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Studies on the Parasitoid Complex Attacking the Globose Scale *Sphaerolecanium prunastri* (Fonscolombe) (Hemiptera: Coccoidea) on *Prunus* Species in Turkey

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ABSTRACT: The globose scale (GS), *Sphaerolecanium prunastri* Fonscolombe (Hemiptera: Coccoidea), is a principle pest of *Prunus* trees, but it is also found on other stone fruit trees in Isparta Province, Turkey. The parasitoid complex was studied in 2006 and 2007 and total of eight (five primary and three secondary) hymenopterous species were found associated with *S. prunastri* at the five sites studied, but not all species were recorded at all five sites. The most important primary species reducing GS population were *Discodes coccophagus*, *Metaphycus silvestrii*, *Coccophagus spartanus* and C. *lycimnia* (Hymenoptera: Chalcidoidea). Average percent parasitism at the five sites by primary parasitoid species was 27%. The level of total parasitism of *S. prunastri* was 71.4% in 2007 in Egirdir. The parasite complex was richer and percent parasitoid-caused mortality was higher at those sites that did not receive chemical treatment to suppress the host population. Seven of the eight species of parasitoids were recovered at Mehmet Tonge in 2006 and at Gonen in 2007.

KEY WORDS: biocontrol, Chalcidoidea, Coccoidea, Hemiptera, host-parasitoid, Hymenoptera, Turkey, globose scale

ÖZET: *Sphaerolecanium prunastri* Fonscolombe (Hemiptera: Coccoidea) erik ağaçlarının ana zararlılarından biri olup, Isparta (Türkiye) bölgesinde diğer taşçekirdekli meyveler üzerinde de bulunmuştur. Bu zararlının asalakları üzerindeki çalışmalar 2006–2007 yıllarında, 5 farklı alanda sürdürülmüş vetoplam sekiz (8) asalak tür (5 birincil ve 3 ikincil asalak) saptanmıştır. Zararlının populasyonunun azalmasında etkili olan bu asalaklar, *Discodes coccophagus*, *Metaphycus silvestrii*, *Coccophagus spartanus* ve C. *lycimnia* (Hymenoptera: Chalcidoidea)'dır. Tüm bölgede ortalama parazitleme oranı %27 olmuştur. Parazitlenmenin enyüksek olduğu Eğirdir'de 2007 yılında bu oran %71.4'e ulaşmış ve herhangi bir kimyasal uygulamaya gerek kalmamıştır. Sekiz asalak türün yedisine 2006 yılında Mehmet Tönge'de ve 2007 yılnda Gönen'de rastlanmıştır.

ANAHTAR KELIMELER: biyolojik savaş, Chalcidoidea, Coccoidea, Hemiptera, konukçu-asalak, Hymenoptera, Türkiye, *Sphaerolecanium prunastri*

The plum or globose scale (GS), *Sphaerolecanium prunastri* Fonscolombe (Hemiptera: Coccidae), is a common and harmful soft scale species that attacks *Prunus* spp. (Rosaceae) and other stone fruit in Turkey and throughout the Holarctic (Borchsenius, 1957; Karaca *et al.*, 2003; Ülgentürk *et al.*, 1999), where it is a widespread and often important pest. It infests the branches and trunks of its host plants, particularly *Prunus* spp. Trees can be seriously damaged, and may even die, although usually they are defoliated due to the accumulation of sooty molds growing on the excreted honeydew (Borchsenius, 1957; Khadzhibeili, 1983; Kosztarab and Kozar, 1988). The female scale lays eggs from May to June. These hatch in June and July, and the crawlers disperse on the trees. At this stage, the crawlers can be easily

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transferred to other plants by wind and on agricultural tools (Japoshvili, 1999). Chemical treatment is ecologically undesirable, especially in urban environments and, due to the waxy cover on the scales, contact insecticides are ineffective. Introduction of natural enemies (parasitoids) appears to be a good alternative, particularly as it has proven beneficial against other harmful scale insects (Camporese and Pellizzari, 1998; Kravchenko, 1991). Among the natural enemies of *S. prunastri*, *Discodes coccophagus* (Ratzeburg) is considered to be the most efficient (Karaca *et al.*, 2003). However, GS is attacked by a large number of parasitoids and predators, all of which play an important role in regulating this pest in some European countries (Karaca *et al.*, 2003).

The aim of this study is to survey the diversity of natural enemies of GS to determine (i) what measures might be taken to improve the efficacy of biological control of this pest and (ii) to determine the influence of some anthropogenic factors on the ongoing processes (host-parasitoid interactions). This paper reports on the parasitoid complex of GS and their distribution, and species compositionat the five selected locations in Isparta Province, Turkey.

Materials and Methods

The investigation was conducted in five different locations in Isparta Province, Turkey, between June–September 2006 and April–August 2007. Two locations (Mehmet Tonge and Gonen) were poorly irrigated and poorly treated (mis-applied) with contact pesticides (Supracide), generally against aphids (Chemicals were applied just once and during the vegetation period trees were irrigated only twice). The other three locations (Egirdir, Kuleonu and Kirinti) were regularly irrigated (8–9 times between May–August) and treated twice during May–June in both years of the study. The composition of the orchards at these five sites were: at Gonen: 20–25 yr old almond (*Prunus dulcis* (Miller) D.A.Webb), and 10 yr old peach (*P. persica* (L.) Batsch); at Egirdir: 10 yr old plum (*P. domestica* L.) and peach (*P. persica*); at Mehmet Tonge: 10 yr old plum (*P. domestica*); at Kirinti: 10 yr old peach (*P. persica*), and at Kuleonu: 7–8 yr old plum (*P. domestica*). The distance between trees in all the orchards was 4–5 m and most of the plum (*P. domestica*) and almond (*P. dulcis*) trees were 3–5.5 m tall. The densities of scales were determined on 10 trees on five randomly selected shoots per tree. One 10 cm shoot with 1–2 cm diameter was selected from each of the four cardinal directions from the outside edge and one from the centre of the tree. The mean population and standard error were calculated for each location. These infested shoots were collected from the orchards every 15 days between June and September, 2006 and April and August, 2007 and taken to the laboratory, placed in glass bottles covered with very fine mesh netting and kept at room temperature (21–23°C) and humidity (40–45) for parasitoid emergence.

The species of parasitoids that emerged from these samples (in total 150) were identified and the percent parasitism calculated using the formula P = Bx100/a, where P = percent parasitism, B = parasitized scale insects and a = total number of scales examined in the samples. The number of trees infested with GS was also counted and the percentage of the total in the orchard calculated; we define this percentage as ''infested'' trees (based on 10 trees per orchard). The number of parasitized scales was determined by the presence of exit holes in the second-instar larvae and adult scales (Karaca *et al.*, 2003). Scales with and without exit holes were

also counted on the shoots at the end of the vegetative period. Emerged parasitoids were identified by the first author and voucher specimens were deposited in the collections of the Museum of Plant Protection Department of Agricultural Faculty of Suleyman Demirel University in Isparta, Turkey, and in the Museum of the Institute of Zoology in Tbilisi, Georgia.

Results and Discussion

GS was the main soft scale species on *Prunus* spp. in this study in the orchards in Isparta Province, Turkey, during this study. During the surveys in 2001 and 2002 (Japoshvili *et al.*, 2002; Karaca *et al.*, 2003) we found five hymenopterous parasitoid species in Isparta Province, and eight species were found in 2006: five primary parasitoids in two families: *Discodes coccophagus* (Ratzeburg), *Metaphycus silvestrii* Sugonjaev, *Microterys hortulanus* Erdös (Encyrtidae), *Coccophagus lycimnia* Walker and *C. spartanus* Japoshvili & Karaca (Aphelinidae), and three species of secondary or hyperparasitoids in three families: *Cerapterocerus mirabilis* Westwood (Encyrtidae), *Aprostocetus trjapitzini* Kostjukov (Eulophidae) and *Pachyneuron muscarum* Linnaeus (Pteromalidae). All species are solitary parasitoids.

In 2006, the percentage of trees infested and the density of GS on 10 cm long shoots in each of the five locations is given in Table 1. The highest density of GS on the three host trees at the five locations was 17.8 ± 3.7 and 12.0 ± 3.7 on *P. persica* recorded at Kirinti in 2006 and 2007, where 97% and 90% of trees were infested respectively. Much lower GS densities and defoliation were found at Egirdir and Gonen. Similarly high (100%) infestations were recorded from Mehmet Tonge and Kuleonu on plum, while it reached 90% at Gonen on almond. The lowest percentage of trees infested (10%) and lowest density of scale (0.6 ± 0.8) was at Egirdir in 2006. No GS was found on plum at Gonen and Kirinti in 2006 and 2007, and in 2007 at Kuleonu. In 2007 the percentage of trees infested and the densities of GS were different from those in 2006 at each site (Table 1). The greatest density of GS (12 ± 3.7) was still recorded from Kirinti, where 90% of all trees were infested in 2007, compared with 97% in 2006. The lowest GS density (0.8 ± 0.9) was recorded at Gonen in 2007. There was no apparent infestation on either plum or almond trees at Kuleonu due to spraying. The total mortality of GS caused by primary parasitoids in 2006 at the five sites was: 48.8% at Egirdir; 40% at Gonen; 35% at Mehmet Tonge; 20% at Kuleonu and 10.7% at Kirinti. In 2007, percent parasitism had changed at three of the five sites: 71.4% at Egirdir; 0% at Kuleonu (probably due to several pesticide applications during 2006); 70.5 at Kirinti. Mortality of GS due to natural enemies (parasitoids and coccinelid predators) in 2007 at Gonen and Mehmet Tonge was the same, almost 95%. 90% of this mortality was caused by predators (parasitoid activity low at these sites due to coccinelid activity). It is estimated that, parasitoids caused only 5% mortality of GS in these sites.

It appears that the percentage of trees infested and GS density was dependent on the species in the parasitoid complex at each site and also on the total number of parasitoids present in each orchard. In Egirdir in 2006, the dominant primary parasitoid was *Discodes coccophagus* (87.9%) (Table 2) and, consequently, the density of GS and damage on the host trees and was low (10%) (Table 1), indicating that this species was effective against GS. However, in Kuleonu in 2006, the secondary or hyperparasitoid, *C. mirabilis* (which attacks *D. coccophagus*), was the

Table 1. Percentage of infested trees and density of globose scale per 10 cm^2 of shoots at five different locations and on different host plants and Percentage of parasitisation of GS in 2006 and 2007.

	Percentage of infested trees and mean density of globose scale ± SE by location and year									
	Egirdir		Mehmet Tonge		Gonen		Kuleonu		Kirinti	
Host Plants	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Prunus persica	25%, 1.2 ± 1.3	96%, 8.3 ± 2.4	0	0	90%, 1.8 ± 1.4	55%, 1.0 ± 1.0	0	0	97%, 17.8 ± 3.7	90%, 12 ± 3.7
Prunus domestica	10%, 0.6 ± 0.8	90%, 9.7 ± 6.7	100%, 1.1 ± 1.2	55%, 1.5 ± 1.1	0	0	100%, 10.1 ± 2.5	0	0	0
Prunus dulcis	0	0	0	0	100%, 4.8 ± 1.8	45%, 0.8 ± 0.9	0	0	0	0
Percentage of parasitisation of GS	48.8%	71.4%	35%	95%	40%	95%	20%	0%	10.7%	70.5%

Table 2. Parasitoids percentage in total number of emerged parasitoids in 2006–2007 in Isparta Province.

	Location and year of sample									
	Egirdir		Mehmet Tonge		Gonen		Kuleonu		Kirinti	
Parasitoids	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Primary										
Discodes coccophagus	87.9	41.4	21.4	0	1.3	28.6	9.4	0	11.9	64.5
Metaphycus silvestrii	0	0	33.1	42.9	22.1	23.5	1.9	0	40.1	10.3
Micorterys hortulanus	0	5.5	0.4	10.7	0	2.2	0	0	0	0
Coccophagus lycimnia	0	0	4.4	42.9	20.7	12.8	1.9	0	8.2	3.8
C. spartanus	0	0	12.2	0	2.6	19.3	0	0	19.8	6.7
Combined Total Parasitism	87.9	46.9	71.5	96.5	46.7	86.4	13.2	0	80.0	85.3
Secondary										
Cerapterocerus mirabilis	11.0	39.5	22.0	3.5	15.6	2.2	81.1	0	0	13
Pachyneuron muscarum	1.1	12.3	6.5	0	37.7	11.4	5.7	0	20.0	1.7
Aprostocetus trjapitzini	0	1.3	0	0	0	0	0	0	0	0
Combined Total Parasitism	12.1	53.1	28.5	3.5	53.3	13.6	86.8	0	20.0	14.7

most abundant species (81%) and the % trees infested and GS density was high (see Tables 1 and 2). The larval parasitoids (*Metaphycus silvestrii* and *Coccophagus* spp.) have a significant effect on GS populations in some sites. This difference may depend on the timing of pesticide application. Primary parasitoids appear early in the year (April) and are active when pesticide sprays are applied in the spring, having a negative affect on the parasitoid population. It seems likely, therefore, that the effectiveness of the primary parasitoids depends on the type and timing of the pesticides used. If the primary parasitoids are active at the time of spraying, then they could easily be killed by the pesticide. At the same time or shortly afterwards, the number of secondary parasitoids increases, reducing the effectiveness of the remaining primary parasitoids and therefore causing an increase in GS density and damage to the host tree. However, it is thought that, once the eggs of the primary parasitoid are laid inside the scale, they are probably protected by the scales waxy coat from the effects of sprays. On the other hand, secondary parasitoids are active later, from July onwards, when the spraying has already been completed. As the results suggest, application of chemical pesticides destroys normal host-parasitic or host-natural enemy relations and changes in the population dynamics are somehow inconsistent and depend on the time of spraying.

Our investigations (Japoshvili, 1999; Japoshvili *et al.*, 2002; Karaca *et al.*, 2003) showed that the most effective biocontrol agent against GS is *Discodes coccophagus*, but that other parasitoids can also be effective, especially *Metaphycus silvestrii* and *Coccophagus* spp., if mass rearing and augmentative releases can be done at a time when host (GS) is in a susceptible stage. Only one species of primary parasitoid *Discodes coccophagus*, and two species of secondary parasitoids *Pachyneuron muscarum* and *Cerapterocerus mirabilis* were recorded from all five of the sites investigated. On the other hand, only a single specimens of the secondary parasitoid *Aprostocetus trjapitzini* were recorded in 2002 (Karaca *et al.*, 2003) and 2007.

At Mehmet Tonge, where pesticides were poorly treated, seven parasitoid species were recorded in 2006 but only four in 2007. In Gonen seven parasitoid species were recorded in 2007 as well. In the other sites, at least two of these species were missing in both 2006 and 2007. However, it should be noted that the balance between parasitoids in Mehmet Tonge and Gonen was more or less stable, with no dominant species as was found in Egirdir. The results show that parasitoids are more or less effective in every site. Even when the trees were 100% infested, the density of GS was very low.

It is considered that GS in Isparta Province can be under parasitoid control. Evidence for this conclusion also comes from our previous investigations conducted in Georgia and Turkey (Japoshvili, 1999; Japoshvili *et al.*, 2002; Karaca *et al.*, 2003), which suggest that GS is controlled cyclically when orchards have the primary parasitoid complex of *Discodes coccophagus*, *Metaphycus* spp. and *Coccophagus* spp. even when secondary parasitoids are present. This cycle will be repeated at 5–7 yr intervals, depending on climatic and anthropogenic factors.

In conclusion, we suggest that farmers need to consider the timing of their spray applications with great care and use chemicals that are less likely to affect the parasitoid complex. To achieve good results using pesticides and parasitoids, we suggest farmers must first learn the phenology of the pest and then apply their pesticides while the GS are hatching from eggs, or at the beginning of their development after overwintering.

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