UF IFAS Extension UNIVERSITY of FLORIDA

EENY-313

Parasitoid of the Citrus Leafminer, *Semielacher petiolatus* (Girault) (Insecta: Hymenoptera: Eulophidae)[1]

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The Featured Creatures collection provides in-depth profiles of insects, nematodes, arachnids and other organisms relevant to Florida. These profiles are intended for the use of interested laypersons with some knowledge of biology as well as academic audiences.

Introduction

The citrus leafminer, *Phyllocnistis citrella* Stainton (Lepidoptera: Gracillariidae), was first detected in Florida in 1993 (Heppner 1993). This invasive pest spread rapidly throughout the citrus-growing areas and is now well established in Florida. The parasitoid *Semielacher petiolatus* (Girault) (Hymenoptera: Eulophdae) was introduced during July 2003 into quarantine facilities in the Division of Plant Industry in Gainesville and the UF/IFAS Department of Entomology and Nematology in Gainesville, where it was evaluated for possible release into Florida's citrus to augment the role of the citrus leafminer's other natural enemies. Unfortunately, *Semielacher petiolatus* did not distinguish between unparasitized citrus leafminer larvae and those parasitized by another parasitoid, *Ageniaspis citricola* Logvinovskaya, so it was not released (Zappalá et al. 2007).

Classical Biological Control of the Citrus Leafminer in Florida

The citrus leafminer (CLM) probably originated in Asia and its host range includes citrus species and a few closely-related Rutaceae (Heppner 1993; Knapp et al. 1995). The citrus leafminer has a relatively simple life history: adult males and females emerge in the early morning hours and mate at dusk and females begin to deposit eggs about 24 hours later on tender new leaves 10–20 mm (0.4 to 0.8 in) in length (also called flush) during the night. The eggs mature within a day in summer and the young larvae immediately chew their way into the tiny leaf, where each produces a mine. There are three larval stages found within the mine and, after five to six days in summer, the larvae become prepupae, a nonfeeding stage. Molting to the pupal stage occurs within this protected chamber and, after about six days, adults emerge from the end of the chamber. Up to 15 generations per year can occur in tropical conditions (Smith et al. 1997). Because the leafminer must oviposit on and develop within tender new leaves, leafminer populations typically decline during the winter in subtropical climates. It is unknown whether the leafminer has a diapause that allows it to overwinter in regions that have cold winters when there is little new growth to attack.

1. This document is EENY-313, one of a series of the Department of Entomology and Nematology, UF/IFAS Extension. Original publication date November 2003. Revised February 2008, June 2021, and September 2024. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication. This document is also available on the Featured Creatures website at https://entnemdept.ufl.edu/creatures/.

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In Florida, a variety of natural enemies cause significant mortality to the citrus leafminer (Amalin and Pena 1999; Browning and Pena 1995; Pena et al. 1996). Several eulophid parasitoid species, already present in Florida when the citrus leafminer invaded, moved on to this new food source (Pena et al. 1996; Schauff et al. 1998; Evans 1999). However, natural enemies from Asia were known to be effective and a classical biological control program was initiated in 1994 (Hoy and Nguyen 1997). *Ageniaspis citricola* Loginovskaya and *Cirrospilus ingenuus* Gahan were introduced from Australia into Florida in 1994 and, after evaluation in quarantine, were released (Hoy and Nguyen 1997). *Semielacher petiolatus* also was introduced into quarantine from Australia at that time but because resources were limited, the *Semielacher petiolatus* colony could not be maintained.

Ageniaspis citricola was released first and established rapidly, spreading throughout the state (Hoy and Nguyen 1994, 1997; Hoy et al. 1995, 1997; Pomerinke and Stansly 1998). *Ageniaspis* is considered a specialist on the citrus leafminer and does not attack other insect species to any significant degree. As a result, when citrus leafminer population densities are low during the winter, *Ageniaspis citricola* has to search intensely for the very rare eggs and first instar larvae of the citrus leafminer on the very limited number of tender new shoots.

Cirrospilus ingenuus (originally released as *Cirrospilus quadristriatus*) also was released in Florida citrus (Hoy and Nguyen 1994, 1997) and subsequently established in south Florida (LaSalle et al. 1999). However, *Cirrospilus ingenuus* appears to be rare in citrus groves outside the Homestead area (Hoy and Nguyen, unpublished). *Cirrospilus ingenuus* is considered relatively restricted in its host range to the citrus leafminer, although Zhu et al. (2002) reported that it parasitized lyonettid leafminers in citrus in China.

In Florida, where rainfall occurs throughout the year, citrus typically has four or five major intervals when new growth (or flush) is produced; typically, flushes occur during February–March, May, June, July–August, September–October (Villanueva-Jimenez et al. 1998). Because citrus leafminer populations decline to nearly undetectable levels over the winter, the first flush interval has very few citrus leafminers and a relatively low rate of parasitism by *Ageniaspis citricola* (Villanueva-Jimenez et al. 1998; Zappala et al. unpublished). Citrus leafminer populations typically increase in the second flush and, if *Ageniaspis citricola* populations lag behind, this generation of the leafminer can increase dramatically. *Ageniaspis citricola* is quite susceptible to drought conditions (Yoder and Hoy 1998), and this could have contributed to its reduced ability to suppress leafminer populations during some recent dry springs in flush intervals 2 and 3. By August, and throughout the fall in Florida, citrus leafminer populations typically exhibit high rates of parasitism by *Ageniaspis citricola* and leafminer populations are often well below the densities seen during the second flush.

To improve the suppression of citrus leafminer populations during the second flush interval in Florida, at least two options are available. One would be to monitor leafminer populations during the spring and apply a pesticide that reduces leafminer populations without disrupting the natural enemies that suppress them (as well as other insect and mite pests). Options include several IPM- compatible pesticides (Villanueva-Jimenez and Hoy. 1998a, 1998b). Alternatively, an additional parasitoid could be introduced in a classical biological control program which, if established, might augment the suppression of citrus leafminer populations during the critical second flush interval in spring.

The following discussion describes what is known about one candidate for release in Florida as part of a continuing classical biological control program against the citrus leafminer. *Semielacher petiolatus* was kindly shipped to us by Dr. G. Siscaro, University of Catania, Italy, and imported into quarantine in Gainesville during July 2003. Although it was not released, it is possible it could one day make its way to Florida.

Biology of *Semielacher petiolatus*

Semielacher petiolatus prefers to attack second- and third-instar larvae of the citrus leafminer, but it can also parasitize fourth instars (= prepupae) (Mineo and Mineo 1999a, 1999b). In addition to killing citrus leafminers by parasitism, adult females kill by host feeding, in which the female sticks her ovipositor into the larva, then drinks the hemolymph (Argov and Rossler 1998).

Adults of *Semielacher petiolatus* are 1–2 mm (0.04 to 0.08 in) long, the female is brown with a yellow abdomen and the male's abdomen is brown at the tip. *Semielacher petolatus* is a solitary ectoparasitic wasp and females deposit eggs near or on the larvae of their hosts (Boucek 1988; Argov and Rossler 1998). *Semielacher* females apparently inject venom into the citrus leafminer and the larvae subsequently can't move or feed. The parasitoid larva hatches and feeds on the citrus leafminer, finally pupating within the leafminer's mine (or within the pupal chamber if the host was a prepupa when parasitized).

There is no published information as to how many citrus leafminer larvae are killed by host feeding and how many by parasitism. *Semielacher petiolatus* completes its life cycle in about 10 days at 25°C (77°F). Both males and females are produced, with a female-biased sex ratio. Mineo and Mineo (1999b) suggested that males are produced when second-instar hosts are parasitized and females are produced from third- and fourth-instar leafminer larvae.

Figure 1. Adult female *Semielacher petiolatus* (Girault), an ectoparasitoid of the citrus leafminer, *Phyllocnistis citrella* Stainton.
Credits: L. Zappala, UF/IFAS

Figure 2. Egg of *Semielacher petiolatus* (Girault), an ectoparasitoid of the citrus leafminer, *Phyllocnistis citrella* Stainton, in a citrus leafminer mine.
Credits: L. Zappala, UF/IFAS

Figure 3. Larva of *Semielacher petiolatus* (Girault), an ectoparasitoid of the citrus leafminer, *Phyllocnistis citrella* Stainton.
Credits: L. Zappala, UF/IFAS

Figure 4. Pupa of *Semielacher petiolatus* (Girault), an ectoparasitoid of the citrus leafminer, *Phyllocnistis citrella* Stainton.
Credits: L. Zappala, UF/IFAS

Semielacher petiolatus has been found attacking the citrus leafminer in Australia (Boucek 1988, Smith et al. 1997) and in the Solomon Islands (Schauff et al. 1998), where the parasitoid was considered to be endemic. *Semielacher petiolatus* has been introduced into other areas where the citrus leafminer has invaded citrus, including Cyprus, Israel, Morocco, Oman, Syria, Tunisia, Turkey, Egypt, Greece, and Spain (Schauff et al. 1998).

Semielacher petiolatus appears to be able to attack leafminer species other than the citrus leafminer, although at low rates. *Semielacher petiolatus* was first found in Italy in 1998, but it is unknown how it arrived there (Mineo et al. 1998). By 2001, *Semielacher petiolatus* appeared to be the most efficient parasitoid of the citrus leafminer in Italy, with parasitism levels reaching nearly 80%. In 2002, *Semielacher*

petiolatus was recovered in all citrus-growing areas of Sicily with most of its activity occurring on citrus leafminer populations in early summer (June–August) while parasitism rates of the introduced eulophid *Citrostichus phyllocnistoides* Narayanan were higher in the later part of the growing season (September–October) (Siscaro et al. 2002). Siscaro et al. (2002) suggested that the establishment of *Semielacher petiolatus* (and of *Citrostichus phyllocnistoides*) was "related to the presence of alternative hosts" and that "their seasonal alternation could be partly explained by the different biological and ecological attitudes these two species showed on hosts of native flora." Siscaro et al. (2002) concluded it is "important to maintain a rich biodiversity in citrus groves in order to provide alternative food and shelter to CLM parasitoids, mainly in winter and spring, when CLM populations are at their minimum levels."

Mineo (1999) reported that *Semielacher petiolatus* was observed overwintering on the citrus leafminer in Sicily and that *Semielacher petiolatus* was found in all its developmental stages during January and February 1999, suggesting that this parasitoid may not have a diapause.

Taxonomic Description of *Semielacher petiolatus*

Keys to the families of Chalcidoidea can be found at: https://www.nhm.ac.uk/our-science/data/chalcidoids/eulophidae1.html. According to the Chalcidoidea Database, the family Eulophidae contains 297 genera and 4472 species in 4 subfamilies. The majority of the Eulophidae are primary parasitoids of concealed larvae, especially those inhabiting leaf mines. The best known species attack Lepidoptera, but eulophids also may attack larvae of Diptera (Agromyzidae), Hymenoptera (heterarthrine Tenthredinidae), and Coleoptera (Curculionidae).

The genus *Semielacher* Boucek is in the subfamily Eulophinae, which are "solitary or gregarious idiobiont ectoparasitoids of the larvae of leafminers or of concealed hosts such as leaf folders case bearers, gall makers and stem borers. Many species are facultative or obligate hyperparasitoids of other chalcids, braconids or ichneumonids" (Chalcidoidea Database). The genus *Semielacher* contains a total of two species according to the Chalcidoidea database, but Boucek (1988) indicated the genus *Semielacher* contains a total of three species from Australia, with two also present from New Guinea. According to Schauff et al. (1998), *Semielacher* is known only from Australasia. In Papua, New Guinea one undescribed species was reared as a parasite of the citrus leafminer. Parasitoids in the genus *Semielacher* Boucek have 4-segmented tarsi and a funicle that is 2-segmented (Schauff et al. 1998).

Smith et al. (1997) describe *Semielacher petiolatus* as indigenous to Australia and note it is the major parasite attacking the citrus leafminer in drier parts of the citrus-growing areas, but it is also important in Queensland (a subtropical citrus-growing area), along with the introduced encyrtid, *Ageniaspis citricola*.

Host Range of *Semielacher petiolatus*

Information on the host range of *Semielacher petiolatus* is based on records of material collected from field samples and, in Asia, it has been recorded only from the citrus leafminer. Elsewhere, the incidence of parasitism in hosts other than the citrus leafminer appears to be low, but the data serve as an indicator of potential host range.

Semielacher petiolatus was found on *Chromatomyia horticola* (Goureau) (Diptera: Agromyzidae) in Sicily about one year after its release in 1996 in Tunisia (Massa et al. 2001). Massa et al. (2001) concluded that the rapid spread and establishment of S. petiolatus in Sicily could be due to its ability to find alternative hosts that provide refuge and food for *Semielacher petiolatus* during seasons of low citrus leafminer population density.

Rizzo (2002) indicated that *Semielacher petiolatus* has been collected from several hosts on native plants in Italy, and that this "helps in maintaining populations of both native and exotic parasitoid, mainly in the seasons of low availability of *Phyllocnistis citrella* larvae."

Massa et al. (2001) evaluated species of leafminers found on approximately 40 of the most common plants associated with citrus groves in Sicily between 1997 and 2000. Leaves infested with miners were held in the laboratory until the insects and their parasitoids emerged; parasitoids found included *Semielacher petiolatus*, *Chromatomyia phyllocnistoides* and *Chromatomyia ingenuus*, which "possibly have switched over onto indigenous hosts after their introduction or immigration." The dipteran *Agromyza hiemalis* Becker (Diptera: Agromyzidae), a leafminer of nettle (Urtica), served as a new host of *Semielacher petiolatus* in Sicily (Massa and Rizzo 2000). Massa et al. (2001) indicated that *Semielacher petiolatus* could be found on five new hosts, including three Lepidoptera (Cosmopterigidae, Nepticulidae and Gracillariidae) and two Diptera (Agromyzidae) (Table 1).

Semielacher petiolatus and *Chromatomyia phyllocnistoides* were found parasitizing native hosts at a low rate, "compared with the whole number of parasitoids (564) obtained" during the project (Massa et al. 2001). Massa et al. (2001) concluded from a "qualitative point of view it seems that the community structure of parasitoids did not change after the introduction of exotic species" (Massa et al. 2001). Thus, at least in Sicily, there is no evidence that these two citrus leafminer parasitoids altered the abundance of other parasitoids within and around citrus groves. What is unknown is whether the community of parasitoids attacking leafmining insects on host plants outside citrus groves was affected. Other questions include: Are *Semielacher petiolatus* and *Chromatomyia phyllocnistoides* attacking agromyzid leafminers in vegetables and other crops in Sicily? Would *Semielacher*, if established in Florida, attack other leafminer species? Would this alter the effectiveness of already-established parasitoids of these leafminers?

Expected Attainable Geographic Range in North America

Based on current knowledge of the biology of *Semielacher petiolatus*, its expected geographic range would be where the citrus leafminer is established in citrus in the United States, which includes Florida, Louisiana, Texas, and California. *Semielacher petiolatus* appears to be able to establish in a diversity of climates, ranging from Mediterranean to subtropical. *Semielacher petiolatus* also may attack other leafminer species, including dipterans, on host plants other than citrus. We would not expect it to colonize temperate regions where winters are below freezing for any length of time. We have no detailed data on temperature or relative humidity tolerances of *Semielacher petiolatus*, however.

Expected Environmental Effects of *Semielacher petiolatus* in Florida

It is unlikely that *Semielacher petiolatus* would have significant negative effects on beneficial species of insects, such as honeybees. No dipteran or lepidopteran leafminers in Florida have been declared to be threatened or endangered. It could, however, disrupt the control of citrus leafminer by *Ageniaspis citricola* (Zappalá et al. 2007).

Potential Effects of *Semielacher petiolatus* on Other Insects in Florida

Based on the data from Sicily (Table 1), in which *Semielacher petiolatus* was found attacking leafminers in weeds in citrus groves, *Semielacher petiolatus* could attack both lepidopteran and dipteran leafminers in Florida. Hosts could include: 1) leafminers on plants of no economic importance; 2) leafminers on weeds; or 3) leafminer species, such as *Liriomyza trifolii*, that are serious pests of vegetable crops. Parkman et al. (1989) evaluated the leafminers and their parasitoids on selected weeds in south Florida; both *Liriomyza trifolii* and *Liriomyza sativae* were found on weed hosts in south Florida, with the most abundant parasitoids and leafminers found on castor bean, *Ricinus communis* L. The weeds were considered to be reservoirs for parasitoids which could possibly enhance the biological control of *Liriomyza trifolii* in vegetable crops.

There is a possibility that *Semielacher petiolatus* could use *Liriomyza trifolii* or *Liriomyza sativae* as alternative hosts, especially during the winter, when citrus leafminer populations are very low. *Semielacher petiolatus* could, during the winter, compete with other established parasitoids of *Liriomyza* species. Whether this could alter the effectiveness of the established *Liriomyza* parasitoids is unknown.

Pesticide Selectivity

No tests have been conducted to determine which pesticides can be used safely without disrupting *Semielacher petiolatus* populations in citrus groves. However, based on laboratory and field tests conducted in Florida on *Ageniaspis citricola*, oil and copper (Kocide) are IPM-compatible, meaning that *Ageniaspis citricola* can persist if these products are used for insect, mite and disease control (Villanueva-Jimenez et al. 1998; Villanueva-Jimenez and Hoy 1998a). Other potential IPM-compatible products may include: azadirachtin (Neemix) + 0.4% oil, and fenoxycarb (Eclipse) + 0.4% oil.

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Table 1. List of host records for Semielacher petiolatus on native plants in Italy and Jordan (Massa et al. 2001).

Host Insect Family	Host Plant	Site	Sex
Chromatomyia horticola Agromyzidae	*Sonchus* spp.	Palermo, Italy	2 males
Liriomyza sp. Agromyzidae	*Mercurialis annua*	Palermo, Italy	1 female
Cosmopterix pulchrimella Cosmopterigidae	*Parietaria diffusa*	Palermo, Italy	4 females
Stigmella aurella Nepticulidae	*Rubus ulmifolius*	Palermo, Italy	1 female
Dialectica sclariella Gracillariidae	*Echium* sp.	Jordan	1 female