Scientific Note

Forcipomyia hardyi (Diptera: Ceratopogonidae), a Potential Pollinator of Cacao (*Theobroma cacao*) Flowers in Hawaii

Daniel C. O'Doherty[1] and **Janna J. K. Zoll**
[1]Department of Tropical Plant and Soil Sciences, University of Hawaii at Manoa, 3190 Maile Way, Honolulu, HI 96822, USA; odoherty@hawaii.edu

Abstract. Biting midges of the genus *Forcipomyia* are known to be important pollinators of cacao trees in cocoa producing countries throughout the world. *Forcipomyia hardyi* is endemic to the Hawaiian Islands and is here reported to pollinate cacao trees on the island of Oahu. We report that *F. hardyi* visits cacao flowers where it picks up pollen, and therefore it is potentially an important pollinator of cacao in Hawaii.

Key words: biting midges, cacao pollination

Forcipomyia species are commercially important pollinators of several crops in tropical areas, including cacao (*Theobroma cacao* L.) (Young 2007). Commercial production of cacao in Hawaii has been expanding in recent years (Schnell 2005), as evidenced by the formation of the statewide Hawaii Cacao and Chocolate Association in 2012. Pollination of cacao trees is completely dependent on insect activity, and a recent study suggests that yield is more limited by pollination than by plant resources (Groeneveld et al. 2010). Because of the high cost of agricultural production in Hawaii compared to that of developing nations, it is important to understand key factors, such as pollination, that may affect yield. However, no research has been conducted to investigate the identity or dynamics of cacao-pollinating insects in Hawaii. We provide here the first report suggesting that *Forcipomyia* midges may contribute significantly to pollination of cacao in Hawaii.

Initial observations of flowers on a single cacao tree in the courtyard of the St. John Laboratory at the University of Hawaii at Manoa revealed the presence of small flying insects, ants, and aphids. Insects associated with cacao flowers were subsequently sampled on the university campus and from a commercial cacao plantation in Waialua, Oahu, owned by Dole Food Company. Insects were captured directly from flowers with an aspirator and trapped by pinning 2 x 2 cm pieces of adhesive flypaper directly under clusters of flowers and nearly mature buds (Figure 1A). Specimens were deposited in the University of Hawaii Insect Museum (Manoa). In February 2012, one live insect aspirated from a cacao flower on the university campus was identified as a member of the Ceratopogonidae by CTAHR entomologist Dick Tsuda and preserved in ethanol. In March 2012, two live midges resting on the petals of a cacao flower at the Manoa campus were aspirated and preserved in 70% ethanol, and several insects trapped on flypaper at Waialua were collected. These were brought to Dr. Frank Howarth at the Bishop Museum, who identified the ethanol-preserved midges as females of *Forcipomyia hardyi* Wirth and Howarth (Figure 1B). Although

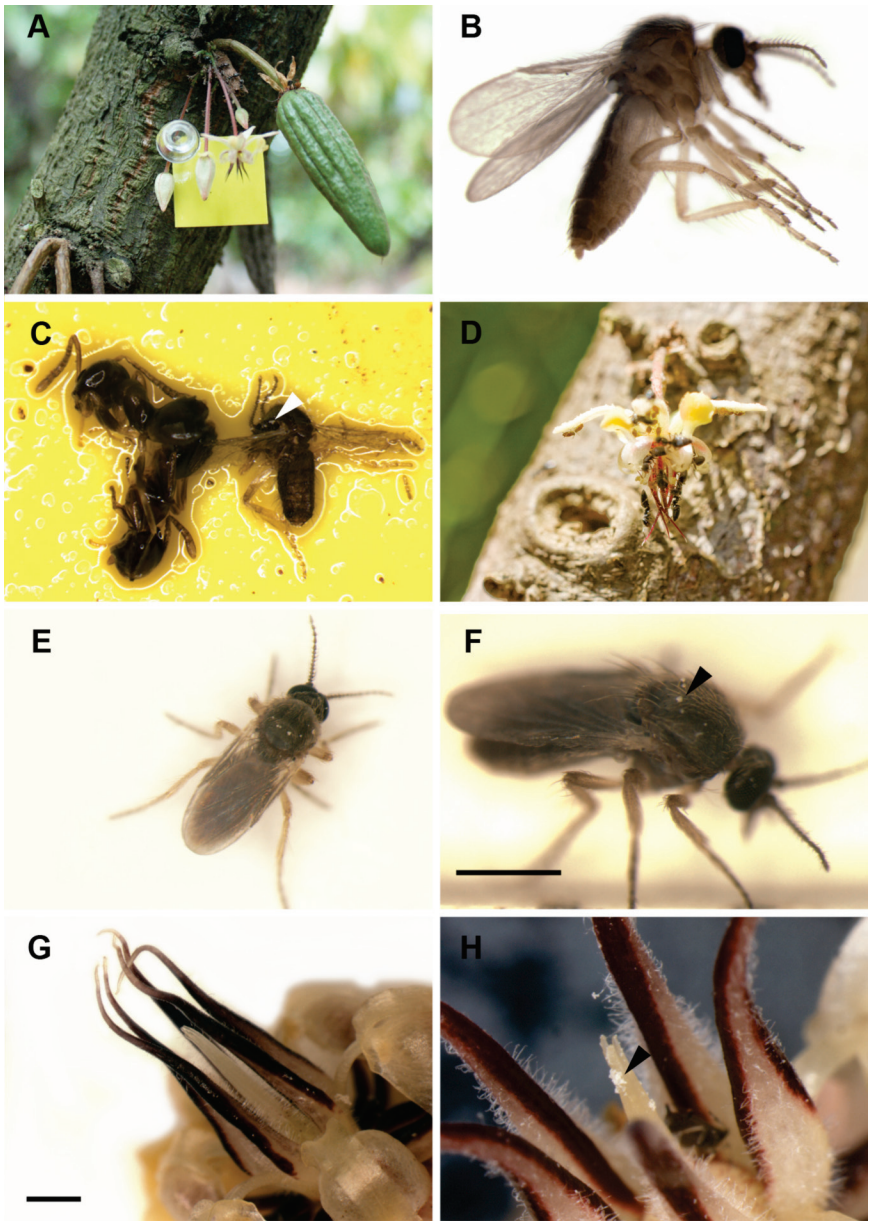

Figure 1. A. Flypaper pinned underneath of cacao flower and buds. **B.** Ethanol-preserved female *F. hardyi* identified by Frank Howarth. **C.** Flypaper trap containing two ants and one midge; arrowhead indicates pollen. **D.** Cacao flower showing presence of ants and aphids. **E.** Dorsal view of live *F. hardyi*. **F.** Lateral view of live *F. hardyi*; arrowhead indicates pollen; scale bar = 0.5 mm. **G.** Freshly opened cacao flower showing style surrounded by staminodes; scale bar = 1 mm. **H.** Pollinated cacao flower showing outwardly-recurved staminodes; arrowhead indicates pollen.

pollen could be seen attached to the live midges, it appeared to have washed off upon immersion in ethanol. The flypaper traps contained several insects including one specimen of *F. hardyi* and several specimens of Aphididae, Drosophilidae, Sciaridae, and Formicidae. Pollen grains were visible on the midge, attached to the side of its thorax (Figure 1C). Despite the observation of aphids and ants moving within cacao flowers (Figure 1D), there was no evidence of pollen on any insects that were captured or photographed, other than *F. hardyi*. In September 2012, another female *F. hardyi* was aspirated from a cacao flower at the university campus with pollen attached to the hairs on the dorsal surface of its thorax, and it was photographed while still alive (Figures 1E and 1F). The pollen grains attached to the midge were compared with pollen on the anther of the flower from which the midge was collected, and appeared to match with regard to size and appearance. The small size and intricate structure of cacao flowers prevent many insects from being effective pollinators. During the short time period that cacao flowers are receptive, five staminodes with inward-facing hairs tightly enclose the stigma and style (Figure 1G), leaving a gap of less than 1 mm for pollinating insects to pass through. The inward-facing hairs may function to allow pollinators access to the receptive surfaces, but discourage easy exit, thereby increasing the likelihood of pollen transfer. After pollen has been deposited, the staminodes curve outward (Figure 1H).

Wirth and Howarth (1982) described *F. hardyi* and several other new species of endemic midges in Hawaii. While most species appeared restricted in distribution, the authors indicated that *F. hardyi* was abundant and widespread throughout the state. The role of *F. hardyi* in flower pollination was supported by Dr. Wirth's collections of specimens at flowers of Compositae and Dr. Howarth's observation of large numbers of midges swarming around mango blossoms (Wirth and Howarth 1982). The current report provides the first evidence supporting the role of a native midge as a pollinator of cacao in Hawaii. Although further studies are needed, the relative ubiquity of *F. hardyi* in Hawaii suggests it may play a primary role as a pollinator of cacao in the state.

Acknowledgments

We would like to thank Michael Conway for providing access to the Waialua Estate cacao orchard. We thank Dick Tsuda (University of Hawaii at Manoa), Luc Leblanc (University of Hawaii at Manoa), and Frank Howarth (Bishop Museum) for allowing the use of microscopes and other equipment, and for expertise in insect identification. We also thank H.C. Bittenbender (University of Hawaii at Manoa) and Curtis Daehler (University of Hawaii at Manoa) for support.

Literature Cited

Groeneveld, J.H., T. Tscharntke, G. Moser, and **Y. Clough.** 2010. Experimental evidence for stronger cacao yield limitation by pollination than by plant resources. Perspectives in Plant Ecology, Evolution, and Systematics 12:183–191.

Schnell, R.J., C.T. Olano, J.S. Brown, A.W. Meerow, C. Cervantes-Martinez, C. Nagai, and **J.C. Motomayor.** 2005. Retrospective determination of the parental population of superior cacao (*Theobroma caca*o L.) seedlings and association of microsatellite alleles with productivity. J. American Soc. Hort. Sci. 130:181–190.

Young, A.M. 2007. Nature in the cacao: mysteries of pollination. p. 115–162 *In* A.M. Young, The chocolate tree: a natural history of cacao. Florida: University Press of Florida.

Wirth, W.W., and **F.G. Howarth.** 1982. The "*Forcipomyia ingrami*" Complex in Hawaii (Diptera: Ceratopogonidae). Proc. Hawaiian Entomol. Soc. 24:128–151.