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THE BITING MIDGE, *FORCIPOMYIA (MICROHELEA) ERIOPHORA* (WILLISTON) (DIPTERA: CERATOPOGONIDAE), AN ECTOPARASITE OF LARVAL *PHOEBIS SENNAE* (PIERIDAE) IN SOUTH FLORIDA

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ABSTRACT. Cloudless sulphur larvae (*Phoebis sennae*, Pieridae) were observed in an experimental plantation and also in a natural setting being fed on by the ectoparasitic biting midge, *Forcipomyia* (*Microhelea*) *eriophora* (Williston) (Diptera: Ceratopogonidae). Larvae parasitized by midges died at higher rates in captivity, in contrast to normal levels of mortality in rearings of this species, providing circumstantial evidence for the potential role of these flies in disease transmission.

Additional key words: multi-trophic interactions, ectoparasitic biting midges, natural enemies, *Senna*, *Cassia*, *Chamaecrista*, Fabaceae

A caterpillar is a feeding machine, little more than a sclerotized head with chewing mouthparts, its body a soft-sided bag in which the organs are bathed in haemolymph. Such a body is delectable to predatory wasps, ants, and other predators, and the potential for biological control by these animals has been demonstrated in numerous studies (e.g., Cuautle & Rico-Gray 2003, Rico-Gray & Oliveira 2007, Stamp & Casey 1993). The attack of larval Lepidoptera by biting midges was first noted by De Geer (1752), and was reviewed extensively by Wirth (1956). Wirth (1972a) asked lepidopterists to "look out for these minute caterpillar pests during their field work", as he felt they were widespread, though available data suggested at the time they were extremely rare. Records of their distribution in North America are continuously being updated (Borkent & Grogan 2009, Grogan et al. 2010), but studies of their biology are few. Notable among these are descriptions of Ceratopogonidae attacking wings of butterfly adults (Lane 1977, 1984, Kawahara et al. 2006), libellulid dragonflies (Clastrier et al. 1994), and reduviid bugs (Clastrier & Delecolle 1997).

Phoebis sennae L. (Lepidoptera: Pieridae) occurs throughout North America, and is abundant in Florida, the West Indies (Smith et al. 1994) and south to Argentina (DeVries 1987). In Florida, this species utilizes both native and ornamental species of *Senna*, *Cassia*, and *Chamaecrista* (Fabaceae) as hostplants (Daniels 2003, Minno et al. 2005).

MATERIALS AND METHODS

During ongoing studies of *Phoebis* sulphurs on native *Bahama senna* (*Senna mexicana* var. *chapmannii* (Isely) H.S. Irwin & Barneby), we monitored individual plants in an experimental site on the grounds of the University of Florida's Tropical Research and Education Center in Homestead, FL. We recorded the occurrence of caterpillars on plants, and also collected them for rearing to obtain information on parasitization and disease (results reported elsewhere).

On 14 November 2003, 5th instar *P. sennae* larvae (n = 3) were encountered, each with several ectoparasitic flies attached to their cuticles (Fig. 1). The parasitic flies were collected for determination, and the caterpillars for rearing. On the same date, additional late instar *P. sennae* larvae (n = 5) observed on the same plants as the parasitized individuals were collected and reared to note any deleterious influence possibly resulting from parasitism. Three of the collected biting flies were slide-mounted in Canada balsam and deposited in the Florida State Collection of Arthropods, Gainesville, FL as vouchers.

RESULTS AND DISCUSSION

Three engorged midges were slide-mounted and determined to be *Forcipomyia* (*Microhelea*) *eriophora* (Williston) (Diptera: Ceratopogonidae), a moderately common, primarily Neotropical ectoparasitic biting

midge known to attack caterpillars (Wirth 1972b). This observation represents the first known report of *F.* (*M.*) *eriophora* parasitism on *P. sennae*. Similar interactions were also documented in Everglades National Park (Fig. 2). This ectoparasitic biting midge was recently discovered while feeding on a larva of the rare Florida leafwing butterfly, *Anaea troglodyta floridalis* F. Johnson and Comstock (Nymphalidae) (Salvato et al. 2012). The species is also known to feed on larvae of *Melanchroia geometroides* Walker, on Cuba (Baker 1907); the Tobacco hornworm, *Manduca sexta*, (Sphingidae) in Puerto Rico (Wolcott 1951); and more recently on a larva of the swallowtail butterfly, *Papilio demoleus*, on Puerto Rico (Grogan pers. obs.). *Forcipomyia eriophora* has been previously recorded in Collier, Dade, Jackson and Monroe counties in the state of Florida (Wilkening et al. 1985). However, it is not nearly as common or widespread as its relative, *F.* (*M.*) *fuliginosa* (Meigen), which occurs throughout New and Old World tropical and temperate regions (Borkent & Grogan 2009).

Each of the three *P. sennae* larvae parasitized by *F.* (*M.*) *eriophora* died prior to pupation. Two caterpillars died within two weeks of their collection, turning black and white, becoming covered with fuzzy mold; the third caterpillar transformed into a malformed prepupa, turning colors (black, pink, and white), and died. Of the five non-parasitized *P. sennae* larvae also collected on 14 November 2003, three pupated and eclosed as adult butterflies, and the other two pupated but did not eclose (one chrysalis became black from a suspected virus). Average rates of death from viruses or other pathogenic organisms, for all caterpillars reared in the larger study (collected for rearing from the 3rd instar onward), were 13% over all treatment groups, approximately equal to the average rates of parasitoid attack (13%); on average, around 60% of all caterpillars (collected in the third or later instar) survived to adulthood.

The remains of the dead caterpillars and pupae were examined by Dr. Leellen Solter (Illinois Natural History Survey) for evidence of visible viruses or microsporidia. She found a variety of bacteria (both pathogenic and saprophytic) and fungi; some of which may have been organisms that grew postmortem, as the specimens were left in tubes at room temperature for various periods after dying. No one common pathogenic agent could be identified from these specimens. Recently, spiroplasmas have been determined to be present in the bodies of ceratopogonid biting midges (Frana et al. 2001, Koerber et al. 2005). Some spiroplasma isolates are known pathogens to their insect hosts, including Lepidoptera (Herren et al. 2007), where they can affect larval growth rate, adult size, and survival (Dowell et al. 1981, Klein & Purcell 1987), and population sex-ratio (Jiggins et al. 2000).

Our observational data also suggest that these ectoparasitic biting midges may transmit disease causing micro-organisms as all three parasitized *P. sennae* larvae failed to develop to the adult stage. Although our sample size was small, we had expected mortality similar to the 40% recorded throughout our long-term studies of *P. sennae*. In addition, the feeding activity of biting midges on Lepidoptera is not always fatal. Salvato et al. (2012) reared late instar *A. t. floridalis* larvae (n = 2) to the adult stage following instances of *Forcipomyia* parasitism, and similar instances of sub-lethal *Forcipomyia* ectoparasitism on Lepidoptera larvae have been noted by Sevastopulo (1973) and Young (1983).

The parasitized *P. sennae* in our studies were not "sucked dry" as Baker (1907) described for the larvae of *M. geometroides* that he observed in Cuba; they continued to feed throughout their development. Mayer

Fig. 1. Fifth instar caterpillar of *Phoebis sennae* studded with numerous *Forcipomyia eriophora* biting midges on *Senna bahamensis* var. *chapmannii* hostplant in Homestead, Florida.

Fig. 2. Caterpillar of *Phoebis sennae* with the same species of midge in Everglades National Park. Photo by John H. Geiger.

(1955) later suggested that the empty, black, hanging skins of the *M. geometroides* described by Baker were caused by virus or other disease, and that the feeding habits of the biting midges enabled them to transmit disease to their hosts. Definitive experiments demonstrating transmission of caterpillar disease via bloodsucking flies remain to be performed. Such experiments could take caterpillars known to be infected with virus, microsporidia, or spiroplasmas; allow them to be fed upon by the flies, which in turn are allowed to feed on other pristine caterpillars; and if those uninfected caterpillars contract disease, the transmission will be demonstrated (a variation on Koch's postulates).

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