season, CW populations reached to a maximum of 0.47, 6.50, and 5.37 larvae and pupae per leaf sample (3 cm^2) in 1993, 1994, and 1995, respectively.

In Dortyol, CW density varied from 20.32 to 21.70 larvae and pupae per leaf (3 cm^2) on 30 June 1992, in the first year of the study in the orchards in which there was no *S. parcesetosum* activity or insecticide used against CW. On the same sampling date, CW density was average of 1.68 and 9.40 larvae and pupae per leaf (3 cm^2) for the first and second orchards,

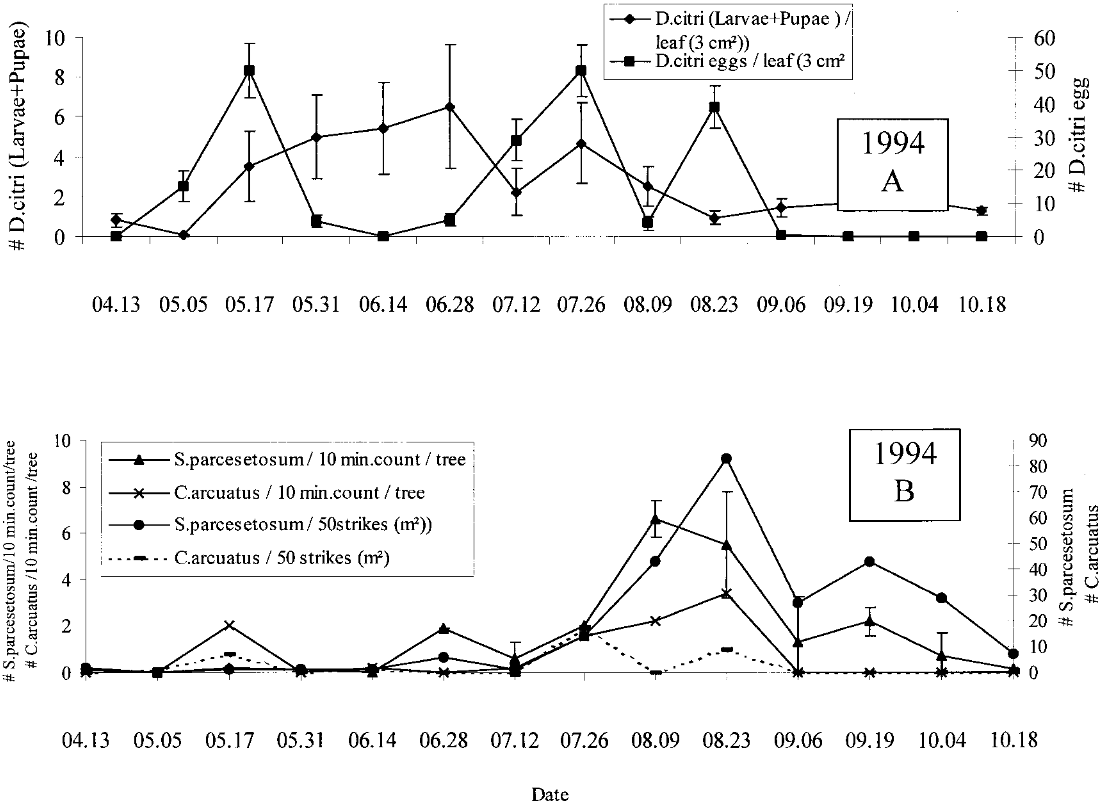

Fig. 7. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* and *C. arcuatus* (B) in the second orchard in 1994 in Dortyol, Hatay province in the East Mediterranean region in Turkey.

respectively, in which the predator had been released (Table 1).

Serangium parcesetosum numbers usually followed the CW populations in both orchards and sustained its population throughout the season (Figs. 1–8). The peak populations of the predator per tree per 10-min count were 18.1, 14.3, 15.7, and 3.8 in the first orchard and 55.0, 7.4, 6.6, and 8.8 in the second orchard, depending on prey density from 1992 to 1995, respectively.

Another lady beetle predator of the CW, *C. arcuatus*, was found at low levels in the first orchard (0.0–2.3 per 10-min count per tree, 0 to7 per 50 strikes (m^2) and in the second orchard (Figs. 5–8). In all 4 yr of the study, we occasionally observed some other negligible natural enemies of CW such as an aphelinid parasitoid, *Encarsia armata* Silvestri, with peak parasitization of 1.8% and coniopterygid predators, *Conwentzia hageni* Banks and *C. psociformis* (Curtis), with a peak density of 0.1 per tree per 10-min count.

The average sooty-mold growth index for the sample trees and other trees at the end of 1992 season was 0.0 for the first orchard and 2.2 for the second orchard. However, the index in some orchards where there was no *S. parcesetosum* activity and no insecticide spray against CW ranged from 3.8 to 4.0 at the end of the 1992 season (Table 1). There was no noticeable sooty-mold growth in either trial orchards or other citrus groves in which the predator became established in successive years, except the little and medium level (density index: 1–2) growth on some trees caused by *C. hesperidum* (maximum density: 14.29 larvae per leaf (3 cm^2) in the first orchard on 5 October 1993.

In the first orchard the peak density of *C. hesperidum* was 13.72, 14.29, and 9.93 larvae per leaf (3 cm^2) in mid June 1993, 1994, and 1995, respectively, whereas there was no noticeable infestation of the pest in the second orchard (maximum of 0.51 larva per leaf (3 cm^2) in 1995). It was observed that *S. parcesetosum* also fed on *C. hesperidum* larvae, and beetle populations reached 246, 215, and 104 adults and larvae per 50 strikes and 14.0, 15.7, and 3.8 adults, larvae, and pupae per tree per 10-min count following the peaks of the pest populations from 1993 to 1995, respectively (Fig. 9). Comparisons of the population levels of *S. parcesetosum* and *D. citri* in two orchards within the years are given in Table 2.

Discussion

In 1992, the significant decrease in CW populations in the first *S. parcesetosum* released orchard when

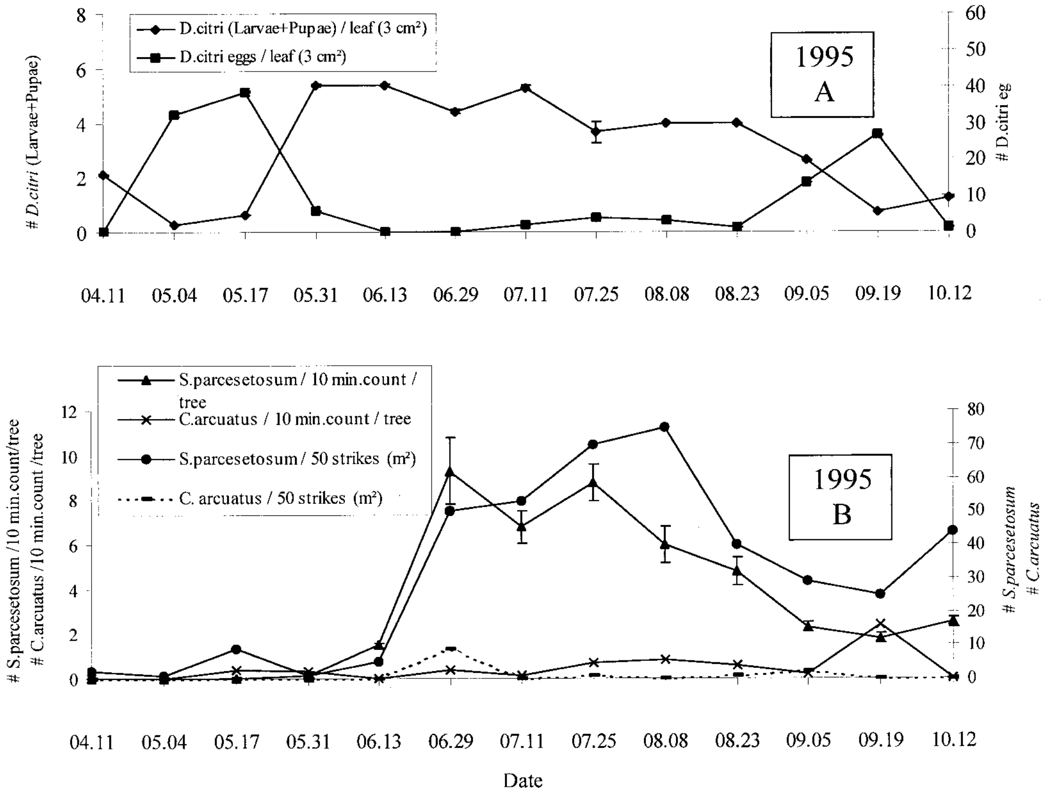

Fig. 8. Seasonal population fluctuations of *D. citri* (A) and *S. parcesetosum* and *C. arcuatus* (B) in the second orchard in 1995 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

compared with the populations where there was no predator activity and no insecticide spray against the pest ($F = 8.312$, df = 24, $P = 0.00$) shows that the predator exerted pressure on its prey (Table 1). The slight difference in population levels of CW between the *S. parcesetosum*-released orchards in 1992 might have been because of the establishment of *S. parcesetosum* in the first orchard in 1991. Timofeeva and Nyuhan (1978), Yasnosh and Chaidze (1986), and Fedorova (1990) observed that *S. parcesetosum* controlled the CW effectively and prevented it from causing sooty-mold growth in the citrus groves in the nation of Georgia. It also has been reported that *S. parcesetosum* is effective as a biological agent on other aleyrodid species (Kuchanwar et al. 1982, Kapadia and Puri 1989, Legaspi et al. 1996, Ellis et al. 2001). Further studies on the biology and consumption capacity of *S. parcesetosum* on CW could be beneficial.

Table 1. Densities of *D. citri* on 30 June 1992 and sooty-mold levels on 6 October 1992 in the *S. parcesetosum*-released orchards and nonreleased orchards in Dortyol, Hatay province, in the East Mediterranean region in Turkey

Orchard	*D. citri* (larvae + pupae)/ leaf (3 cm²)[a]	Sooty-mold growth	
		Sooty-mold index	Mean rank[b]
Nonreleased 1	20.3 ± 3.62b	3.8	16.9a
Nonreleased 2	21.7 ± 3.11b	4.0	18.5a
Nonreleased 3	20.4 ± 5.79b	4.0	18.5a
Released 1 (first orchard)	1.7 ± 1.08a	0.0	3.0b
Released 2 (second orchard)	9.4 ± 5.64ab	2.2	8.1ab

[a] Means within a column followed by the same letter are not significantly different (Duncan test, $P < 0.05$).

[b] Means within a column followed by the same letter are not significantly different (Tukey test, $P < 0.01$).

The absence of noticeable natural enemies of CW in the orchards indicates the effectiveness of *S. parcesetosum* against this pest. The low parasitization of CW by *E. armata* reported by Ulusoy (1998) and observed in the current study also indicates the ineffectiveness of other natural enemies on CW.

The lower level of *C. arcuatus* populations than *S. parcesetosum* may be attributable to interspecific competition between the species that share similar niches (Odum 1959, Price 1975, Varley et al. 1984). However, greater levels of *C. arcuatus* in the second orchard than the first orchard might have been because CW population density was usually higher in the second orchard than the first (Table 2 and Figs. 1–8).

It was seen that the sooty-mold growth halted in the orchards after release of *S. parcesetosum* (Table 1).

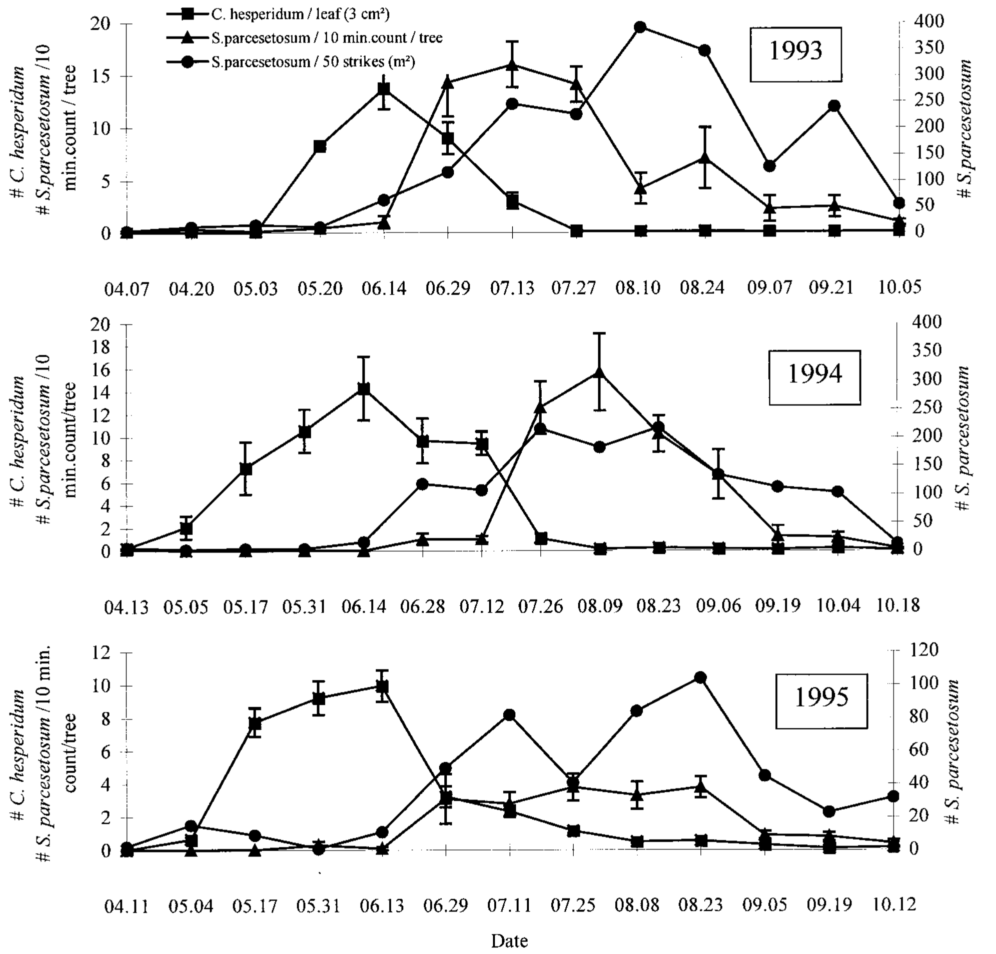

Fig. 9. Seasonal population fluctuations of *S. parcesetosum* and *C. hesperidum* in the first orchard from 1993 to 1995 in Dortyol, Hatay province, in the East Mediterranean region in Turkey.

The sooty-mold growth index value for first orchard was significantly lower than others. Although the index value for the second orchard was higher than for the first orchard, they were not significantly different (chi-square = 22.7; df = 4; $P = 0.001$). The reason for the small difference in sooty-mold growth in the two orchards could be the establishment of the predator in the first orchard 1 yr earlier.

In spite of the significantly reduced populations of CW in 1993–1995 ($t = 2.80$, df = 24, $P = 0.01$; t = −4.69, df = 26, $P = 0.0001$; t = −5,61, df = 24, $P = 0.00$), *S. parcesetosum* densities obtained from the strike technique were significantly higher in the first orchard than in the second in 1993 and 1994 ($t = 2.26$, df = 24, $P = 0.033$; $t = 3.07$, df = 26, $P = 0.005$) (Table 2). The result suggests that *S. parcesetosum* may have fed

Table 2. Comparison of populations of *Dialeurodes citri* and *Serangium parcesetosum* in *S. parcesetosum*-released orchards in 1993 to 1995 in Dortyol, Hatay province in the East Mediterranean region in Turkey

Years	*D. citri* (larvae + pupae)/leaf (3cm^2)		*S. parcesetosum*/50 strikes (m^2)		*S. parcesetosum*/10 min count/tree	
	First orchard	Second orchard	First orchard	Second orchard	First orchard	Second orchard
1993	0.063 ± 0.02a	0.188 ± 0.040b	142 ± 37a	48 ± 19b	4.88 ± 1.7a	2.25 ± 0.71a
	$t = 2.80$, df = 24, $P = 0.01$		$t = 2.26$, df = 24, $P = 0.033$		$t = 1.45$, df = 24, $P = 0.16$	
1994	0.209 ± 0.059a	2.71 ± 0.53b	87.8 ± 22a	18.4 ± 6.5b	3.58 ± 1.4a	1.52 ± 0.56a
	$t = -4.69$, df = 26, $P = 0.0001$		$t = 3.07$, df = 26, $P = 0.005$		$t = 1.33$, df = 26, $P = 0.20$	
1995	0.10 ± 0.029a	3.05 ± 0.52b	38.4 ± 9.3a	31.1 ± 7.3a	1.48 ± 0.44a	3.38 ± 0.94a
	$t = -5{,}61$, df = 24, $P = 0.00$		$t = 0.61$, df = 24, $P = 0.54$		$t = -1.82$, df = 24, $P = 0.081$	

Means within a row followed by the same letter are not significantly different (t-test, $P < 0.05$).

and reproduced on *C. hesperidum* as an alternate prey. Fig. 9 shows that population development of *S. parcesetosum* followed the larval populations of brown soft scale, *C. hesperidum,* and suggests that *S. parcesetosum* suppressed the pest all three years.

The fact that *S. parcesetosum* fed on *C. hesperidum,* another citrus pest, and contributed to its biological control, along with other predators of coccoids (*Chilocorus bipustulatus* (L.) and *Exochomus quadripustulatus* L.) is a new observation. Thus, *S. parcesetosum* is a significant addition to the predator complex for controlling *C. hesperidum.* Additionally, there is opportunity for *S. parcesetosum* to maintain its population at higher levels in citrus ecosystems by preying on *C. hesperidum* as an alternate host when the CW population is very low. We suggest that detailed investigations on prey-predator interactions between *C. hesperidum* and *S. parcesetosum* could be helpful.

We conclude that *S. parcesetosum* introduced into the citrus ecosystem is an effective biological control agent of CW and also is capable of suppressing *C. hesperidum* populations in the citrus orchards in the East Mediterranean region.

Acknowledgments

We thank Turkey Scientific and Technical Research Council for its partial support and H. Kutuk and K. Zaman for their help in the fieldwork.

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Received for publication 7 May 2002; accepted 30 April 2003.