Predatory Behavior of Long-Legged Flies (Diptera: Dolichopodidae) and Their Potential Negative Effects on the Parasitoid Biological Control Agent of the Asian Citrus Psyllid (Hemiptera: Liviidae)

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Predatory behavior of long-legged flies (Diptera: Dolichopodidae) and their potential negative effects on the parasitoid biological control agent of the Asian citrus psyllid (Hemiptera: Liviidae)

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The Dolichopodidae, or long-legged flies, are one of the largest families of Diptera, with more than 6,000 species worldwide (Pollet et al. 2004). Best known for their long legs and the bright metallic green, blue, and yellow hues of the most conspicuous species, most are small, 5 to 10 mm long, although the family also contains "microdolichopodids" measuring approximately 1 mm. Adults are predaceous. Ulrich's (2004) list of all known published records of predation by adult dolichopodids includes approximately 200 records representing at least 168 predator species in 47 genera. The prey species are mostly Diptera, and more than half belong to the families Chironomidae and Culicidae. However, various *Condylostylus* species (Diptera: Dolichopodidae) have been recorded to prey on dark-winged fungus gnats, leaf-miner flies, aphids, leafhoppers, thrips, whiteflies, and mites. A *Chrysotus* species (Diptera: Dolichopodidae) was observed to feed on springtails and psyllids. Two independent records of predation on Psyllidae were also listed.

Larvae of dolichopodids are not well known, but consensus reports suggest that they are mostly predaceous. In general, laboratory and field observations of dolichopodids indicate that the larvae live in aquatic, muddy, or at least humid or mulched habitats (Robinson & Vockeroth 1981; Corpus 1986; Gill et al. 2011; Decleer et al. 2015).

Two fly taxa, robber flies (Diptera: Asilidae) and hunter flies (the species *Coenosia attenuata* Stein; Diptera: Muscidae), the latter a recent entry into the US fauna from the Old World (Pons 2005), are well known for their classical, textbook, "hawking" behavior in catching prey. They perch motionless on vantage points, dart out to catch passerby insects, and bring them back to the perch to feed on them. Several studies indicate that, at least for asilids and depending on the species, perching behavior may also be associated with other behavioral motifs, such as those involved in thermoregulation and mate location (Shelly 1984; Hastings et al. 1994). Regardless, the predatory hawking or perching behavior is herein considered to be a genetically based tactic with an evolved function for partitioning available resources. By specializing in catching in-flight prey, these predators minimize their time in motion and the distance needed to secure prey relative to the distance travelled by other predators that use a foraging strategy.

Dolichopodids are not known to perform their predatory behavior in a specific motif that can be interpreted as an evolved tactic. In this scientific note, we report a stereotypic foraging behavior among a multispecies complex of dolichopodids (hereafter: long-legged flies) in east central Florida and direct observations of predation on the parasitoids (hereafter: wasps) *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) and *Diaphorencyrtus aligarhensis* (Shafee, Alam & Agarwal) (Hymenoptera: Encyrtidae), mass reared and released for biological control of the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Liviidae), the vector of the bacterium '*Candidatus* Liberibacter asiaticus' associated with huanglongbing, or citrus greening, a disease that is challenging the nation's citrus industry (Kuchment 2013; Santa Ana 2014).

Observations were conducted during the summer of 2014 in the citrus grove of the Florida Research Center for Agricultural Sustainability, Vero Beach, Florida, which practices routine pesticide spraying, and in the nearby citrus grove of the Osceola Organic Farm, which maintains several vegetable and fruit groves with organic cultural methods. The organic citrus grove was surrounded by a rain retention furrow filled with wind-breaking vegetation—*Casuarina* (Casuarinaceae), *Eugenia* (Myrtaceae), *Eucalyptus* (Myrtaceae), *Tithonia* (Asteraceae), *Sabal* (Arecaceae), and other plants—on 3 sides that fostered a heavy buildup of moist detritus and, at times, stagnant water puddles. The citrus trees were approximately 2.5 to 3 m tall and sustained a moderate population of *D. citri* along with the associated citrus greening symptoms. Wasps were received weekly, in lots of 3,000 to 6,000, from the mass rearing facility at the Florida Department of Agriculture, Division of Plant Industry, Gainesville, Florida.

Peak population density of long-legged flies occurred from Jun to Aug. During this time, the genus *Condylostylus* was by far the most numerous in terms of species and individuals collected by sweeping the citrus foliage. Four species of *Condylostylus* were recognized based on the most recent catalog (Pollet et al. 2004)—*Condylostylus longicornis* (F.), *Condylostylus crinitus* (Aldrich), *Condylostylus graenicheri* (Van Duzee), and *Condylostylus mundus* (Wiedemann). Also, 2 species of

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Chrysotus—*Chrysotus nigripalpis* Van Duzee and *Chrysotus picticornis* Loew—and 1 unidentifiable species, possibly *Sciapus* sp., were among the series collected. Voucher specimens were placed in the Florida State Collection of Arthropods (FSCA), Gainesville, Florida.

Visual observations of predatory behavior of long-legged flies were conducted on citrus only, in the early afternoon when wasps were released by slowly sprinkling them out of their shipping containers onto horizontal leaf surfaces. Extended observations were taken as late as 3:00 PM eastern standard time. Because of the overt nature of the predation behavior, formal population assessments or bioassays of predators were deemed non-germane to describing it. Visual identifications of long-legged flies could not be made during observations because the flies lacked overt features for recognition at the species level. Fly behavior was carefully observed in the field, but attempts to photograph these predation events were unsuccessful.

Collectively, the presence of long-legged flies on citrus foliage was highest during the full sun of midday between ca. 10:00 AM and 3:00 PM eastern standard time, and during this peak activity, the flies were so abundant that at least 1 fly, sometimes 2 or 3, occurred on the adaxial side of all citrus leaves under observation at any given moment. The flies would constantly "canvas" the full upper surface area of a leaf with a rapid, jerked, frantic ambulation, then hop onto another leaf and do the same, while another fly, or other flies, having finished canvassing a different leaf, would then hop onto the vacated leaf, canvassing it over again. Importantly, the flies were well spaced by maintaining some unmeasured average distance, perhaps a few centimeters, from each other. In this way, the collective surface area of leaves was given constant scrutiny. Mating was not observed. The flies were not observed canvassing stems, petioles, axils, or the abaxial leaf surfaces.

During this peak activity, observations of natural predation events were relatively few in number but unmistakable. While wasps were sprinkled onto the leaves, long-legged flies circumstantially nearby would "hawk" wasps out of the air. Also, canvassing flies would grab and eat wasps, one per event, on the leaves as they were encountered (Fig. 1). In the managed grove, where scheduled pesticide spraying and mulch clearing were maintained, long-legged flies were very sparse in number, but the canvassing motif could be recognized in individual fly behavior after identifying it in flies at high population densities.

An estimated 162 species in 29 dolichopodid genera are known to occur in Florida, 112 of which are validated by voucher specimens in FSCA. Photographs and videos of fly predatory events are posted on the internet (e.g., Barrentine 2011) and considered testimony to the predatory behavior of long-legged flies; however, because little to nothing is known of possible sexual dimorphisms, intraspecific variations, and other features, these media would likely not allow for accurate identification.

It is clear that, at high population levels, dolichopodids enter into a scramble competition for food (Nicholson 1954) and are entrained into maintaining a well-spaced yet very fast and frantic rate of canvassing. Such observed uniformity and efficiency of search tactic gives credibility to the suggestion that these behaviors are genetically perpetuated. Without such an epiphenomenal show, canvassing behavior would not have been recognized in the managed plot, where numbers are very low and entrainment is not in operation.

As predators, dolichopodids are considered prospective beneficial insects in biocontrol efforts when used against arthropod vectors of disease pathogens and pests in agroforestry (Coulibaly 1993). However, we identified certain organic citrus management practices that can potentially foster heavy predation on chalcidoid wasp biocontrol agents mass released against the invasive *D. citri* during peak fly activity. These parasitoids are most vulnerable when landing and ambulating on a leaf and least vulnerable in the axils, where adults assume prolonged, stationary postures for drilling and ovipositing. Therefore, the biocontrol effort may be compromised directly following release of the wasps, when they ambulate to the axils, and when they leave an axil to find another.

Fig 1. A parasitoid wasp and 1 of 7 species of predaceous long-legged flies collected in this study. The photograph is insufficient for identification. Although predation events could not be duplicated in captivity, the parasitoid wasp appears to be within a size range that the long-legged fly would attack (e.g., Barrentine 2011). Scale bar = 2 mm.

Organic citrus groves can still benefit from mass inundation techniques if releases are conducted at dusk or night. Also, cultural control can be implemented to eliminate the buildup of ground detritus and other habitats, such as palm frond axils, which may serve as breeding milieu for the predatory flies. This practice can reduce the potential increase in fly populations when pesticides are not used.

In non-organic groves, fly predation pressure is probably on par with that of spiders and other predators at large, but it needs to be recognized for its role in agricultural ecosystems because it falls into a category of intraguild predation that is disruptive and can reduce biological control efficiency (Harvey & Eubanks 2005). Finally, improvement of habitat in surrounding uncultivated space, such as plantings of flora with nectaries that parasitoids are attracted to and feed upon, can improve survival and establishment of biological control agents (Patt & Rohrig 2017).

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Summary

Apparently because of mulch buildup and abstinence from pesticide use, an organically managed citrus grove in Vero Beach, Florida, can support large populations of long-legged flies (Diptera: Dolichopodidae) that impose predation pressure on inundative releases of *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) parasitoid wasps to control the Asian citrus psyllid (Hemiptera: Liviidae). During peak activity, flies on wing characteristically hawk wasps in mid-air as the wasps are sprinkled from shipment containers onto the leaves of citrus plants. Flies on leaves enter into entrained scramble competition for prey by systematically "canvassing" upper leaf surfaces in rapid, jerked movements and, albeit infrequently, attack and eat wasps when encountered during this behavior.

Key Words: long-legged flies; scramble competition; canvassing; citrus greening; inundative release; *Diaphorina citri*

Sumario

Aparentemente debido a la acumulación de mantillo y a la abstinencia del uso de pesticidas, un huerto de cítricos manejado orgánicamente en Vero Beach, Florida, puede soportar grandes poblaciones de moscas de patas largas (Diptera: Dolichopodidae) que imponen presión de depredación sobre liberaciones inundadas de *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) para controlar el psílido asiático de los cítricos (Hemiptera: Liviidae). Durante la actividad máxima, las moscas vuelan y atacan las avispas en el aire, cuando salen de los recipientes de envío a las hojas de plantas de cítrico. Las moscas sobre las hojas entran en la competición de arrastre de la presa mediante la "prospección sistemática" de las superficies superiores de las hojas con movimientos rápidos y bruscos, aunque con poca frecuencia, atacan y comen avispas cuando se encuentran durante este comportamiento.

Palabras Clave: moscas de patas largas; competencia revuelta; prospección; enverdecimiento de los cítricos; liberaciones inundativas, *Diaphorina citri*

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