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The coloration of *Aphis gossypii* mummies as a useful tool for Aphidiinae parasitoid identification (Hymenoptera: Braconidae)

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ABSTRACT

The color of *Aphis gossypii* Glover mummies is used as a distinctive identification character of the genus, and even of the species, of Braconidae parasitoids of the subfamily Aphidiinae, before the adult emerges. Mummies were collected from several citrus growing areas in Greece. From 98.5%of the brown mummies, two species of *Binodoxys* Mackauer (*Binodoxys angelicae* (Haliday) ,93.9%and *Binodoxys acalephae* (Marshall) 4.6%)emerged; while from the remaining ,1.5%*Lysiphlebits confusus* Tremblay and Eady emerged. From the golden-whitish mummies, 62.5%of the emerged parasitoids were *Lysiphlebus testaceipes* (Cresson), 32.5%were *Aphidius colemani* Viereck, and the rest (5%)were *Aphidius matricariae* Haliday, *Diaeretiella rapae* (MTntosh), *Lysiphlebus fabamm* (Marshall), and *L. confusus*. From a small number of black mummies, only *Ephedras persicae* Froggat emerged. From the brown and golden-whitish *A. gossypii* mummies that were collected from various non-citrus host plants in several regions in Greece, similar para- sitoisids emerged in similar proportions. The colors of the mummies of *Toxoptera aurantii* Boyer de Fonscolombe were not found to correlate with the taxon of the parasitoids.

INTRODUCTION

Aphidiinae (Braconidae) and Aphelinidae parasitoids mummify their host aphids before emerging as adults. Mummies that are parasitized by aphelinids are black (Lykouressis, ;1982Powell, 1982), whereas those that are parasitized by aphidiines are of various colors (Stary, 1966; Powell, 1982; Mescheloff and Rosen, 1988, 1990a, 1990b, 1993). Krespi et al. (1994) showed that the mummies of *Sitobion avenae* Fabricius, which were parasitized by *Aphidius rhopalosiphi* De Stefani Perez, were brownish when the parasitoids were in diapause but whitish to slightly brownish when the parasitoids were in the non-diapausing stage. However, Stary (1970) commented that mummy color is of

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doubtful value for determining whether the parasitoid is in diapause or not. Our earlier field observations showed that mummies of *Aphis gossypii* Glover revealed distinct differences in color: some were brown, others were golden-whitish, and a few were black. Following those observations, we carried out the present study to investigate the possible relationships between the color of the mummy and the species of the parasitoid. This research was mostly conducted on citrus trees, on which high levels of aphid populations develop each year, as well as on other cultivated and non-cultivated host plants.

MATERIALS AND METHODS

Leaf samples with mummies of *A. gossypii* and other aphid species were collected in 1996 and 1997 from various citrus trees in 26 citrus-growing regions in eight counties, five in Peloponnese (Argolis, Arkadia, Ilia, Korinthia, and Messinia) and three in central Greece (Aitoloakarnania, Arta, and Attiki). The samples were taken from *Citrus aurantium* L., *Citrus deliciosa* Ten., *Citrus limon* (L.) Burm. fil., and *Citrus sinensis* (L.) Osbeck. Samples were also collected from other cultivated and non-cultivated host plants in 12 regions in six counties, four in Peloponnese (Argolis, Ilia, Korinthia, and Messinia) and two in central Greece (Attiki and Magnissia).

The leaf samples were cut into small pieces, each with a single aphid mummy attached to the leaf by secretion from the salivary glands of the parasitoid larva. These pieces were separated into groups by the color of the mummies (brown, golden-whitish, black). Mummies of the same color group were kept in small plastic containers (35 mm in diameter, 40 mm high) for parasitoid emergence. Each plastic container was closed by a lid with a muslin-covered circular opening for ventilation. The containers were placed in a controlled growth chamber at 22.5 °C, 65% RH and 16:8 hours L:D.

The aphidiine parasitoids were identified using keys and descriptions published by Starý (1976, 1985), Starý et al. (1998), Tremblay and Eady (1978), Powell (1982), Mescheloff and Rosen (1988, 1990a, 1990b), Pennacchio (1989), and Tomanović (2000).

RESULTS

A total of 5019 aphidiines were identified from *A. gossypii* mummies collected from citrus trees.

Two aphidiine genera emerged from the brown mummies: the genus *Binodoxys* Mackauer was the dominant one (98.5%), while *Lysiphlebus* Förster comprised only 1.5% of the emerging parasitoids. There were two species of the genus *Binodoxys*: *B. angelicae* (Haliday) with 1537 specimens (93.9%), and *B. acalephae* (Marshall) with only 75 specimens (4.6%). There was one species of the genus *Lysiphlebus*: *L. confusus* Tremblay and Eady, with only 25 specimens (1.5%) (Fig. 1).

From the golden-whitish mummies six aphidiine species of the genera *Lysiphlebus*, *Aphidius* Nees, and *Diaeretiella* Stary emerged: *L. testaceipes* (Cresson) was the most

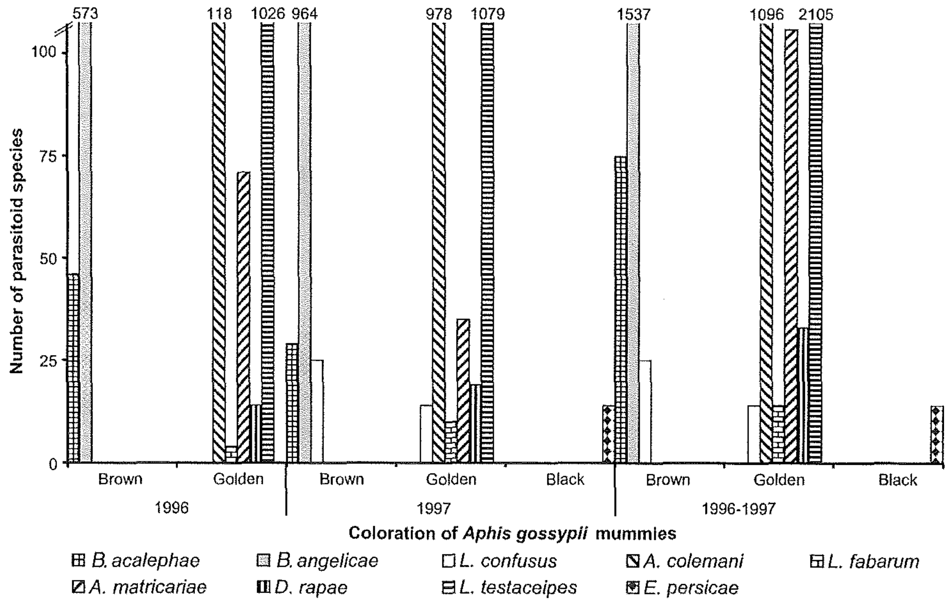

Fig. 1. Coloration and parasitization of *Aphis gossypii* mummies by aphidiine parasitoid species on citrus trees collected in 1996 and 1997 from several regions in Greece.

abundant, with 2105 specimens (62.5%), followed by *A. colemani* Viereck, with 1096 specimens (32.5%), and a small representation (5% combined) of the following four species: *A. matricariae* Haliday, *D. rapae* (M'Intosh), *L. fabarum* (Marshall), and *L. confusus*.

We found black mummies (Fig. 7) only in 1997, from which there emerged the primary parasitoid *Ephedrus persicae* Froggat.

Similar observations were made for the 2449 specimens that were identified from mummies collected from various other host plants (Table 1). From the brown mummies *B. angelicae* was the dominant species, with 524 specimens (96.2%), while *B. acalephae* was represented by only 21 specimens (3.8%). In contrast, from the golden-whitish mummies there emerged 1522 specimens of *L. testaceipes* (79.9%), and 382 specimens (20.1%) of *A. colemani, A. matricariae* and *L. fabarum* together (Table 1).

Key to Aphidiinae parasitoids of *Aphis gossypii*, based primarily on the color of the mummies

1. Mummies brown **2**
–. Mummies of other colors **3**
2. Emergence hole always on apical part of host abdomen (Fig. 3) .... ***Binodoxys* spp.**
–. Emergence hole on dorsal part of abdomen (Fig. 5) .... ***Lysiphlebus confusus***
3. Mummies black (Fig. 7) .... ***Ephedrus persicae***
–. Mummies golden-whitish (Figs. 2, 4, 6) ....
.... ***Diaeretiella rapae*, or *Aphidius* spp., or *Lysiphlebus* spp. (including *L. confusus*)**

DISCUSSION

We considered the color of the mummy of the infested *A. gossypii* as a useful indicator for the taxon of the infesting parasitoid only in those cases in which we were able to determine that a single taxon emerged from at least 90% of the mummies of the same color. The two species of *Binodoxys* comprised 98.5% of the parasitoids that emerged from brown mummies, and we consider this color as a useful field indicator for this genus. The most abundant species was *B. angelicae*, with an infestation rate of 93.9% on citrus, and 96.2% on other host plants.

Along the northwestern coasts of the Peloponnese, we found almost only golden-whitish mummies of *A. gossypii* (99.7% of the mummies on citrus, and 99.4% of the mummies on other host plants). From those mummies emerged *L. testaceipes*, almost exclusively (99.01% from citrus, and 98.77%, from other hosts). Therefore, the golden-whitish color may be a good field indicator, but only in this region.

From all the black mummies there emerged only *E. persicae,* although we had only a small sample. Thus, black mummies may be a good field indicator for this parasitoid.

L. confusus was scarcely recorded (only 39 specimens) in northwestern Greece and only in the absence of *B. angelicae* and *B. acalephae*. In addition, the color of the mummies from which *L. confusus* emerged was variable, i.e., either golden-whitish (Fig. 6) or brown (Fig. 5). Because of the small number of individuals and the variation in color we cannot consider this as a useful field indicator for these species.

In addition, we recorded another character of the host that can be used for identification of the parasitoid after its emergence: the position of the emergence hole (Starý, 1974).

In brown mummies, the emergence hole made by *B. angelicae* and *B. acalephae* was always on the apical part of the abdomen (Fig. 3), whereas the emergence hole of *L. confusus* (Fig. 5) was on the dorsal part of the aphid's abdomen. In the golden-whitish mummies the emergence holes of *A. colemani, A. matricariae, D. rapae, L. confusus, L. fabarum,* and *L. testaceipes* were all on the dorsal part of the aphid's abdomen (Figs. 4, 6).

We compared our results for *A. gosypii* with our observations on the colors of the mummies of *Toxoptera aurantii* Boyer de Fonscolombe. The latter are not good indicators for the taxon of the parasitoid of *T. aurantii.* We observed brown, golden, and

Figs. 2–10 *facing page*. Mummies of *Aphis gossypii* and *Toxoptera aurantii* after parasitization by various parasitoids. 2. Golden-whitish mummies of *A. gossypii* containing *Lysiphlebus testaceipes.* 3. Brown mummy of *A. gossypii* parasitized by *Binodoxys angelicae.* 4. Golden-whitish mummy of *A. gossypii* parasitized by *A. colemani.* 5. Brown mummy of *A. gossypii* parasitized by *L. confusus.* 6. Golden-whitish mummy of *A. gossypii* parasitized by *L. confusus.* 7. Black mummy of *A. gossypii* parasitized by *E. persicae.* 8. Whitish, golden, and brown mummies of *T. aurantii* parasitized by *Binodoxys angelicae* (clockwise from top left). 9. Light golden, whitish, and dark golden mummies of *T. aurantii* parasitized by *A. colemani, L. testaceipes,* and *A. matricariae,* respectively (clockwise from top). 10. Black mummy of *T. aurantii* parasitized by *E. persicae.*

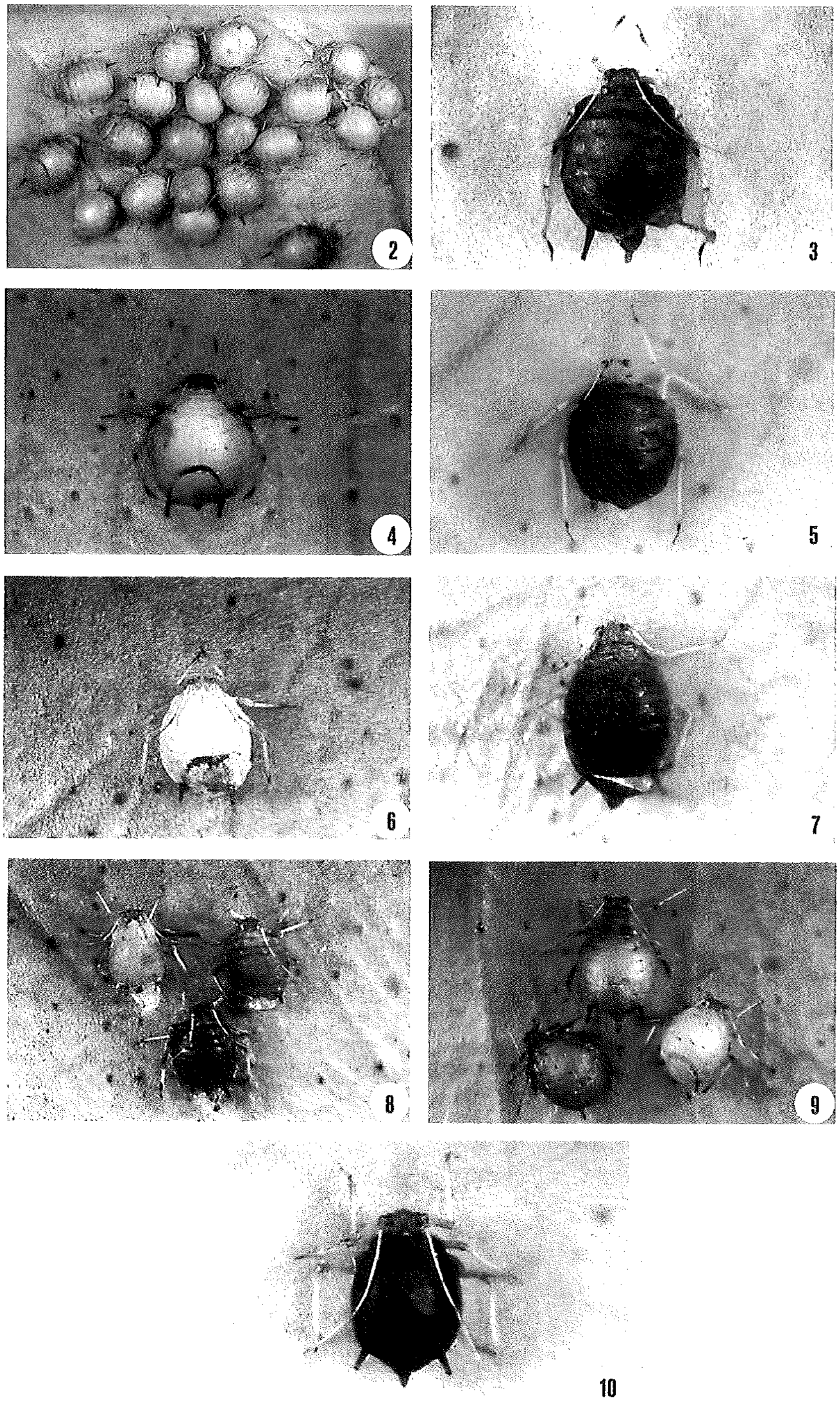
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Table 1

Coloration and parasitization of *Aphis gossypii* mummies by aphidiine parasitoid species on various plants collected in 1996 and 1997 from several regions in Greece

Plant	Year	County	Number of specimens	*Binodoxys angelicae*	*Binodoxys acalephae*	*Aphidius colemani*	*Aphidius matricariae*	*Lysiphlebus fabarum*	*Lysiphlebus testaceipes*
Abelmoschus esculentus	1997	Attiki	62			62 G-W			
Abutilon darwinii	1996	Attiki	35			35 G-W			
Chamomilla recutita	1996	Ilia	19			2 G-W			17 G-W
Chrysanthemum coronarium	1996	Ilia	21	2 B					19 G-W
Chrysanthemum segetum	1997	Messinia	840	4 B		9 G-W			827 G-W
Gladiolus italicus	1996	Attiki	31	19 B	2 B	8 G-W	2 G-W		
Hibiscus mutabilis	1996	Attiki	85	57 B	5 B	13 G-W		10 G-W	
Hibiscus syriacus	1997	Messinia	124	4 B					120 G-W
Hibiscus syriacus	1996	Attiki	472	302 B	10 B	140 G-W	20 G-W		
Hibiscus syriacus	1996	Korinthia	153	62 B		91 G-W			
Lapsana communis	1996	Ilia	547				2 G-W	6 G-W	539 G-W
Nerium oleander	1996	Attiki	9	1 B		2 G-W	3 G-W	3 G-W	
Nerium oleander	1997	Attiki	11	11 B					
Punica granatum	1997	Argolis	22	22 B					
Pyrus malus	1996	Attiki	12	8 B		2 G-W	2 G-W		
Reichardia intermedia	1996	Attiki	52	32 B	4 B	10 G-W	6 G-W		
Solanum tuberosum	1996	Magnissia	16			9 G-W	7 G-W		
Total			2449	524 B	21 B	321 G-W	42 G-W	19 G-W	1522 G-W

B = Brown color of *A. gossypii* mummies, G-W = Golden-Whitish color of *A. gossypii* mummies.

whitish mummies, from which emerged *B. angelicae* (Fig. 8), whereas *A. colemani, A. matricariae, D. rapae, L. fabarum,* and *L. testaceipes* emerged from dark or light golden and whitish ones (Fig. 9). However, we were able to identify the mummies that were infested by *B. angelicae* by the position of the emergence hole. From the small sample of black *T. aurantii* mummies, there emerged only *E. persicae* (Fig. 10).

In summary, in the case of *A. gossypii* the brown color of the mummies may be a useful field indicator for a quick, easy, and fairly accurate estimate of parasitism rate by *Binodoxys,* usually by *B. angelicae,* which was found to be the dominant parasitoid species of the genus in most of the studied areas in Greece. However, in the northwest, where *Binodoxys* is absent, a different species, *L. confusus,* may emerge from brown mummies. Therefore, for an efficient use of this field indicator, a preliminary study of the local parasitoids of *A. gossypii* should be undertaken. Black mummies may also be a good field indicator because only *E. persicae* emerged from them. However, the golden-whitish mummies cannot serve as a good field indicator for the parasitoid taxon, because there are six species, belonging to three genera, that induce this color in *A. gossypii* mummies.

We were not able to establish the relationship between the colors of *T. aurantii* mummies and the taxon of the parasitoid attacking this species. Therefore, color cannot be used as a distinctive character for identifying the parasitoids that attack *T. aurantii.*

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