New Records and Accounts

Oomyzus sokolowskii (Hymenoptera: Eulophidae) Joins the Small Complex of Parasitoids Known to Attack the Diamondback Moth on Kauai

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The diamondback moth, *Plutella xylostella* (Linnaeus 1758) (Lepidoptera: Plutellidae) is an extremely important pest of crucifers worldwide, found in nearly all regions where crucifers are grown (Philips et al. 2014). Its ability to feed on nearly all species and varieties of cruciferous vegetables, its propensity to develop resistance against almost all classes of insecticides, and a lack of effective natural enemies in much of its invasive range makes it a problematic and difficult insect to control (Talekar and Shelton 1993, Philips et al. 2014). Due to the intractability of many aspects of this species as a pest, sustainable cultural and biological control measures are important in its management (Talekar and Shelton 1993, Furlong et al. 2004, Philips et al. 2014, Li et al. 2015).

Over 90 parasitoids are known to attack *P. xylostella* worldwide over its native and invasive ranges, a subset of which are thought to exert considerable control (Talekar and Shelton 1993). Introduction of parasitoids, and an increase in their populations due to a decrease in broad-spectrum insecticide use, has resulted in substantial decreases in pest pressure by *P. xylostella* in many world regions, including New Zealand, Australia, Indonesia, Malaysia, Carribbean Islands, Taiwan, and the Phillippines (Talekar and Shelton 1993). A complex of natural enemies has been released for the control of *P. xylostella* in Hawaii. Of these, *Cotesia vestalis* (Kurdjumov 1912) (formerly *C. plutellae*) (Hymenoptera: Bracondiae) and *Diadegma insulare* (Cresson 1865) (Hymenoptera: Ichneumonidae) are known to be established (Johnson et al. 1988, Waterhouse 1992). *Cotesia vestalis* is found widespread in the Hawaiian Islands, while *D. insulare* is found predominantly in cooler areas (Johnson et al. 1988, Mau and Kessing 1992). *Pristomerus hawaiiensis* Perkins, 1910 (Hymenoptera: Ichneumonidae) and *Chelonus blackburni* Cameron, 1886 (Hymenoptera: Braconidae) have also been reared from *P. xylostella* larvae on Maui, though the percent parasitism has not been found to be at a level that would exert substantive control (Johnson et al. 1988). *Brachymeria boranensis* (Masi 1939) (Hymenoptera: Chalcididae), *Diadegma semiclausum* (Hellén 1949) (Hymenoptera: Ichneumonidae), *Diadromus collaris* (Gravenhorst 1829) (Hymenoptera: Ichneumonidae), and

Trichogramma chilonis (Ishii 1941) (Hymenoptera: Trichogrammatidae) were also introduced, but with the exception of *T. chilonis* are considered not to have established (Lai and Funasaki 1986, Waterhouse 1992). A *Tetrastichus* sp. nr. *sokolowskii* was also released but its relation to *P. xylostella* is unclear, and is discussed later. Here we report *Oomyzus sokolowskii* (Kurdjumov 1912) (Hymenoptera: Eulophidae), distinct from the released *T.* sp. nr. *sokolowskii*, emerging from a recent collection of *P. xylostella* pupae on Kauai, which is, as far as we are aware, the first record of this species in Hawaii.

Approximately 75 larvae and 30 pupae of *P. xylostella* were collected from kale (*Brassica oleracea* L. var. *acephala*) on a commercial farm in Kekaha, Kauai on 20 April, 2021. All *P. xylostella* pupae were placed together in a plastic jar. The *P. xylostella* larvae were reared on kale leaves in the laboratory until pupation, and these *P. xylostella* pupae were added to the plastic jar for adult emergence with the intent to collect *P. xylostella* eggs. Upon emergence of the *P. xylostella* adults, we noticed at least 20 small wasps in the jar. Since only *P. xylostella* pupae were placed in the jar, the wasps must have emerged from the *P. xylostella* pupae. The number of *P. xylostella* pupae that were parasitized was not confirmed. Additionally, because of the small size of the wasps, many escaped from the jar when *P. xylostella* eggs were being collected. Therefore, the total number of wasps that emerged is unknown, and only four were collected for identification. The wasps were identified by DH, JNM, and Mohsen Ramadan (Hawaii Department of Agriculture, Plant Pest Control Branch) as *Oomyzus sokolowskii*, a known parasitoid of *P. xylostella*. Voucher specimens (3♀, 1♂) were slide mounted and deposited in the Hawaii Department of Agriculture (HDOA) Insect Collection. *O. sokolowskii* can be distinguished within the Eulophidae subfamily Tetrastichinae by the following combination of characters (Kurdjumov 1912, Graham 1991, LaSalle 1994, Gibson et al. 1997).

Head: female with three non-claval funicular segments, these segments subquadrate, first funicular segment slightly shorter than pedicel, three-segmented clava slightly greater than two times as long as wide, scape not reaching anterior ocellus; malar sulcus mostly straight, only weakly curved; clypeal margin bidentate; POL/OOL slightly greater than two; male antennae with basal whorls of setae that extend beyond the end of their respective segments.

Mesosoma: propodeum with plicae weak, and not forking posteriorly; midline of mesoscutum at least partially present but weak; scutellum with distance between sublateral lines subequal to distance between sublateral lines and submedial lines; two or three adnotaular setae; hind coxae smooth dorsally; submarginal vein with one longer dorsal seta, though some populations are reported to have individuals with two setae; first segment of mid and hind tarsi slightly shorter or subequal to second.

Metasoma: female gaster short ovate.

Coloration: female as in Fig. 1, male of similar coloration.

O. sokolowskii was formerly placed in the genus *Tetrastichus (*Haliday 1844), and records show that a *Tetrastichus* sp. nr. *sokolowskii* was released on the Hawaiian Islands of Hawaii, Maui, Oahu, and Kauai for control of *P. xylostella* in 1953 (Weber 1954, 1955). Comparison with voucher specimens presumably from the release, however, indicate that this released species was not the same as the *O. sokolowskii* found and reported here, and two individual specimens identified as *T.* sp. nr. *sokolowskii* and matching the

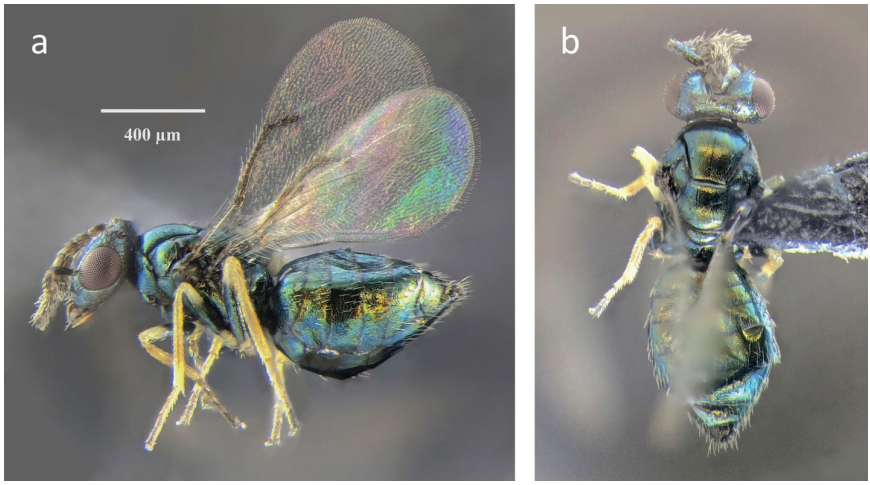

Figure 1. *Oomyzus sokolowskii* reared from *Plutella xylostella* larvae on kale from Kauai. Female habitus lateral (**a**) and dorsal (**b**) view.

voucher specimens from the 1953 release were reared from the beet webworm moth, *Spoladea recurvalis* (Fabricius, 1775) (Lepioptera: Crambidae) eggs in Maui in 1983, the only known record of this species since the time of its release (JNM, HDOA Insect Collection). A search of the Bernice Pauahi Bishop Museum Entomology Collection and the University of Hawaii Insect Museum did not yield additional vouchers from the 1953 release. Thus, the specimens of *O. sokolowskii* collected from *P. xylostella* larvae reported here represent the first record of this species in the Hawaiian Islands, and imply that *O. sokolowskii* is adventive or, possibly naturalized, and an unintentional arrival.

O. sokolowskii is a gregarious larval-pupal koinobiont parasitoid of *P. xylostella* that has been introduced to much of the world as a biological control agent, with a wide variation in levels of success of establisment and subsequent control (Waterhouse and Norris 1987, Waterhouse 1992, Talekar and Shelton 1993). It appears that this parasitoid is a serendipitous biocontrol agent in Hawaii, though the level of control it provides is currently unclear. Parasitism of *P. xylostella* should be monitored through the collection of larvae and pupae to determine its abundance and distribution in Hawaii. *O. sokolowskii* is thought to be particularly effective against *P. xylostella* in areas with high temperatures (Talekar and Hu 1996). Insecticides are known to severely affect parasitoids of *P. xylostella*, and agricultural practices that emphasize cultural and biological control instead of chemical approaches could be expected to increase their numbers and biological control potential (Talekar and Shelton 1993, Cordero et al. 2007, Philips et al. 2014).

In addition to being a primary parasitoid of *P. xylostella*, *O. sokolowskii* is a facultative hyperparasitoid of late instar *C. vestalis* larvae within *P. xylostella* larvae (Waterhouse and Norris 1987, Liu et al. 2000, Mahmood et al. 2003, Shi and Liu 2003). *O. sokolowskii* has also been shown in laboratory studies to attempt multiparasitim on *P. xylostella* larvae already parasitized by *C. vestalis*. In such

circumstances, *O. sokolowskii* larvae are nearly exclusively outcompeted by *C. vestalis*, while emergence of *C. vestalis* is largely unaffected (Mahmood et al. 2003, Shi and Liu 2003, Bai et al. 2010). Liu et al. (2000) found a negative correlation in parasitism rates between the two species and suggested there may be a competitive relationship. Whether the two species are competitive or complementary in Hawaii and how their interaction affects overall parasitism rates in different habitats would be an interesting topic for future study. Waterhouse and Norris (1987) predicted that these two species will act complementarily, citing a population ecological modeling study by May and Hassell (1981) that shows the effect of a facultative hyperparasitoid is essentially equivalent to an additional primary parasitoid that outcompetes its host in cases of multiparasitism.

As an unintentional arrival for which no host specificity testing was carried out, it is unknown whether *O. sokolowskii* may be attacking or persisting on other species. *O. sokolowskii* has largely been reported as a parasitoid of *P. xylostella* or as a hyperparasitoid of *C. vestalis* within *P. xylostella*, but one study also reports its parasitism of *Pieris brassicae* (Linnaeus 1758) (Lepidoptera: Pieridae), the cabbage butterfly, in India (Lal and Chandra 1976), and there are also reports of parasitism of *Plutella* sp. of unclear identity (De Santis 1989, Noyes 2019). There are three known Hawaiian endemic *Plutella* spp., two of which use the endemic coastal plant *Capparis sandwichiana* DC. as their host (Robinson and Sattler 2001). Parasitism of these endemic *Plutella* spp. by *O. sokolowskii* is not known, but it is possible they may act as alternative hosts. Discovery of the presence of *O. sokolowskii* in Hawaii is welcome news for growers of cruciferous vegetables, as it joins *C. vestalis* and *D. insulare* as the complex of parasitoids known to act against the diamondback moth in the Hawaiian Islands.

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