

STATUS AND IMPORTANCE OF *RHYZOBIOUS FORESTIERI*
(COL.: COCCINELLIDAE) ON CITRUS AT CHIOS ISLAND, GREECE,
NINE YEARS AFTER ITS INTRODUCTION

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The originally Australian coccidophagous predator *Rhyzobius forestieri* (Coleoptera: Coccinellidae), imported from California into Greece in 1981, was first released on citrus at Cambos, Chios, in 1983 against soft scales *Coccus pseudomagnoliarum* and *Saissetia oleae* (Homoptera: Coccidae). It was successfully established in two orchards there.

During the following decade, *R. forestieri* spontaneously dispersed throughout the Cambos coastal plain. In July 1992, a survey of coccidophagous coccinellids was carried out, to follow up on the dispersal of *R. forestieri* on citrus and to compare its population size with that of the main native coccidophagous coccinellids.

The samplings were made in 4 selected scale-infested orchards of Cambos spaced 1-2 km apart. Of a total of 337 adults and 237 larvae of coccidophagous coccinellids found, *R. forestieri* comprised 84.0% and 75.1%, respectively. It was present in all 4 localities; in 2, *R. forestieri* adults and larvae were by far the most abundant coccidophagous coccinellids.

KEY-WORDS: *Rhyzobius forestieri*, exotic predator, colonization, Citrus, Chios Island, Greece.

Citrus is the main crop at the coastal plain of Cambos in Chios island, located between the 38th and 39th parallels in the eastern Aegean Sea, Greece. Scales (Homoptera: Coccoidea) and especially soft scales (Coccidae) are serious insect pests of citrus in Chios. Among soft scales, the black scale *Saissetia oleae* (Olivier) and the citricola scale *Coccus pseudomagnoliarum* Kuwana tend to cohabit in mixed populations. Local outbreaks of these mixed populations often occur.

For biological control of soft scales, the originally Australian predator *Rhyzobius forestieri* Mulsant (Coleoptera: Coccinellidae) was introduced and released in Chios and elsewhere in Greece, in spring and summer 1983 (Katsoyannos, 1984). The *R. forestieri* individuals released were insectary-reared descendants of 30 adults collected in the field from Oakland, California, U.S.A., and imported by the author into Greece in 1981 (Katsoyannos, 1983). *R. forestieri* preys mostly on soft scales, including *S. oleae* and *C. pseudomagnoliarum* on trees and shrubs (Katsoyannos, 1983). Following the introduction releases, *R. forestieri* was successfully established in two mandarin orchards at Cambos, Chios (Katsoyannos, 1984).

A survey of coccidophagous coccinellids and their associated soft scales on citrus was carried out in 1992, in July, at peak of the annual period of activity of both soft scales and

their coccinellid natural enemies. The purpose of the survey, reported here, was to follow up on the dispersion of *R. forestieri* in the Cambos plain, and to assess its establishment and its relative contribution to the long-term biological control of soft scales on citrus.

MATERIALS AND METHODS

Cambos is an agricultural plain about 5 km long (North-South) and 1 km wide, extending along the east coast of the island immediately south of the midway town of Chios. About 80% of Cambos' citrus are mandarins of a local variety and the rest are oranges, sour oranges and lemons. Most citrus farms in Cambos are 1-2 ha in area; they are characteristically enclosed by stone walls of 2-3 m in height.

For this survey, 4 scale-infested citrus farms, more or less evenly distributed throughout the Cambos plain, were selected as sampling sites (fig. 1). They were spaced 1-2 km apart. The 1983 *R. forestieri* introduction releases were carried out at 2 sites, one located at the northern end of Cambos plain and the other at the northwestern of it. Locality No. 1 of this study was the same farm as the first of the above 2 sites.

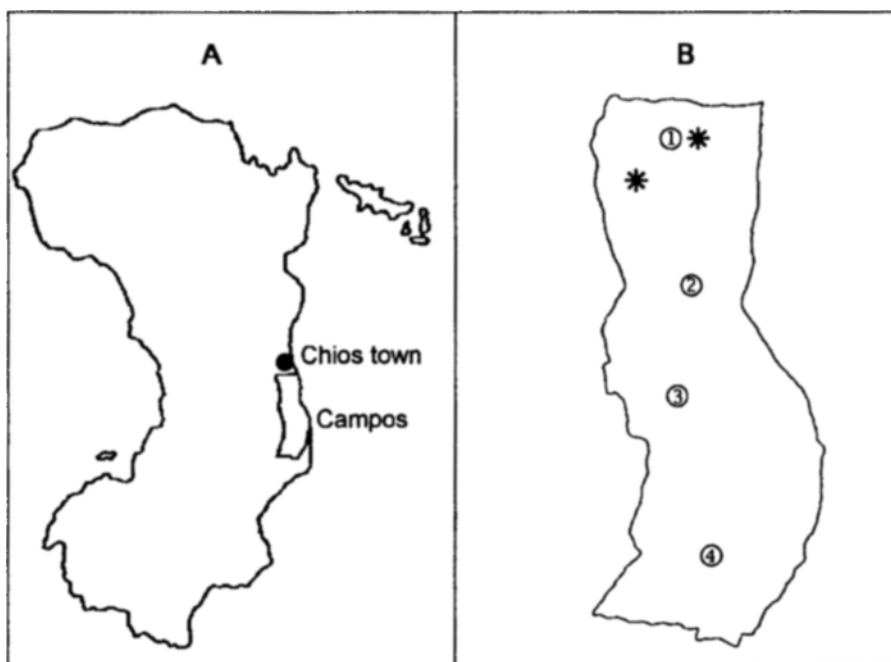
In the selected sites, coccinellids and associated soft scales populations were sampled. The coccinellids were sampled by beating 4 branches of each of 7 randomly-selected trees at each locality with a rubber-covered stick over a 1m² cloth screen, and recording the numbers of adults and larvae of coccidophagous coccinellids thus dislodged. For sampling the associated soft scales on the same date, 4 twigs of 20 to 30 cm in length - one from each compass direction - were cut at shoulder height from each of 5 randomly-selected trees at localities 1 through 4. In the laboratory, the leaves of each sample were cut off the twigs and mixed together. 100 leaves and 5 leafless twigs 20-30 cm long from each sample were then randomly taken and examined under stereoscope. The numbers and developmental stages of living soft scales as well as of those attacked, parasitized and dead from unknown causes, were recorded for each leaf and twig.

Meteorological data for the years 1983-1992 were provided by the National Weather Service Station of the airport at Cambos, Chios.

RESULTS

The results of the survey of coccidophagous coccinellids are given in table 1. Larvae and adults of the introduced *R. forestieri* were collected in all 4 localities. Of the native species, *Exochomus quadripustulatus* Linnaeus was found as larvae in 2 of the 4 localities and as adults in 3 of the 4; *Chilocorus bipustulatus* Linnaeus was found as larvae in 3 of the 4 localities and as adults in all 4. In localities 3 and 4, *R. forestieri* larvae and adults accounted for the majority of the coccidophagous coccinellids found. Of the total of 569 coccinellid individuals collected at all the localities in the survey, 80% were *R. forestieri*.

Table 2 presents the results of the survey of the associated soft scales, *S. oleae* and *C. pseudomagnoliarum*. The citrus trees were infested by *S. oleae* and *C. pseudomagnoliarum* in mixed populations, with the latter species comprising the predominant adult population. The great majority of scales of both species were at their nymphal stages of development at the time of sampling. Rates of parasitism on the nymphs, mostly due to encyrtid (Hymenoptera) parasitoids *Metaphycus* spp., were very low compared to the high rates of nymphal mortality from unknown causes, including predation.



- A : Chios island
 B : Campos area
 * : Site of the introduction release in 1983
 O : Site of sampling in 1992

Fig. 1. Location of the sites of *Rhyzobius forestieri* releases in 1983 and the sites of sampling for the survey in 1992 at the citrus growing plain of Campos in Chios island, Greece.

In table 3, the extreme low (January - February) and high (July - August) daily temperatures of the years 1983 through 1992 are given. In the period between the spring 1983 *R. forestieri* releases in Campos and the July 1992 follow-up survey there, the coldest recorded temperature was -3°C (January 1987) and the warmest was 37.6°C (July 1987). The abundance of *R. forestieri* in July 1992 indicates that extreme low and high daily temperatures recorded during the years between 1983 and 1992, which might have affected the colonized insects detrimentally, did not cause any noticeable harm to *R. forestieri* in Campos.

DISCUSSION

In the 9 years following its 1983 introduction, *R. forestieri* successfully survived existing weather conditions (table 3) and became endemic on citrus at Cambos, Chios. By July 1992, *R. forestieri* was found to be as widely distributed as, and more numerous than, the 2 major indigenous coccidophagous coccinellids, *E. quadripustulatus* and *C. bipustulatus*.

TABLE 1
Coccidiphagous coccinellids sampled on citrus at Cambos, Chios, in July 1992.

Locality	Sampling date	Coccinellids							
		Larvae				Adults			
		Total No.	<i>Rhyzobius forestieri</i> %	<i>Exochomus quadripustulatus</i> %	<i>Chilocorus bipustulatus</i> %	Total No.	<i>Rhyzobius forestieri</i> %	<i>Exochomus quadripustulatus</i> %	<i>Chilocorus bipustulatus</i> %
1	July 23	23	8.7	34.8	56.5	16	31.2	43.7	25.0
2	July 22	26	15.4	0	84.6	14	35.7	0	64.3
3	July 20	182	92.8	3.8	3.3	283	91.9	4.2	3.9
4	July 20	3	100	0	0	22	59.1	13.6	27.3
Total		234	76.1	6.4	17.5	335	84.5	6.6	8.9

TABLE 2
Saissetia oleae and *Coccus pseudomagnoliarum* counted on citrus samples (100 leaves and 5 leafless twigs 20-30 cm long) taken in July 1992 at Cambos, Chios.

Locality	Date	Crop	Adult females				Nymphs 1 st , and 2 nd instar of <i>S. oleae</i> and <i>C. pseudomagnoliarum</i> together			
			Total No	<i>Saissetia oleae</i> %	<i>Coccus pseudomagnoliarum</i> %	Total No	Living %	Parasitized %	Dead from unknown causes, predation included %	
1	July 23	mandarins	11	27.3	72.7	1435	54.3	0.5	45.2	
2	July 22	mandarins	201	44.3	55.7	1067	69.3	2.8	27.9	
3	July 20	oranges	22	36.4	63.6	582	20.4	2.0	77.6	
4	July 20	mandarins	46	34.8	65.2	1217	63.3	1.0	35.6	

TABLE 3

Extreme daily temperatures °C recorded at Cambos, Chios, during the period 1983-1992.

Years	Minimal		Maximal	
	January	February	July	August
1983	- 2.4	- 4.0	35.6	31.8
1984	1.0	3.0	35.0	31.0
1985	2.0	0.0	32.0	35.0
1986	- 1.2	- 1.0	31.2	32.4
1987	- 3.0	- 1.0	37.6	33.0
1988	0.0	- 1.0	36.6	33.4
1989	0.0	- 0.4	33.0	34.0
1990	0.0	2.0	34.6	34.0
1991	- 0.8	- 2.8	33.0	34.0
1992	- 1.0	- 2.0	30.4	35.0

Source: Chios Island Airport Weather Station of the National Weather Service.

The successful establishment and domination of *R. forestieri* in Cambos is attributed mainly to: multivoltinism, with 6-7 annual generations (one per month during summer); high rates of fecundity, with 400-1000 eggs per female; continuous reproductive activity throughout the year, without summer or winter diapause; relative longevity of the adults, with a lifespan of 3-10 months; and good mobility (Katsoyannos, 1983).

The important contribution of *R. forestieri* in controlling *S. oleae* and *C. pseudomagnoliarum* on Cambos citrus is indicated by the predominance of its population in the complex of coccidophagous coccinellids found at localities 3 and 4. The trees at these localities showed signs of recovery from a heavy infestation of *S. oleae* and *C. pseudomagnoliarum*, recently suppressed. Since the rates of nymphal parasitism of *S. oleae* and *C. pseudomagnoliarum* taken from citrus at localities 3 and 4 were of minor importance, it seems likely that the predatory activity of *R. forestieri* was the major factor contributing to the suppression of the scales there.

R. forestieri has proved efficient as a biological control agent, against heavy infestations of *S. oleae* on olive trees in Chios island, Greece (Katsoyannos, 1984), and on clementines in the island of Porquerolles, France (Iperti *et al.* 1989).

On the basis of its bionomics, *R. forestieri* should be considered for use not only for its long-term effects, but also as a curative agent for control of citrus soft scales in Integrated Pest Management Programmes (Katsoyannos, 1996). In this case, precisely timed augmentative releases of insectary-produced *R. forestieri*, applied in individual citrus orchards, seem to be an appropriate strategy for integrated management of soft scales.

RÉSUMÉ

Situation et importance de *Rhyzobius forestieri* (Coleoptera : Coccinellidae) sur agrumes dans l'île de Chios, Grèce, neuf ans après son introduction.

Le prédateur coccidophage *Rhyzobius forestieri* (Coleoptera : Coccinellidae) d'origine australienne, importé en Grèce de Californie en 1981, a été pour la première fois lâché sur agrumes contre *Coccus pseudomagnoliarum* et *Saissetia oleae* (Homoptera : Coccidae) dans la région de Cambos à Chios en 1983.

Au cours de la décennie suivante, *R. forestieri* s'est dispersé spontanément dans toute la plaine littorale de Cambos. En juillet 1992, un inventaire des coccinelles coccidiphages a été fait pour suivre la dispersion de *R. forestieri* sur agrumes et pour comparer l'importance de sa population à celle des coccinelles coccidiphages indigènes les plus importantes.

Des échantillonnages ont été faits sur 4 vergers d'agrumes à une distance de 1-2 km l'un de l'autre dans la région de Cambos, choisis pour leur infestation par les cochenilles. Sur un total de 337 adultes et de 237 larves de coccinelles coccidiphages trouvées, *R. forestieri* représente respectivement un pourcentage de 84.0 % et 75.1 %. Sa présence a été notée dans les 4 localités ; dans 2 d'entre elles, adultes et larves de *R. forestieri* sont les coccinelles prédominantes.

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