

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

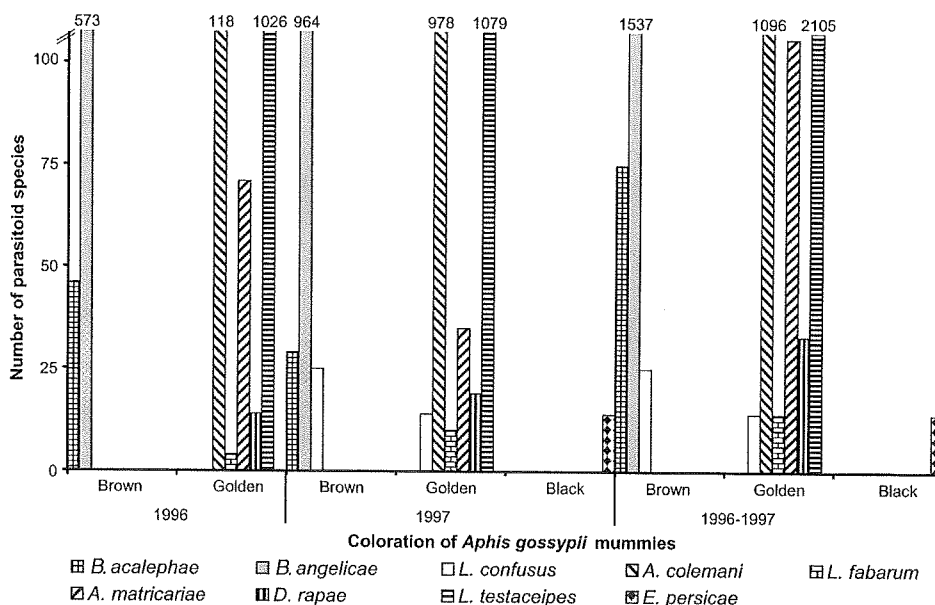


Fig. 1. Coloration and parasitization of *Aphis gossypii* mummies by aphidiine parasitoid species on citrus trees collected in 1996 and 1997 from several regions in Greece.

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. gossypii* 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*.

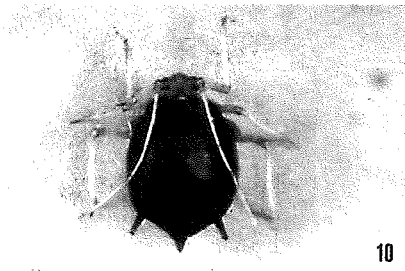
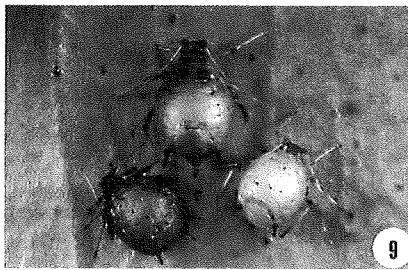
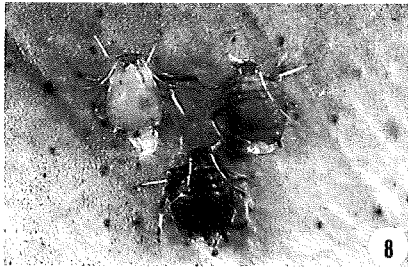
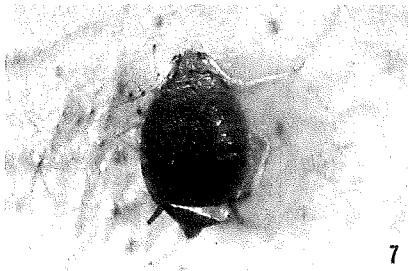
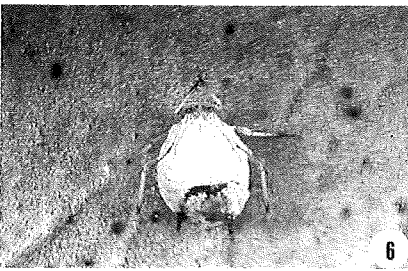
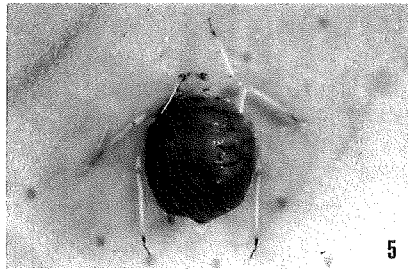
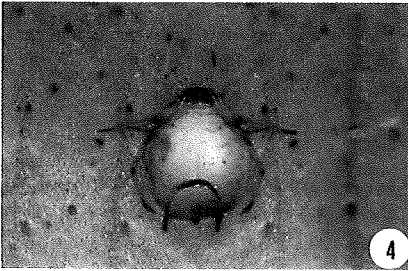
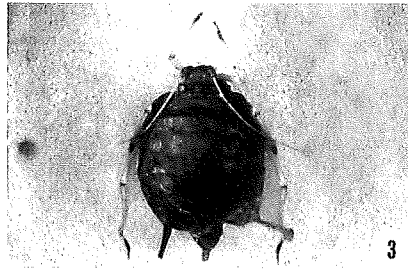
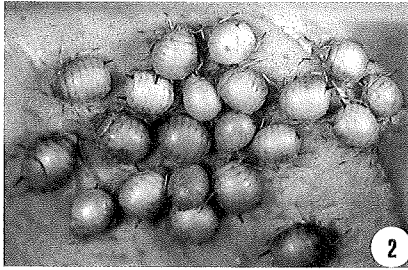


Table 1
Coloration and parasitization of *Aphis gossypii* mummies by aphidine parasitoid species on various plants collected in 1996 and 1997 from several regions in Greece

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

ACKNOWLEDGMENT

We thank Prof. Georgios Sarlis, Agricultural University of Athens, for his help in identifying *Ampelopsis hederacea*, *Gladiolus italicus*, *Hibiscus mutabilis*, *Lapsana communis*, and *Reichardia intermedia*.

REFERENCES

- Krespi, L., Dedryver, C.A., Rabasse, J.M., Némon, J.P. 1994. A morphometric comparison of aphid mummies containing diapausing vs. non-diapausing larvae of *Aphidius rhopalosiphii* (Hymenoptera: Braconidae: Aphidiinae). *Bulletin of Entomological Research* 84: 45–50.
- Lykouressis, D. 1982. Studies under controlled conditions on the effects of parasites on the population dynamics of *Sitobion avenae* (F.). Ph. D. thesis, University of Reading, 342 pp.
- Mescheloff, E., Rosen, D. 1988. Biosystematic studies on the Aphidiidae of Israel (Hymenoptera: Icheumonoidea). 2. The genera *Ephedrus* and *Praon*. *Israel Journal of Entomology* 22: 75–100.
- Mescheloff, E., Rosen, D. 1990a. Biosystematic studies on the Aphidiidae of Israel (Hymenoptera: Icheumonoidea). 3. The genera *Adialytus* and *Lysiphlebus*. *Israel Journal of Entomology* 24: 35–50.
- Mescheloff, E., Rosen, D. 1990b. Biosystematic studies on the Aphidiidae of Israel (Hymenoptera: Icheumonoidea). 4. The genera *Pauesia*, *Diaeretus*, *Aphidius* and *Diaeretiela*. *Israel Journal of Entomology* 24: 51–91.
- Mescheloff, E., Rosen, D. 1993. Biosystematic studies on the Aphidiidae of Israel (Hymenoptera: Icheumonoidea). 5. The genera *Trioxys* and *Bionodoxys*. *Israel Journal of Entomology* 27: 31–47.

- Pennacchio, F. 1989. The Italian species of the genus *Aphidius* Nees (Hymenoptera: Braconidae: Aphidiinae). Bolletino del Laboratorio di Entomologia Agraria "Filippo Silvestri" di Portici 46: 75–106.
- Powell, W. 1982. The identification of hymenopterous parasitoids attacking cereal aphids in Britain. Systematic Entomology 7: 465–473.
- Starý, P. 1966. Aphid parasites of Czechoslovakia. Dr W. Junk, The Hague, 242 pp.
- Starý, P. 1970. Biology of aphid parasites. Dr W. Junk, The Hague, 643 pp.
- Starý, P. 1974. The emergence hole of aphid parasites (Hymenoptera: Aphidiidae): its significance in a natural system. Acta Entomologica Bohemoslovaca 71: 209–216.
- Starý, P. 1976. Aphid parasites (Hymenoptera: Aphidiidae) of the Mediterranean area. Dr W. Junk, The Hague, 101 pp.
- Starý, P. 1985. Two new *Lysiphlebus* species from Europe (Hymenoptera: Aphidiidae). Acta Entomologica Bohemoslovaca 82: 426–430.
- Starý, P., Tomanović, Ž., Petrović, O. 1998. A new parasitoid of roof-feeding aphids from the Balkan Mountains (Hymenoptera: Braconidae: Aphidiinae). Deutsche Entomologische Zeitschrift 45: 175–179.
- Tremblay, E., Eady, R.D. 1978. *Lysiphlebus confusus* n. sp. per *Lysiphlebus ambiguus* sensu auct. nec Haliday (1834) (Hymenoptera: Ichneumonoidea). Bolletino del Laboratorio di Entomologia Agraria "Filippo Silvestri" di Portici 38: 209–216.
- Tomanović, Ž. 2000. New findings of aphid parasitoids (Hymenoptera: Aphidiidae) from Serbia and Montenegro. Acta Entomologica Serbica 5: 111–118.