

The parasitoid complex of the red-striped soft scale, *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae) and its long-term effect on the scale on sugarcane in Egypt

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Abstract: Leaves infested by the red-striped soft scale, *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae), were collected from untreated sugarcane, *Saccharum officinarum* L. in the Atfieh region (Giza Governorate, Middle Egypt) during October-November 2005 and October-December 2006. The level of parasitism, the population trend of the parasitoid complex and the role that each species plays in the regulation of the scale population was determined. Parasitoid activity in 2005 was low in late October (2%), peaked in mid November (14.7%) and began declining the following week (10.8%), with an overall mean level of 8.7%. In 2006, parasitoid activity began at a higher level in October (27.7%), peaked at 74% in early November then fell drastically to 20.7% in early December, with an overall mean of 35.5%. Nineteen species of parasitoids (Hymenoptera: Chalcidoidea), emerged from *P. tenuivalvata*, most of which had been previously reported from this species and some representing new distribution records for Egypt (as indicated with an asterisk*). Of these, the following nine species are primary parasitoids: Aphelinidae - *Coccophagus semicircularis* (Förster), *Coccophagus obscurus* Westwood, *Coccophagus ochraceus* Howard*; Encyrtidae - *Metaphycus flavus* (Howard), *Metaphycus citricola* Annecke & Mynhardt, *Metaphycus* sp., *Microterys tricoloricornis* (De Stefani)*, *Parechthrodryinus coccidiiphagus* (Mercet) and *Diversinervus elegans* Silvestri; and the following ten species are hyperparasitoids (Hymenoptera: Chalcidoidea): Aphelinidae - *Marietta leopardina* Motschulsky, *Ablerus chionaspidis* (Howard) (= *A. greatheadi* Annecke & Insley); Encyrtidae - *Cerapterocerus mirabilis* Westwood, *Cheiloneurus* nr. *victor* Hoffer*, *Cheiloneurus paralia* (Walker)*, *Cheiloneurus latifrons* Hayat Alam & Agrawal*, *Mahencrytus comara* (Walker); Pteromalidae - *Pachyneuron muscarum* Linnaeus; Signiphoridae -, *Chartocerus subaeneus* (Förster) and *Thysanus* sp. The number of primary to secondary parasitoids was about 85:15 in 2005-6, and about 93:7 in 2006-7. The most abundant primary parasitoid species (in order of prevalence) were *Coccophagus semicircularis*, *Metaphycus citricola* and *Metaphycus flavus*. The first encyrtid and aphelinid individuals emerged in late October of 2005 and continued to emerge until the third week of December and in early January of 2006, respectively. During the second season, parasitoids began to emergence in October of 2006 and continued to emerge into February 2007. *Cheiloneurus* nr. *victor* was the most abundant hyperparasitoid, representing about 64% (in 2005-6) and 51% (in 2006-7) of the total hyperparasitoids that emerged. Competition between the primary parasitoids, and the impact of secondary parasitoids, resulted in decreased populations of *Metaphycus citricola* (28.3%), *Parechthrodryinus coccidiiphagus* (6.2%), *Microterys tricoloricornis* (3.5%) and *Diversinervus elegans* (1%) from 2005-6 to 2006-7. However, their overall effect on the scale population may have been reduced by the increased numbers of *Metaphycus flavus* and *Coccophagus ochraceus*, from 0.3 to 22.3% and from 0.4 to 7.7%, respectively during the same period. The general decrease in the number of hyperparasitoids in 2006-7 could have been due to increased numbers of *Coccophagus semicircularis* and *Coccophagus obscurus* and the appearance of *Coccophagus ochraceus*, which had not been previously recorded as a parasitoid of *P. tenuivalvata*. *Coccophagus semicircularis*, *Metaphycus citricola* and *Metaphycus flavus* seem to be the most promising parasitoid species for use as biological control agents against the red-striped soft scale on sugarcane in Egypt.

Key words: parasitism, primary and secondary parasitoids, red-striped soft scale, sugarcane.

Introduction

In 1998, the red-striped soft scale, *Pulvinaria tenuivalvata* (Newstead) (Hemiptera: Coccidae), was discovered on sugarcane at Luxor and Nagh-Hammidi in the Qena Governorate, Upper Egypt. In late September 2005, activity by the parasitoid wasps (Hymenoptera: Chalcidoidea), *Coccophagus semicircularis* (Förster) [Aphelinidae] and *Parechthrodryinus coccidiphagus* (Mercet) [Encyrtidae], resulted in a parasitism rate of 38%. Currently, this scale species is only known to occur in Uganda and Egypt. Since its introduction to Egypt, *P. tenuivalvata* has become a major pest of sugarcane. It attacks leaves, causing a major reduction in yield due to depletion of sap, production of honeydew and growth of sooty mould, which cause a dramatic reduction of photosynthesis and respiration. Early and heavy infestations of this pest have resulted in complete yield losses. With intensive insecticide applications, the population of the soft scale has fluctuated and parasitism has been retarded. El-Serwy (2001) recorded five primary parasitoids of *P. tenuivalvata* in different parts of Egypt: *Coccophagus semicircularis* (Förster) [Aphelinidae], *Metaphycus flavus* (Howard), *Microterys* sp., *Microterys nietneri* (Motschulsky) and *Diversinervus elegans* Silvestri [Encyrtidae], and two hyperparasitoids, *Cheiloneurus* sp. [Encyrtidae] and *Pachyneuron muscarum* Linnaeus [Pteromalidae]. Parasitism of adult female and nymphal scales was respectively higher at Atfieh (50.5% and 33.6%) than at Al-Aiat (44.7% and 6%) in Middle Egypt. El-Serwy & Guerrieri (2005) found considerable variation in the level of parasitism (37-55.8%). The most abundant species in the *P. tenuivalvata* parasitoid complex were *Metaphycus flavus* and *Pachyneuron muscarum*, representing about 64% and 60% respectively of the total primary and secondary parasitoids collected during the 1999-2000, 2001-2 and 2002-3 seasons at Atfieh. Four new records of primary parasitoids, *Coccophagus obscurus* Westwood [Aphelinidae], *Metaphycus citricola* Annecke & Mynhardt, *Parechthrodryinus coccidiphagus* (Mercet) and *Comperia alfieri* (Mercet) [Encyrtidae], and 4 new hyperparasitoid records, *Marietta leopardina* Motschulsky, *Ablerus chionaspidis* (Howard) (= *A. greatheadi* Annecke & Insley) [Aphelinidae], *Cerapterocerus mirabilis* Westwood and *Mahencrytus comara* (Walker) [Encyrtidae] were reported. To achieve sustainable control of this pest, research studies were initiated to determine the parasitoid complex of *P. tenuivalvata* in Egypt and select the best candidates to be used as biological control agents of this pest where it occurs.

Materials and methods

Sugarcane fields infested by *P. tenuivalvata* were selected at Atfieh (east of the Nile, 80 km south Cairo). Weekly leaf samples were taken from the 29th of October to the 19th of November of 2005 and from the 29th October to the 3rd of December of 2006 and taken to the laboratory for study.

In the laboratory, the samples of infested leaves were placed on paper sheets to dry, to avoid fermentation and growth of fungi. To assess the parasitisation rate, three hundred red-striped soft scales, representing different instar stages, were selected at random on the infested leaves. These were examined and assigned to one of the following categories: 1) unparasitized, 2) parasitoid exit holes present, 3) adult parasitoid (alive or dead) present, and 4) immature parasitoid present. The next day, the semi-dried leaves were placed in pinned plastic bags each closed with an elastic band, to allow the parasitoids to emerge, whereas the detached scales of different instar stages, left on the paper, were placed in petri dishes (each 15 cm in diameter). Daily examination of the bags and petri dishes using a

stereomicroscope was made from October 31, 2005 to January 5, 2006 and from October 31, 2006 to February 11, 2007. The emerging parasitoids were attracted to light; they were collected into 70% ethanol. All the parasitoids obtained were identified, counted and classified as primary parasitoids or hyperparasitoids.

Results and discussion

During the growing seasons of sugarcane in this long-term study, the rate of parasitism of *P. tenuivalvata* fluctuated greatly, with a mean rate of 8.7% in 2005-2006 and 35.5% in 2006-2007. In 2005, the initial parasitisation rate was 2% and parasitism continued until the third week of November. A distinct peak of 14.7% was attained in mid-November, but abruptly decreased to 10.8% about 7 days later. In 2006, the initial parasitisation rate was 27.7% and parasitism continued until early December. A distinct peak of 74% was attained in early November, but abruptly decreased to 20.7% about 30 days later.

Parasitoids emerged from parasitized scales in both emergence seasons were arranged into two groups: (A) primary parasitoids and (B) secondary parasitoids.

A- Primary parasitoids

Nine primary parasitoid species (Hymenoptera: Chalcidoidea) were identified and were classified into two groups: (1) predominant species and (2) newly recorded species. The predominant species were: *Coccophagus semicircularis*, *Coccophagus obscurus*, [Aphelinidae]; *Metaphycus flavus*, *Metaphycus citricola*, *Parechthrodryinus coccidiphagus* and *Diversinervus elegans* [Encyrtidae]. The newly recorded species were: *Coccophagus ochraceus* Howard (new record), [Aphelinidae], *Microterys tricoloricornis* (De Stefani) (new record) and an undetermined species, *Metaphycus* sp. [Encyrtidae].

1) Predominant species:

The activity of the six predominant species collected in the two emergence seasons fluctuated. Two of these, *Metaphycus citricola* and *Coccophagus semicircularis* represented 50.5 and 31.2% respectively of the total primary parasitoids that emerged in the 2005-6 season; however, *Metaphycus citricola* dropped to 22.2% and *Coccophagus semicircularis* increased to 39.4% in 2006-7 (Table 1). In 2005-6, parasitoid emergence started in late October and continued until the third week of December and early January but in the 2006-7 season, emergence continued for an additional month (Table 2). The population of *Metaphycus citricola* reached its peak during the third week of November in both seasons, whereas *Coccophagus semicircularis* reached its peak in the fourth week of November in 2005 and the second week of November in 2006. The population of a third species, *Metaphycus flavus* was highly variable. Individuals emerged in low numbers during the last three weeks of November in 2005; however in 2006-2007, this species emerged in huge numbers (22.3% of the total collected primary parasitoids) from late October to mid February, with two peaks in early November and late December. *Parechthrodryinus coccidiphagus* represented 8.2% and 2.0% of the total primary parasitoids collected in 2005-2006 and 2006-2007 emergence seasons, respectively; whereas *Coccophagus obscurus* represented 4.1% and 5.4% of the total primary parasitoids collected in 2005-2006 and 2006-2007, respectively (Table 1). During the first emergence season (2005- 2006), adult wasps first appeared in early and mid-November and continued until the third week of December, with a distinct peak in numbers in late November. Both *Parechthrodryinus coccidiphagus* and *Coccophagus obscurus*

followed a similar pattern of emergence, beginning in late October and ending in late December in the second emergence season. The aphelinid and the encyrtid species had a distinct peak during the second and the third weeks of November. Finally, *D. elegans* represented 1.2% and 0.2% of the total beneficials collected in 2005-6 and 2006-7 emergence seasons, respectively. It appeared in low numbers in the second week of November and continued until the first week in December in 2005; whereas in 2006, it first appeared in the first week of November and continued until the third week of December.

Table 1. Primary parasitoids collected in 2005-6 and 2006-7 emergence seasons.

Family	Species	2005-6		2006-7	
		No.	%	No.	%
Aphelinidae	<i>Coccophagus semicircularis</i>	1408	31.2	11921	39.4
Encyrtidae	<i>Metaphycus citricola</i>	2283	50.5	6728	22.2
Encyrtidae	<i>Metaphycus flavus</i>	12	0.3	6762	22.3
Aphelinidae	<i>Coccophagus ochraceus</i>	17	0.4	2345	7.7
Aphelinidae	<i>Coccophagus obscurus</i>	188	4.1	1630	5.4
Encyrtidae	<i>Parechthrodryinus coccidiphagus</i>	369	8.2	606	2.0
Encyrtidae	<i>Microterys tricoloricornis</i>	188	4.1	165	0.6
Encyrtidae	<i>Diversinervus elegans</i>	53	1.2	56	0.2
Encyrtidae	<i>Metaphycus sp.</i>	0	0.0	62	0.2
Total		4518		30275	

2) Newly recorded species:

Two newly recorded, primary parasitoid species emerged from *P. tenuivalvata*. *Coccophagus ochraceus* appeared in small numbers between early November and the second week of December in 2005, representing only 0.4% of the total primary parasitoids collected. However, in 2006, this species began to emerge in late October, peaked in the first week of December and continued until February 2007, and represented 7.7% of the total primary parasitoids collected in 2006-7 emergence season. The second species, *Microterys tricoloricornis*, emerged from early November to the third and fourth weeks of December in the first and the second seasons, respectively peaking in the third week of November 2005 and the second week of November 2006. It accounted for 4.1% of the total primary parasitoids collected in 2005-6, but decreased to only 0.6% of the total in the second season. The undetermined species, *Metaphycus sp.*, emerged in small numbers from early November to early January in 2006-7.

Table 2. Distribution no. of primary parasitoids emerged during October-February in 2005-2006 and 2006-2007 emergence seasons.

Seasons	Species	No. of emerged parasitoids during:																								Total	
		Oct.				November				December				January				February									
		4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd											
2005-2006	<i>M. citricola</i>	8	135	647	800	487	124	75	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2283	
	<i>C. semicircularis</i>	1	81	176	330	455	264	71	17	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1408	
	<i>P. coccidiphagus</i>	0	12	20	87	149	66	22	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	369	
	<i>C. obscurus</i>	0	0	22	29	62	51	18	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	188	
	<i>M. tricoloricornis</i>	0	4	27	78	55	10	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	188	
	<i>D. elegans</i>	0	0	4	9	28	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	
	<i>C. ochraceus</i>	0	2	5	3	4	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	
	<i>M. flavus</i>	0	0	3	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	
	Total	9	234	904	1341	1244	528	196	49	9	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4518	
	2006-2007	<i>C. semicircularis</i>	82	3450	5836	1663	588	147	69	33	29	13	4	4	2	1	0	0	0	0	0	0	0	0	0	0	11921
<i>M. flavus</i>		108	2480	1547	219	239	590	562	315	600	59	5	8	10	18	2	0	0	0	0	0	0	0	0	0	6762	
<i>M. citricola</i>		28	684	1773	2148	1520	442	92	28	5	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0	6728	
<i>C. ochraceus</i>		14	208	198	156	300	523	453	262	131	51	17	12	11	9	0	0	0	0	0	0	0	0	0	0	2345	
<i>C. obscurus</i>		3	373	844	311	68	16	8	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1630	
<i>P. coccidiphagus</i>		5	40	112	216	151	49	22	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	606	
<i>M. tricoloricornis</i>		0	17	42	39	22	20	18	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	165	
<i>Metaphycus</i> sp.		0	3	3	3	10	12	13	8	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62
<i>D. elegans</i>		0	5	23	19	4	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56
Total		240	7260	10378	4774	2902	1802	1238	667	778	128	28	27	23	28	2	0	0	0	0	0	0	0	0	0	0	30275

Discussion

A- Primary parasitoids

The ratio between the predominant and newly recorded species that emerged was about 95:5 in 2005-6, and 92:8 in 2006-7. Populations of the predominant primary parasitoids were highly variable over the term of this study. The three most abundant beneficial species, *Coccophagus semicircularis*, *Metaphycus citricola* and *Metaphycus flavus*, accounted for the majority (>83%) of primary parasitoids that emerged. El-Serwy (2001) reported a higher rate of parasitism (69.6%) occurring on nymphs of *P. tenuivalvata* reared on elephant grass than from those reared on sugarcane at Atfih. The level of parasitism on adult females and nymphs was higher in Atfih (50.5% and 33.6%, respectively) than in Al-Aiat (44.7% and 6%, respectively). The most abundant parasitoid species were *Coccophagus semicircularis* and *Metaphycus flavus* in both regions of Giza Governorate, Middle Egypt. El-Serwy & Guerrieri (2005) reported that at Atfieh, parasitism of the red-striped scale ranged between 37 and 55.8%, with *Metaphycus flavus* as the most abundant species (> 64% of the total primary parasitoids collected) followed by *Metaphycus citricola* (16.4%) and *Coccophagus semicircularis* (10.7%).

In Egypt, the reproductive capacity of the *P. tenuivalvata* females parasitized by *Coccophagus semicircularis* was reduced by about 39% and there was a reduction of approximately eight days in the ovipositional period which was about 25% of that of unparasitized females. *Metaphycus flavus* was shown to reduce the reproductive capacity of another soft scale, *Pulvinaria regalis* Canard, by 83% in Germany (El-Serwy, 2001; Arnold & Sengonca, 2003). *Coccophagus semicircularis* and *Parechthrodryinus coccidiphagus* were found in low numbers at Nagh-Hammidi (Qena Governorate), the main cultivated area in Upper Egypt. *Coccophagus semicircularis* has been reported as a parasitoid of *Sphaerolecanium prunastri* (Fonscolombe) in Greece and *Saissetia oleae* (Olivier), *Coccus hesperidum* Linnaeus and *Pulvinaria mesembryanthemi* (Vallot) (Hemiptera: Coccoidea: Coccidae) in France. *Metaphycus flavus* was reported as a parasitoid of *C. hesperidum* and *C. pseudomagnoliarum* Kuwana in Turkey and of *S. oleae*, *C. hesperidum* and *P. mesembryanthemi* in France (Bakoyannis, 1984; Tryapitsyn & Doğanlar, 1995; Panis, 2001).

Competition between the primary parasitoids of *P. tenuivalvata* resulted in a decrease of 39% in the number of the encyrtid species, *Metaphycus citricola*, *Parechthrodryinus coccidiphagus*, *Microterys tricoloricornis* and *D. elegans*, that emerged in 2005-6 compared to that of 2006-7. Despite this decrease, the overall impact of the parasitoid complex on the population of *P. tenuivalvata* may have been compensated for partially by the increase in the emergence rate of *Metaphycus flavus* from 0.3 to 22.3% and partially by the three species, *Coccophagus semicircularis*, *Coccophagus obscurus* and *Coccophagus ochraceus* which increased by 16.8% in the same period. *Coccophagus ochraceus* was the most abundant of the newly recorded species that emerged in the second season and perhaps will become one of the most abundant species in the future. It was imported and released in California to control the black scale, *S. oleae* (Daane *et al.*, 2005). *Microterys tricoloricornis* is present in Mediterranean countries and is known to parasitize *Coccus hesperidum* and *C. pseudomagnoliarum* in Turkey (Tryapitsyn & Doğanlar, 1995).

B - Secondary parasitoids (hyperparasitoids)

Ten secondary parasitoids (Hymenoptera: Chalcidoidea) were identified and were classified into two groups: (1): previously reported hyperparasitoid species and (2) newly recorded species. Previously recorded species were: *Marietta leopardina*, *Ablerus chionaspidis*

[Aphelinidae]; *Cheiloneurus* sp. (= *Cheiloneurus* nr. *victor* Hoffer) *Cerapterocerus mirabilis*, *Mahencrytus comara* [Encyrtidae]; *Pachyneuron muscarum* [Pteromalidae]. The newly recorded species were: *Cheiloneurus paralia* (Walker), *Cheiloneurus latifrons* Hayat, Alam & Agrawal [Encyrtidae], *Chartocerus subaeneus* (Förster) and *Thysanus* sp. [Signiphoridae].

1) Previously reported hyperparasitoid species

Of the six previously reported hyperparasitoids collected, *Cheiloneurus* nr. *victor* (reported as *Cheiloneurus* sp. in El-Serwy 2001) was the most abundant, representing 64.1 and 50.5% of the total number of secondary parasitoids in the 2005-6 and 2006-7 emergence seasons, respectively (Table 3). *Pachyneuron muscarum* accounted for 29.4% of the total hyperparasitoids that emerged in 2005-6, but decreased to 9.7% in the 2006-7 season.

Table 3. Secondary parasitoids collected during 2005-6 and 2006-7 emergence seasons.

Family	Species	2005-2006		2006-2007	
		No.	%	No.	%
Encyrtidae	<i>Cheiloneurus</i> nr. <i>victor</i>	500	64.1	1081	50.5
Aphelinidae	<i>Marietta leopardina</i>	22	2.8	622	29.0
Pteromalidae	<i>Pachyneuron muscarum</i>	229	29.4	208	9.7
Aphelinidae	<i>Ablerus chionaspidis</i>	0	0.0	146	6.8
Encyrtidae	<i>Mahencrytus comara</i>	17	2.2	36	1.7
Encyrtidae	<i>Cheiloneurus paralia</i>	5	0.6	20	0.9
Encyrtidae	<i>Cerapterocerus mirabilis</i>	0	0.0	16	0.8
Encyrtidae	<i>Cheiloneurus latifrons</i>	4	0.5	3	0.2
Signiphoridae	<i>Chartocerus subaeneus</i>	1	0.1	5	0.2
Signiphoridae	<i>Thysanus</i> sp.	2	0.3	5	0.2
Total		780		2142	

Marietta leopardina represented 2.8% of the total hyperparasitoids in 2005-6, but increased to 29% in the next season. The three species followed a similar pattern of emergence, starting in early November and peaking in the fourth week of November in 2005 and starting in late October and peaking in the third week of November in 2006 (Table 4). The emergence period of *Pachyneuron muscarum* continued until mid and late December; whereas that of *Marietta leopardina* extended until early January and mid February in 2005-6 and 2006-7, respectively. In both emergence seasons, *Cheiloneurus* nr. *victor* continued to emerge until the third week of December. A fourth species, *Mahencrytus comara*, appeared in small numbers during the third week of November and continued to emerge until the first week of December in 2005 whereas, in 2006, this species began to emerge in the first week of November and continued to emerge until the second week of December. In 2006-7, *Ablerus chionaspidis* emerged from early November to early February, with a peak in its population occurring in late November, representing 6.8% of hyperparasitoids that were collected. *Cerapterocerus mirabilis* appeared in small numbers during the last three weeks of November 2006-7.

Table 4. Distribution no. of secondary parasitoids emerged during October-February in 2005-6 and 2006-7 emergence seasons.

Seasons	Species	No. of emerged parasitoids during																		Total
		Oct.		November				December				January				February				
		4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd				
2006-2007	<i>C. nr. victor</i>	0	6	47	94	245	84	21	3	0	0	0	0	0	0	0	0	0	0	500
	<i>P. muscarum</i>	0	7	43	46	106	24	3	0	0	0	0	0	0	0	0	0	0	0	229
	<i>M. leopardina</i>	0	1	1	3	6	3	5	1	1	1	0	0	0	0	0	0	0	0	22
	<i>M. conara</i>	0	0	0	3	9	5	0	0	0	0	0	0	0	0	0	0	0	0	17
	<i>C. paralia</i>	0	0	0	0	2	2	1	0	0	0	0	0	0	0	0	0	0	0	5
	<i>C. latifrons</i>	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	4
	<i>Thysanus</i> sp.	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	<i>C. subaeneus</i>	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	Total	0	14	91	147	370	119	33	4	1	1	0	0	0	0	0	0	0	0	780
2005-2006	<i>C. nr. victor</i>	5	54	241	412	310	25	26	8	0	0	0	0	0	0	0	0	0	0	1081
	<i>M. leopardina</i>	1	35	81	181	178	42	33	21	20	11	9	0	2	7	1	0	0	622	
	<i>P. muscarum</i>	1	40	47	56	38	4	14	7	1	0	0	0	0	0	0	0	0	208	
	<i>A. chionaspidis</i>	0	2	13	21	36	15	15	13	17	2	5	3	1	3	0	0	0	146	
	<i>M. conara</i>	0	6	17	11	0	1	1	0	0	0	0	0	0	0	0	0	0	0	36
	<i>C. paralia</i>	0	2	0	4	14	0	0	0	0	0	0	0	0	0	0	0	0	0	20
	<i>C. mirabilis</i>	0	0	6	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	16
	<i>C. subaeneus</i>	0	0	0	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	5
	<i>Thysanus</i> sp.	0	0	0	2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	5
<i>C. latifrons</i>	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	3	
Total	7	139	405	695	584	89	92	49	38	13	14	3	3	10	1	0	0	0	2142	

2) Newly recorded species

Four newly recorded hyperparasitoid species, *Cheiloneurus paralia*, *Cheiloneurus latifrons*, *Chartocerus subaeneus* and *Thysanus* sp. emerged in small numbers between the first and the third weeks of November and mid December in 2005-6 and 2006-7 emergence seasons respectively.

The ratio between the predominant and newly recorded species that emerged was about 98:2 in both seasons. The population of the secondary parasitoids fluctuated greatly over the term of the study. The three most abundant species, *Cheiloneurus* nr. *victor*, *Marietta leopardina* and *Pachyneuron muscarum* represented about 91% of the total hyperparasitoids collected. *Cheiloneurus* nr. *victor* was the most abundant species (54%), followed by *Marietta leopardina* (22%) and *Pachyneuron muscarum* (14.9%). Competition between these species resulted in a decrease in the number of *Cheiloneurus* nr. *victor* (13.6%) and *Pachyneuron muscarum* (19.7%) from the first to the second season. Their activity was probably replaced by that of *Marietta leopardina*, whose emergence rate increased from 2.8 to 29% during the same period. The two species, *Aberus chionaspidis* and *Cerapterocerus mirabilis*, could also have played a role in this competition; they represented 6.8 and 0.8% of the hyperparasitoids collected in 2006-7, respectively. The hyperparasitoid complex was completed by small collections of *Mahencrytus comara* (1.8%) and the four newly recorded species (together about 1.5%).

It has been reported that in the competition among the hyperparasitoids that attack *Metaphycus flavus* in *Coccus hesperidum*, *Marietta javensis* (Howard) displaced *Cheiloneurus paralia* (Walker) completely in six weeks and *Pachyneuron muscarum* in eight weeks, and *Cheiloneurus* sp. displaced *Pachyneuron* in 20 weeks (Kfir et al., 1983). *Pachyneuron muscarum*, *Cerapterocerus mirabilis*, *Cheiloneurus paralia*, *Marietta* sp., *Aberus* sp., and *Chartocerus subaeneus* were recorded as hyperparasitoids on parasitoids of scale insects in Turkey (Ülgentürk et al., 2004). The former species, *Pachyneuron muscarum*, was found at Nagh-Hammadi in Upper Egypt. *Chartocerus subaeneus* belongs to family Signiphoridae which are hyperparasitoids of other parasitic Hymenoptera associated with, cyclorrhaphous Diptera, scale insects (Hemiptera: Coccoidea), and whiteflies (Hemiptera: Aleyrodidae) and have been reared from *Maconellicoccus hirsutus* Green (Hemiptera: Pseudococcidae) on hibiscus in Egypt (Abd-Rabou, 1999; Noyes, 2003).

In conclusion, the parasitism rate of red-striped soft scale fluctuated greatly during this study. The rate was about four times greater in 2006-7 than in 2005-6. In both seasons, parasitic activity started in late October and continued until the third week of November and early December in 2005-6 and 2006-7 growing seasons, respectively. Of the total number of parasitoids that emerged, the ratio of primary to secondary parasitoids was 85:15 in 2005-6 and 93:7 in 2006-7. Increased activity by hyperparasitoids in the first season may have hindered the effect of the primary parasitoids on the *P. tenuivalvata* population. The species composition and relative numbers of the parasitoid complex varied markedly over time. All the primary and secondary parasitoids that emerged had been recorded previously from soft scales, except for the beneficial species, *Microterys nietneri* and *Comperia alfieri* (Encyrtidae). The population of the three most abundant primary parasitoids varied from season to season; the population of *Metaphycus citricola* decreased by 28.3%, *Metaphycus flavus* increased by 22% and *Coccophagus semicircularis* increased by 8.2% between the 2005-6 and 2006-7 seasons. Regarding the three most abundant secondary parasitoids, *Cheiloneurus* nr. *victor* and *Pachyneuron muscarum* decreased by 13.6 and 19.7%, respectively, and *Marietta*

leopardina increased 26.2% between the 2005-6 and 2006-7 seasons. The most abundant primary and secondary species in this study, *Coccophagus semicircularis* and *Cheiloneurus* nr. *victor*, may have replaced the most abundant primary and secondary species, *Metaphycus flavus* and *Pachyneuron muscarum*, that were recorded in earlier studies.

Two primary parasitoids and four secondary parasitoid species were newly recorded from *P. tenuivalvata*. The most abundant of these primary parasitoids was *Coccophagus ochraceus*. The peak of activity of the secondary parasitoids, *Cheiloneurus* nr. *victor*, *Pachyneuron muscarum* and *Marietta leopardina* in the third and the fourth weeks of November corresponded to a decrease of primary parasitoids during that period for the second and the first seasons, respectively. This result corroborates previous findings on the seasonal fluctuation of the parasite complex of *P. tenuivalvata* in Egypt (El-Sewry & Guerrieri, 2005).

The primary parasitoid species having the longest emergence period was *Metaphycus flavus* (15 weeks) followed by *Coccophagus semicircularis* and *Coccophagus ochraceus* (14 weeks). The secondary parasitoid having the longest emergence period was *Marietta leopardina* (15 weeks) followed by *Ablerus chionaspidis* (13 weeks), which showed that these parasitoids were active on the scale nymphs at the end of the season. The most common primary parasitoid species recorded from the red-striped soft scale in Egypt were *Coccophagus semicircularis*, *Metaphycus flavus* and *Metaphycus citricola*. Many other species of aphelinids, primarily of the genus *Coccophagus*, and many other species of encyrtids, primarily of the genus *Metaphycus*, are known to attack soft scales and have been used effectively in biological control programs conducted worldwide (Guerrieri & Noyes, 2000; Arnold & Sengonca, 2003). Further studies on the natural enemies of *P. tenuivalvata* in other areas where it occurs are needed to determine the most effective biological control agent for this pest species.

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