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Armored scales (Hemiptera: Diaspididae) infesting Hass avocado intercepted in Florida and a new parasitoid–host association for *Davidsonaspis aguacatae*

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Hass avocado (*Persea americana* Mill.; Lauraceae) is the most widely consumed of the many commercially cultivated varieties of avocado available in the United States and is grown almost exclusively in Mexico and California, USA. Avocados grown in Mexico and distributed to restaurants, grocery stores, and other retail stores in the United States enter the country after clearance by the United States Department of Agriculture (USDA) at the Mexico–United States border in California. If destined for Florida markets, shipments may face additional scrutiny at one of the several interstate highway stations in Florida by Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS-DPI) inspectors; these stations are operated under the Cooperative Agricultural Pest Survey (CAPS) program funded by the USDA. Of the many agricultural and horticultural commodities inspected in the CAPS program since 2012, over 100 Hass avocado shipments were inspected and found to be infested at various levels with one or more species of armored scale.

In 2007, the last trade restriction was removed on the >90 yr ban on avocado imports into the United States from Mexico (Stouthamer & Morse 2011), and almost immediately an undescribed scale was intercepted by inspectors with the California Department of Food and Agriculture (CDFA) (Morse et al. 2009). Aguacatae scale, *Davidsonaspis aguacatae* (Evans, Watson & Miller) (Hemiptera: Diaspididae) was described in the genus *Abgrallaspis* Balachowsky based on specimens infesting imported avocados (Evans et al. 2009), but subsequently transferred to *Davidsonaspis* (Normark et al. 2014). Because Hass and other avocado varieties are grown commercially in California, the frequency with which this pest was entering California was a concern for regulators with CDFA, and attempts to impose regulations resulted in a now-settled trade dispute, which is summarized by Morse et al. (2009).

Avocado is widespread throughout the Americas and Caribbean, and in Florida is planted as an ornamental and commodity crop, primarily in Miami-Dade County. Imported avocado fruit infested with pests present an additional risk to a commodity already under threat by exotic and invasive species, such as redbay ambrosia beetle, *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae) (Crane et al. 2008). The economic impact of avocado production in Florida was recently estimated at nearly US\$100 million (Evans & Lozano 2014).

The crawler, or 1st-stage immature, is the only development stage capable of moving from the fruit and establishing on a new host, but generally, it has very low vagility and is particularly vulnerable. The USDA considers fruit packaged for consumption and distributed directly to retailers a low-risk entry pathway for armored scales. However, al-

though the risk may be low, the interdiction history in California (Morse et al. 2009) and FDACS-DPI interception records from >100 avocado shipments indicate that it is not zero.

The most frequently intercepted armored scale in avocado shipments inspected in Florida is latania scale, *Hemiberlesia lataniae* (Signoret) (Hemiptera: Diaspididae) (62% of interception records; Fig. 1), a widespread and highly polyphagous species that in Florida is an occasional pest until suppressed by one of several species of parasitoid wasps. Aguacatae scale, which may co-occur with latania scale on the same fruit, accounts for 25% of interception records (Figs. 2–6). *Clavaspis perseae* (Davidson) (Hemiptera: Diaspididae) (3 interception records) was described from specimens on avocados intercepted at the United States–Mexico border in Brownsville, Texas (Davidson 1964), and *Acutaspis albopicta* (Cockerell) (Hemiptera: Diaspididae) (2 interception records) was described from citrus leaves in Mexico; neither species is present in Florida. The frequency with which *A. albopicta* is intercepted in California is a serious concern for California avocado growers (Millar et al. 2012; Waterworth et al. 2012), many of whom have orchards in close proximity to imported avocado packing and distribution houses. *Clavaspis perseae* is apparently host-restricted to avocado, but *A. albopicta* is recorded from species in over 13 plant families (García Morales et al. 2016).

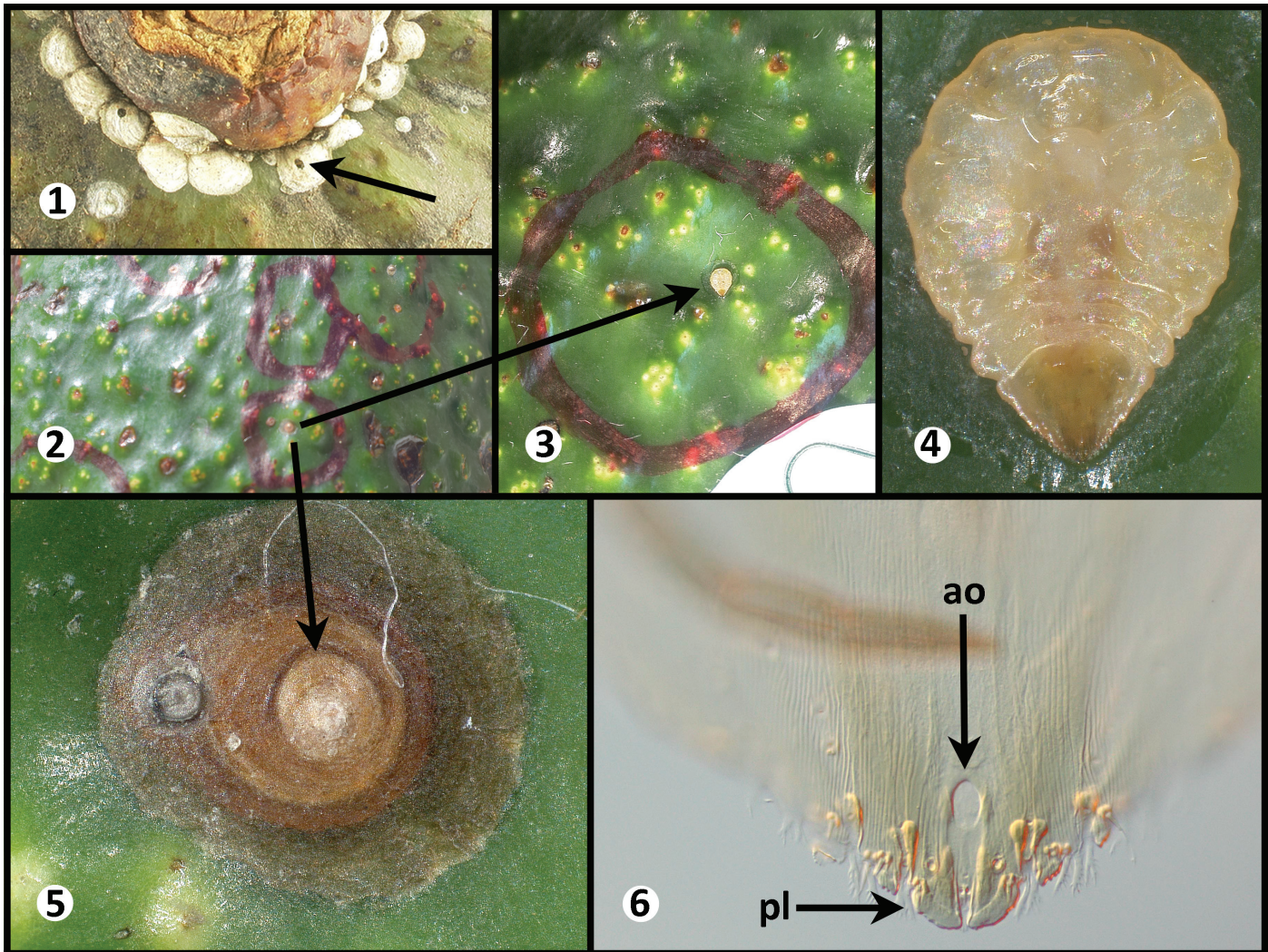
In May 2016, aguacatae scale specimens parasitized by aphelinid wasps (Hymenoptera: Chalcidoidea) were intercepted on several occasions (Figs. 7–9), one of which, vouchered as slide E2016–2002, contained an adult female of *Encarsia lounsburyi* (Berlese & Paoli) (Hymenoptera: Aphelinidae) and is a new host association for this species. *Encarsia lounsburyi* is globally distributed and associated with 50 armored scale host species (Noyes 2016) but is neither one of the 5 species collected in field surveys for armored scale pests in avocado orchards in Michoacán, Mexico (Lázaro-Castellanos et al. 2012), nor a species identified in intercepted Mexican avocados or during field and packing house surveys for parasitoids in California (Morse et al. 2016). In Florida, *E. lounsburyi* and the closely related *Encarsia citrina* (Craw) (Hymenoptera: Aphelinidae) have been documented armored scale parasitoids since at least 1949 (Thompson & Griffiths 1949; Muma & Clancy 1961).

It is not uncommon in Florida for adventive and potentially pestiferous insects to become established with beneficial associates, such as parasitoids, already in association elsewhere (Stocks & Evans unpublished). Should aguacatae scale become established in Florida, it may arrive with *E. lounsburyi* parasitoids from Mexican populations or

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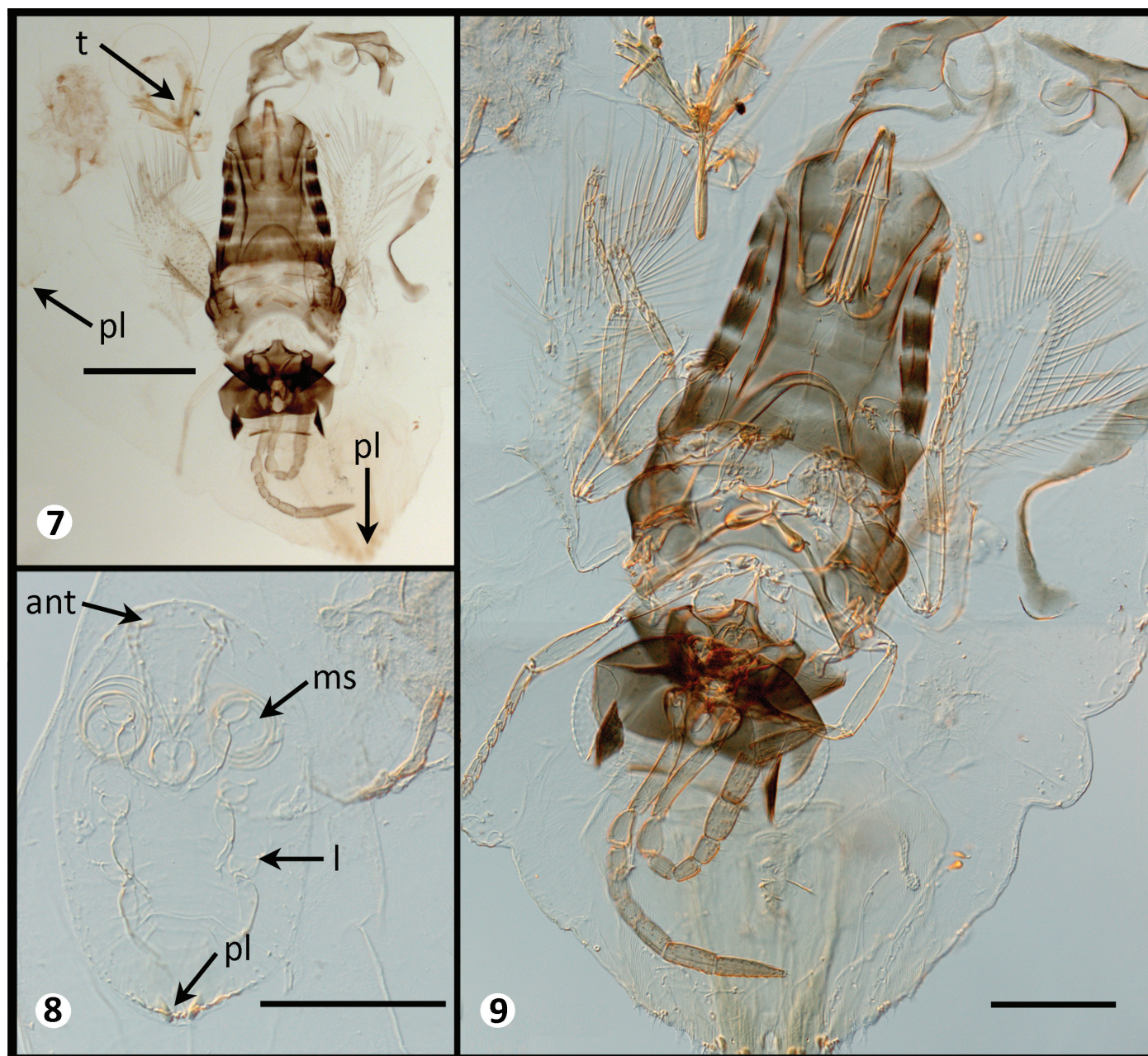


Figs. 1–6. Scale insects on intercepted Hass avocado. 1. Latania scale, *Hemiberlesia lataniae*, adult females on avocado surrounding peduncle remnant. Arrow indicates parasitoid emergence hole. 2–6. Aguacatae scale, *Davidsonaspis aguacatae*: 2. Adult female scales on avocado skin on intercepted fruit. Ink circles applied by interception officer, arrows indicate actual scale. 3. Adult female with scale cover removed. 4. Close-up of same. 5. Adult female scale cover. 6. Pygidium of slide-mounted female, with diagnostic characters; ao=anal opening, pl=pygidial lobe.

acquire them secondarily from populations already present in Florida. However, due to natural population-level genetic variation that may influence host seeking behavior and likelihood of survival through development, the fidelity of the association between host and parasitoid may vary depending on the provenance of the host and parasitoid (Hopper et al. 1993; Allendorf & Lundquist 2003; Uesugi et al. 2016). Recent examples relevant to Florida are the lepidopteran citrus pest *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae) and the parasitoid *Ageniaspis citricola* Logvinovskaya (Hymenoptera: Encyrtidae) (Hoy & Nguyen 1997), and the noxious adventive plant Brazilian peppertree, *Schinus terebinthifolia* Raddi (Anacardiaceae) and the herbivore *Pseudophilothrips ichini* (Hood) (Thysanoptera: Phlaeothripidae) (Cuda 2016). Thus, it is valuable to document that *D. aguacatae* is susceptible to *E. lounsburyi* derived from populations in Mexico should it become established in Florida and the parasitoids already present not suppress it adequately.

The parasitized aguacatae scale specimen examined, which is in remarkably good condition, contained not only the adult parasitoid but also the intact remains of a crawler (Fig. 7), and we are unaware that this observation has previously been recorded. Aphelinidae is one of the many groups of wasps that are koinobiont endoparasit-

oids, in which the host nearly always dies during parasitoid development. Typical koinobiont hosts are the immature stages of insects in several orders, but in armored scales, it is common for the adult wasp to emerge from the 3rd-stage, or adult, female. By definition, the outcome of a koinobiont endoparasitoid using an immature as a host is that the host is unable to leave progeny and therefore has zero fitness. However, if a female armored scale is able to produce viable crawlers while gradually being consumed by a developing parasitoid, and the crawlers that are produced avoid being consumed by the larval parasitoid, then in principal the parasitized female has non-zero fitness. It may, in fact, be common for crawlers to emerge from an otherwise parasitized female, but the likelihood of documenting this is quite low, if for no other reason than that the specimens must be slide-mounted and evidence of both parasitism and developing crawlers remain intact during the slide-making process. If the phenomenon is more common than currently realized, then it warrants additional study because it may be a variable not accounted for in pest management techniques that rely on biological control. Furthermore, the koinobiont endoparasitoid strategy is quite old evolutionarily, yet the prospect of a parasitized host retaining some fitness raises intriguing evolutionary consequences, such as whether certain



Figs. 7–9. Parasitized *Davidsonaspis aguacatae* adult female: 7. *Encarsia lounsburyi* adult female and adjacent *D. aguacatae* crawler; pl–pygidial lobe, t–tentorium. 8. Details of *D. aguacatae* crawler; ant–antenna, l–leg, ms–maxillary stylet, pl–pygidial lobe. 9. Details of *E. lounsburyi* adult female.

scales are able to simultaneously “manage” the physiology of both parasitism and reproduction.

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Summary

A new parasitoid–host association between *Davidsonaspis aguacatae* (Evans, Watson & Miller) (Hemiptera: Diaspididae) and *Encarsia*

lounsburyi (Berlese & Paoli) (Hymenoptera: Aphelinidae) is documented, and an overview of armored scales infesting Hass avocados intercepted in Florida is given. An observation of the occurrence of crawler scales developing inside a parasitized female scale is discussed.

Key Words: Coccoidea; adventive species; economic entomology; regulatory agency; trade

Sumario

Se documenta una nueva asociación parasitoide-hospedero entre *Davidsonaspis aguacatae* (Evans, Watson y Miller) (Hemiptera: Diaspididae) y *Encarsia lounsburyi* (Berlese & Paoli) (Hymenoptera: Aphelinidae) y se provee perspectiva general de las escamas con armadura

que infestan aguacates Hass interceptadas en la Florida. Se discute una observación sobre la presencia de escamas del primer estadio ninfal que se desarrollaban dentro de una escama hembra parasitada.

Palabras Clave: Coccoidea; especies adventicias; entomología económica; agencia reguladora; comercio

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