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Establishment and dispersal of *Serangium parcesetosum* Sicard (Coleoptera, Coccinellidae), a predatory beetle of citrus whitefly, *Dialeurodes citri* Ashm. (Homoptera, Aleyrodidae) in the East Mediterranean region of Turkey

Die Etablierung und Verbreitung von *Serangium parcesetosum* Sicard (Coleoptera, Coccinellidae), ein Prädator der Weissen Fliege der Citrusgewächse, *Dialeurodes citri* Ashm. (Homoptera, Aleyrodidae) im Ostmediterranen Gebiet der Türkei

A. Yiğit[1]*, R. Canhilal[2]
[1] Department of Plant Protection, University of Mustafa Kemal, Faculty of Agriculture, Antakya/Hatay, Turkey.
[2] Plant Protection Research Institute, P. O. B. 21, 01321 Adana, Turkey.
* Corresponding author, e-mail: ayigit@baum.mku.edu.tr

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Summary

Studies on the establishment and dispersal of *Serangium parcesetosum* Sicard, a predatory beetle of the citrus whitefly, *Dialeurodes citri* (Ashm.) were carried out in the East Mediterranean region of Turkey. *Serangium parcesetosum* was surveyed in released orchards by walking around the periphery of each tree for 10 min. A strike technique was also employed for this purpose. The releases of *S. parcesetosum* in citrus orchards resulted in the establishment of this predator on citrus and its dispersal throughout the region. The minimum and maximum temperatures were –5.3 and 40.9 °C during the study (1990–1997). This showed *S. parcesetosum* could tolerate large temperature intervals in the region. The success in colonisation of the predatory beetle within a certain period shows its high potential of searching capacity in addition to prey suitability. The predator is now an important factor in the suppression of the citrus whitefly on citrus.

Key words: beneficial arthropod; biological control; strike technique

Zusammenfassung

Die Etablierung und Verbreitung von *Serangium parcesetosum* Sicard, ein Prädator der Weissen Fliege der Citrusgewächse, *Dialeurodes citri*, wurde im Ostmediterranen Gebiet der Türkei untersucht. *S. parcesetosum* wurde nach der Freilassung in Obstgärten durch eine zehnminütige Umrundung jedes Baums überwacht, bei der die Klopfmethode angewendet wurde. Nach der Freilassung von *S. parcesetosum* in Citrusgärten wurde dieser Prädator im Citrusanbaugebiet eingebürgert und ist jetzt weit verbreitet. Während des Freilassungszeitraums (1990–1997) schwankten die Temperaturen zwischen –5.3 und 40.9 °C. Dieses Ergebnis zeigt, dass *S. parcesetosum* große Temperaturwechsel tolerieren kann. Der Erfolg bei der Einbürgerung dieses Prädatorin während des Untersuchungszeitraums zeigt das hohe Potenzial seiner Suchkapazität und die Beuteeignung von *D. citri*. Dieser Prädator leistet gegenwärtig einen wichtigen Beitrag zur biologischen Kontrolle der Weissen Fliege an Citrusgewächsen.

Stichwörter: biologische Bekämpfung; Klopfmethode; Nutzarthropoden

1 Introduction

Citrus is a valuable cash crop of Turkey, which is grown mostly along the Mediterranean and the Aegean Sea, and partially in the 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 faced in citrus production in the region is pest control.

The citrus pests could be kept under control by integrated pest management (IPM) approaches based on biological control. Among them, citrus whitefly (CW), *Dialeurodes citri* (Ashmead) has recently become a major pest in the region, after replacing the Japanese bayberry whitefly, *Parabemicia myricae* (Kuwana) which was suppressed successfully by a specific introduced parasitoid, *Eretmocerus debachii* Rose and Rosen (Uygun et al. 1994).

High CW populations weaken citrus trees and retard fruit development by extraction of large amounts of plant sap. Following the heavy infestations of CW, trees become more susceptible to cold winter conditions. Loss of fruit quality is evident as a result of sooty-mold growth on leaves and fruits covered with honeydew excreted by the pest (Ebeling 1959; Lodos 1982; Ulu 1985). Although many natural enemies of CW were recorded in the citrus-growing areas of Turkey, no indigenous parasitoids and predatory species are capable of suppressing the pest populations (Zoral 1974; Soylu 1980; Ulu 1984).

Serangium parcesetosum Sicard, an effective predacious lady-beetle of CW found first in India, was introduced into the Caucasian Black Sea cost of Georgia in 1974 and to the south of continental 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 predatory beetle was introduced into the East Black Sea coast of Turkey from Georgia accidentally, and introduced into the East Mediterranean region of the country in 1990 (Yiğit 1992 a).

S. 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* Geen, 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).

Our objective was to determine the extent of establishment and dispersion of *S. parcesetosum* from 1990 to 1997 in citrus-growing areas that were heavily infested by CW in the Turkish East Mediterranean region.

2 Material and Methods

2.1 Establisment of *S. parcesetosum*

After its introduction into the East Mediterranean region in late September 1990 (Yiğit 1992 a), *S. parcesetosum* was surveyed in the release orchards heavily infested by CW [8.32–21.70 larvae and pupae/leaf (3 cm^2)], in the following spring or early summer.

We randomly sampled 10–25 trees in each orchard by walking around the periphery of each sample tree for 10 min; adults, larvae, and pupae of *S. parcesetosum* on the leaves and twigs at the observer's height (1.5–2 m) were recorded (McMurtry et al. 1969). A strike technique was also employed to detect *S. parcesetosum* and *Clitostethus arcuatus* (Rossi), another lady-beetle predator of whitefly (Steiner 1962; Horsburg and Asquith 1968): one or two branches of 10–25 trees/orchard were struck three times 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 cloth) were recorded.

1990–1991 Studies: Approximately 500 *S. parcesetosum* adults collected from citrus plantations of the turkish East Black Sea region (Giresun, Trabzon, and Rize provinces) (Yiğit 1992 a) were released in 10 citrus trees heavily infested by CW at the center in a 30–35-yr old "Jaffa" (Shamouti) orange orchard (Orchard 1) with 250 trees on September 22, 1990 in Dortyol, Hatay province, Turkey. *S. parcesetosum* was surveyed in the orchard by the two methods mentioned above every 7–15 d from April 30 to July 31 in 1991.

1991–1992 Studies: A total of 388 adult predatory beetles were released in a second orchard (Orchard 2) containing 410 "Satsuma" mandarin trees infested by CW during the period of May 14 –

June 28, 1991 in Dortyol. Activity and reproduction of the predator was observed in the orchard during the summer months.

S. parcesetosum was surveyed by the same sampling methods mentioned above in the following year at the orchards where *S. parcesetosum* was first released in 1990 (Orchard 1) and in 1991 (Orchard 2) during the period of March 31 – May 26 in 1992.

Additionally, to observe the establishment and activity of *S. parcesetosum* under field conditions, the predator adults were released at a rate of 20 adults/plot (50 m^2) in eggplant and cotton fields that were heavily infested with the cotton whitefly, *B. tabaci* [10 larvae + pupae/leaf (1 cm^2)] with four replications in the experimental plots of Adana Plant Protection Research Institute at the end of August 1991 and 1992, respectively. Observations for the predators' activity were made three times every 10 d in 1991 and 1992. Daily maximum temperature during the observation periods was 40–42 °C in both years.

While the establishment of the predator was being conducted, the main focus of the research was on the spread of *S. parcesetosum* in the citrus groves infested with CW in the region. Its establishment in these groves was observed as well.

2.2 Colonization and dispersal of *S. parcesetosum* within an orchard

In 1991, the study was conducted in an 11-yr old Satsuma mandarin orchard with 410 trees, heavily infested by CW (average of 125 larvae + pupae/leaf) in the previous year, in Dortyol, Hatay province, to colonize *S. parcesetosum* and determine its dispersal in the orchard.

S. parcesetosum adults reared in the laboratory (Yiğit 1992 b) were released inside the periphery of four trees at the center of the orchard at a rate of 15 adults/tree on May 14, 1991. Adults and eggs prevailed in the CW population at the release time. Release was repeated at the same rate on May 24, because there was a heavy rain within a few hours (6.3 mm/day) and strong wind (6.0–9.0 m/sec) on the second day of the first release, which decreased the CW adult populations dramatically and *S. parcesetosum* adults had not been seen on the release trees. Additionally, 48 and 40 adults were released in the same four trees on June 18 and June 28, respectively. On June 28, 60 adults were liberated in three trees adjacent to the first four trees and on July 31, 120 adults were released in 12 trees around the first release trees. The total number of adults released in the orchard was 388. The dispersion of *S. parcesetosum* was followed by examining the trees around the release point with the methods mentioned above throughout the season (June 18 – September 10).

2.3 Area-wide colonization and dispersal of *S. parcesetosum*

Adult predators reared in the laboratory and collected from the field were released in orchards heavily infested by CW at the late spring and early summer of 1992–1997 to disperse and establish them in the East Mediterranean region (Figure 1). The predators were released in four to five trees at the center of the orchards at a rate of 15–20 adults/tree and they were checked at the beginning of fall by the methods mentioned above.

1992 Studies: *S. parcesetosum* adults were released in nine orchards at a rate of 60–100 adults/orchard in 1992: Five "Satsuma" mandarin orchards in Dortyol, Hatay on May 5 and 21, one Satsuma mandarin orchard in Erzin, Hatay on June 2, one Satsuma mandarin and one "Jaffa" orange orchards in Anamur, Mersin and one lemon orchard in Bozyazi, Mersin on May 12 and July 9. The predators were sampled in these orchards from September 29 to October 6.

1993 Studies: In 1993, 628 and 400 *S. parcesetosum* adults were released in two orchards in Kozan, Adana on May 21 – August 18. One hundred adults were released in one orchard in Duzici, Adana on August 11 and 450 and 100 adults were released in two orchards in Kadirli, Adana on August 11 and 18, respectively. The total number of the predators released was 1678 in 1993. To check the activity of the predators in these orchards, samplings were done on September 9, 1993. Additionally, 2130 *S. parcesetosum* adults were released in two orchards in Kozan, three orchards in Kadirli, Adana and one orchard in Erdemli, Mersin from June 10 to September 22, 1993. To spread *S. parcesetosum* to other citrus-growing areas, 350 adults and larvae were transferred into the orchards where CW has been a problem in Antalya province, the West Mediterranean region and Izmir province, Aegean region each on June 8–9, 1993.

Fig. 1. Locations of releases of *Serangium parcesetosum* in the East Mediterranean region of Turkey.

1994–1995 Studies: To colonize and spread *S. parcesetosum*, at least 200 adults were released in each of the five orchards infested by CW in June 1994 and 1995 in the provinces of Adana (Kozan, Kadirli, Yuregir), Hatay (Dortyol, Erzin, Iskenderun, Samandag), and Mersin (Central district, Anamur, Erdemli, Silifke, Tarsus). Visual checks and the strike method were used to determine the activity of the predatory beetle at the end of the season.

1996–1997 Studies: To spread *S. parcesetosum* to citrus orchards infested by the other whitefly species, 1130 and 45 adults were released by the method explained above from July 15 to November 7, 1996 and May 17 to 31, 1997 in the orchards infested by the wooly whitefly, *Aleurothrixus floccosus* (Maskel) and the citrus spiny whitefly, *Paraleyrodes minei* Iaccarina, which was found for the first time in 1994 in Samandag, Turkey (Ulusoy and Uygun 1996). The densities of *A. floccosus* and *P. minei* were 3–5 and 1–3 larvae + pupae/leaf, respectively. The release and nearby orchards were sampled by the same methods mentioned above to check the activity of the predatory beetle.

Farmers in all the orchards where *S. parcesetosum* were released were warned not to apply any insecticides. During the entire study, the daily temperature varied from –5.3 °C (min.) to 40.9 °C (max.) in the citrus-growing area of the Turkish East Mediterranean region.

3 Results

3.1 Establisment of *S. parcesetosum*

1990–1991 Studies: Average population levels of *S. parcesetosum* obtained from the survey orchard where the predator was released on September 22, 1990 are given in Table 1. On July 31, 1991, the last-stage larvae of the predator were seen on the trunks and branches as well as on the leaves infested

Table 1. Average population levels of *Serangium parcesetosum* in a 'Jaffa' orange orchard infested with citrus whitefly, *Dialeurodes citri*, at the beginning of the 1991 season, where it was released on September 22, 1990 in Dortyol, Hatay

Sampling dates	No. of trees on which *S. parcesetosum* was seen on the sampling dates in the orchard	Population levels of *S. parcesetosum** Adult, larva, pupa/tree/10 min observation
30 April 1991	1	1 A
7 May 1991	0	0
14 May 1991	2	4.5 A, 5.5 L
24 May 1991	1	2 E, 15 L
28 June 1991	6	11.5 A, 11.9 L, 1.4 P
18 July 1991	17	17.5 A, 9.5 L, 6 P
31 July 1991	25	2.3 E, 10 L

* A: Adult, L: Larva, P: Pupa

by CW. The predatory beetle was found over the entire orchard and on about 100 trees in a nearby orchard in a survey on August 14, 1991. *Clitostethus arcuatus*, another predatory beetle of CW, was observed at lower densities [0–0.7 adult + larva/strike (1 m^2)] than *S. parcesetosum* during all growing seasons.

1991–1992 Studies: The average density of *S. parcesetosum* was 0.2–4.1 adults/tree/10-min observation and 0.3–3.6 adults/strike (m^2) on March 31, 1992, April 27, 1992, and May 5, 1992 in the two orchards (Orchard 1 and Orchard 2) in Dortyol. Several *S. parcesetosum* adults were seen under tree bark on March 31, 1992 in these orchards, and the first larvae were seen on the leaves on May 26, 1992. During observations made in eggplant and cotton plots in Adana where *S. parcesetosum* was released in late August, no adults and larvae of the predator were seen under field conditions.

3.2 Colonization and dispersion of *S. parcesetosum* within an orchard

The colonization of *S. parcesetosum* in the first four release trees and its distribution in the orchard in Dortyol is indicated in Figure 2. The average density of the predator was 2–14 adults and 10–25 larvae/tree/10-min observation on the four release trees on June 18, 1991. It continued to spread on July 31, 1991 and by September 10, 1991, it had spread to all trees infested with CW in the orchard of 1.5 ha (Figure 2).

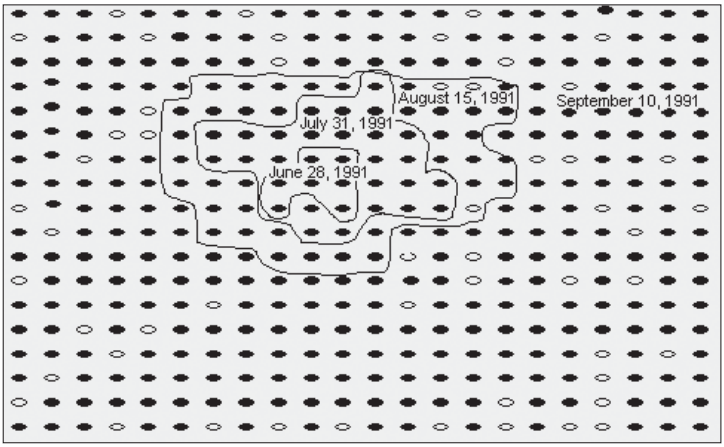

Fig. 2. The dispersion of *Serangium parcesetosum* in a 'Satsuma' mandarin orchard infested by citrus whitefly, where it was released on May 14, 1991, in Dortyol, Hatay. (●: Trees containing *S. parcesetosum*, ⬭: The trees that do not contain *S. parcesetosum*)

3.3 Area-wide colonization and dispersion of *S. parcesetosum*

1992 Studies: The average density of *S. parcesetosum* varied from 0 to 18.5 adults/strike ($1m^2$) in fall in the orchards where it was released in early summer. No predatory beetle was found in the two orchards, because of insecticide applications with quinalphos made by the farmers. *S. parcesetosum* spread to an approximately 70-ha area in the citrus orchards within a 2-yr period in Dortyol and there was no sooty-mold growth caused by CW [average 1.7 ± 1.08 larvae and pupae/leaf (3 cm^2)].

1993 Studies: The average density of *S. parcesetosum* in the orchards was 0.1–15 adults, 1.8–23.5 larvae, and 1.2–4.2 pupae/tree/10-min observation and 0.2–14.1 adults and 0.4–19.3 larvae/strike (1 m^2).

1994–1995 Studies: In the release orchards, the average density of *S. parcesetosum* varied from 3.5 to 13.7 adults and 6.4–17.15 larvae/tree/10-min observation and 3.1–8 adults and 6.5–15.9 larvae/strike (1 m^2). *S. parcesetosum* was abundant in the release orchards and had spread to the orchards where no releases were made.

1996–1997 Studies: In the orchards infested with the wooly whitefly, *A. floccocus*, and citrus spiny whitefly, *P. minei*, the average density of *S. parcesetosum* was 0.1–0.2 adults/tree/10-min observation and 0.05–0.06 adults/strike (1 m^2) on August 10, 1996 and September 25, 1996 and 0.2–0.03 adults/tree/10-min observation and 0.04–0.06 adults/strike (1 m^2) on May 31, 1997 and September 19, 1997. However, the predator's population did not grow well in this orchard. Unlike this orchard, *S. parcesetosum* reproduced well on the eggplant plot adjacent to the orchard heavily infested with cotton whitefly, *B. tabaci* [average 23.7 larvae and pupae/leaf (1 cm^2)] and suppressed it within 10–14 d in Samandag, where the daily maximum temperature was 25–28 °C during the release period.

4 Discussion

As a result of the releases, *S. parcesetosum* became established in the citrus orchards in the East Mediterranean region of Turkey. It also became established in other citrus-growing regions, the West Mediterranean and Aegean regions of Turkey (Kumas et al. 1994; Koclu et al. 1996). In the East Mediterranean region, daily minimum and maximum temperatures were –5.3 and 40.9 °C during 1990–1997. This shows that *S. parcesetosum* could tolerate a large temperature range in the citrus ecosystem. Antadze and Timofeeva (1975) indicated that *S. parcesetosum* could overwinter in 1974–1975 in Georgia where it was –2 °C and all of its stages were observed in July; Yasnosh and Chaidze (1986) mentioned that it overwintered as adults and could resist –6 to –8 °C; Malausa et al. (1988) stated that *S. parcesetasum* overwintered on the Côte d'Azur and Corsica. The predatory beetle also overwintered in Israel (Argov 1992).

S. parcesetosum populations did not developed well in the citrus orchard infested by *A. floccocus* and *P. minei*. This may be due to low population density of the whiteflies for the reproduction of *S. parcesetosum* and/or *P. minei* is not a preferred prey for *S. parcesetosum* (Abboud and Ahmad 1998).

During the field studies conducted in 1991 and 1992, failure in establishment of the predatory beetle in cotton and eggplant plots, despite plenty of prey, may be attributed to high temperatures (40–42 °C) under field conditions. Nonetheless, it reproduced and dispersed in the eggplant plots adjacent to citrus groves in Samandag, where the daily maximum temperature was lower than Adana conditions. LeGaspi et al. (1996) also reported that *S. parcesetosum* adults died within three days under constant temperature of 40 °C.

Depending on *D. citri* densities, colonisation and dispersion of *S. parcesetosum* within an orchard was satisfactory. The success in colonisation of the predatory beetle within a certain period shows its high potential of searching capacity in addition to the prey suitability. Tolerating extreme temperatures indicates that the predator has good adaptation skills to a wide range of environmental conditions as well. Huffaker et al. (1972) and van Driesche and Bellows (1996) also stated that high searching ability including general mobility and adaptation to varying ecological conditions are two main characteristics of an effective natural enemy.

We conclude that releases of the predatory beetle should preferably be done in central point in an orchard, heavily infested by CW to spread the predator to other orchards. Any spraying should not be done on the release part of the orchard. The reproduction of the predatory insect at the release cites

should be observed and additional releases should be done when necessary (e. g., unexpected environmental conditions). Following the establishment of *S. parcesetosum* within an orchard, any practice disruptive to survival of the predator should be avoided. Further studies on seasonal population fluctuations, biology and consumption capacity of *S. parcesetosum* on CW could be useful.

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