Occurrence of Coccinellids that Prey on Diaphorina citri (Hemiptera: Liviidae) on Euphorbia heterophylla (Euphorbiaceae) and Chamaecrista fasciculata (Fabaceae) in a South Florida Residential Area

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Occurrence of coccinellids that prey on *Diaphorina citri* (Hemiptera: Liviidae) on *Euphorbia heterophylla* (Euphorbiaceae) and *Chamaecrista fasciculata* (Fabaceae) in a south Florida residential area

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Asian citrus psyllid (ACP), *Diaphorina citri* (Kuwayama) (Hemiptera: Liviidae), the vector of the causal agent responsible for citrus greening disease or huanglongbing (HLB), can thrive in urban areas, abandoned citrus groves, and other areas that are not managed to control the psyllid (Tsai et al. 2002; Halbert & Manjunath 2004; Chong et al. 2011; Kondo et al. 2015). Psyllids in these unmanaged areas often occur on the widespread ornamental shrub, orange jasmine (*Murraya paniculata* (L.) Jacq. [Rutaceae]), as well as citrus trees; from there they can readily disperse to nearby commercial groves and transmit HLB (Tiwari et al. 2010; Lewis-Rosenblum et al. 2015). Despite the significant threat these psyllids pose to the citrus industry, there are few practical options available for managing *D. citri* in urban and unmanaged areas. Biological control has long been thought to be the most promising means of suppressing *D. citri* in urban and unmanaged areas because the psyllids are vulnerable to attack by predaceous arthropods such as lady beetles, lacewings, and spiders, as well as by introduced parasitoids such as *Tamarixia radiata* (Waterston) (Hemiptera: Eulophidae) (Michaud 2001, 2002; Michaud & Olsen 2004; Pluke et al. 2005; Qureshi & Stansly 2009; Lozano Contreras & Jasso Argumendo 2012; Hall et al. 2013; Qureshi et al. 2014; Kondo et al. 2015).

Studies have shown that, in the absence of chemical spray controls, generalist predators can be relatively abundant in commercial citrus groves and can negatively impact *D. citri* populations (Michaud 2001, 2002; Michaud & Olsen 2004; Pluke et al. 2005; Qureshi & Stansly 2009; Qureshi et al. 2014). While generalist predators have the potential to reduce *D. citri* populations in urban and unmanaged areas, their frequency and distribution is largely unknown and their impact on *D. citri* populations has been reported to be uneven. For example, Tsai et al. (2002) saw very little evidence of generalist predator occurrence while documenting *D. citri* population dynamics on orange jasmine and citrus in south Florida. Chong et al. (2011) reported that the most common predators associated with orange jasmine hedges in south Florida were the coccinellids *Harmonia axyridis* (Pallas) and *Chilocorus stigma* (Say) (both Coleoptera: Coccinellidae) but these species also had low observed frequencies of occurrence.

Adding plant-based nutritional resources to a landscape may help to recruit and retain predaceous and parasitic arthropods (Landis et al. 2000; Wäckers et al. 2005; Lundgren 2009; Gurr et al. 2017). This is because, in addition to prey or hosts, many natural enemy taxa also rely on nectar and pollen at some point during their life cycles (Jervis et al. 1993; Wäckers et al. 2005; Lundgren 2009). Plant-based nutrients can be crucial to natural enemies during transit between locations, during periods of prey scarcity, and are often necessary for gamete maturation (Wäckers et al. 2005; Lundgren 2009). Because most natural enemies do not possess mouthparts that enable them to probe into floral tubes, they obtain nectar primarily from plant species with extrafloral nectaries or whose flowers have relatively exposed nectaries (Patt et al. 1997; Wäckers 2004). Many of the ornamental plant species commonly grown in southern Florida cannot provide nectar or pollen to *D. citri* natural enemies because they have been bred to have multiple petals that obscure or lack nectaries altogether, or have tubular flowers that prevent natural enemies from accessing the nectaries. It is therefore important to select ‘nectary plants’ that have either extrafloral nectaries or flowers whose nectaries are morphologically accessible to natural enemies (Patt et al. 1997; Sivinski et al. 2011; Géneau et al. 2012; Tschumi et al. 2014; Wäckers & van Rijn 2012).

As a first step in determining whether the addition of nectary plants might increase the abundance and diversity of biocontrol agents of *D. citri* and thus augment psyllid suppression in urban and unmanaged landscapes in southern Florida, the occurrence of coccinellids was recorded on two nectary plants grown in a residential area. Lady beetles were chosen as a focal taxon because they are among the most important predators of ACP (Michaud 2001, 2002; Michaud & Olsen 2004; Pluke et al. 2005; Qureshi & Stansly 2009; Lozano Contreras & Jasso Argumendo 2012; Qureshi et al. 2014; Kondo et al. 2015).

The two nectary plant species chosen for observation were partridge pea, *Chamaecrista fasciculata* (Michx.) Greene (Fabaceae), a native legume, and a native poinsettia, *Euphorbia heterophylla* (L.) (Euphorbiaceae). *Chamaecrista fasciculata* is an annual that tolerates nutrient-poor soils, withstands drought, and readily re-seeds (Houck & Row 2006). Commonly grown as an ornamental, its numerous and bright yellow flowers make it a popular choice for use in native gardens. It is also planted to support gamebirds, which feed on the seeds (Martin et al. 1951), and is a recognized wildlife conservation plant. *Chamaecrista fasciculata* has a single extrafloral nectary located at the base of the rachis of each compound leaf (Fig. 1A). *Euphorbia heterophylla* has numerous protruding nectaries within each inflorescence (Fig. 1B). Whereas *E. heterophylla* can be a serious annual weed of field crops such as soybeans and cowpeas (Wilson 1981), its nectary architecture and quick growth habit made it a useful species to investigate as a nectary plant in an urban setting.

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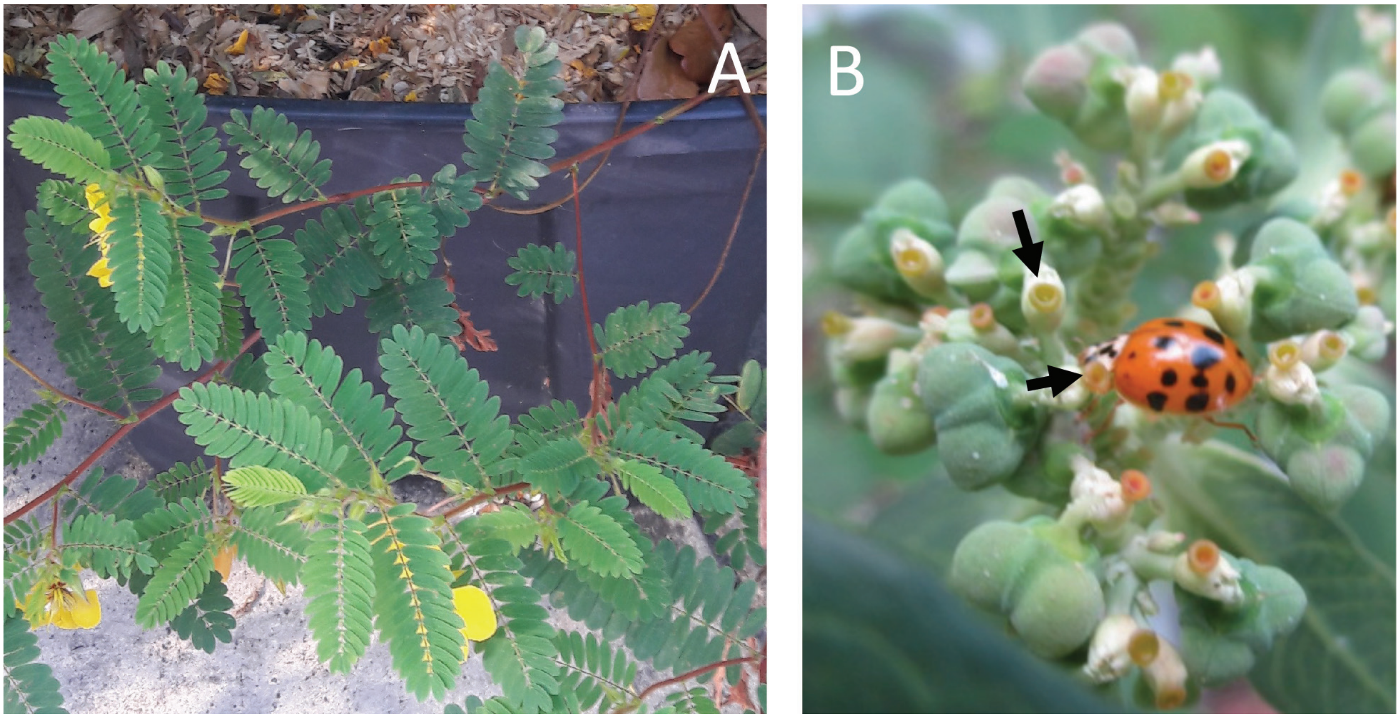

Fig. 1. Nectary plants monitored for presence of coccinellids. (A) *Chamaecrista fascisculata* foliage. (B) *Euphorbia heterophylla* with adult *Harmonia axyridis*. Arrows show nectaries.

The studies were conducted in a residential neighborhood with mature live oak trees in Fort Pierce, Florida, USA, from Jun 2016 to Feb 2017. Fort Pierce has a subtropical climate and is located approximately 35 km southeast of the Indian River citrus growing region. The plants were grown in planters made from 79.5 L plastic storage boxes filled with ca. 60 L of commercial peat-based potting soil (Farfard 4P Mix, Sungro Horticulture Distribution, Inc., Agawam, Massachusetts, USA). Prior to filling with soil, the bottoms of the boxes were drilled to create 8 drainage holes (1.5 cm diam). *Euphorbia heterophylla* seeds were obtained by hand collection from plants growing in the study locality; *C. fasciculata* were obtained from a regional commercial seed supplier (Hancock Seed Company, Dade City, Florida, USA). The seeds were sown in 7.6 cm square pots and the seedlings transplanted to the planters when they had 4-6 true leaves. To provide each planter with equivalent amounts of plant mass when each species had reached maturity, each planter received either 15 *E. heterophylla* seedlings or 5 *C. fasciculata* seedlings. After transplanting, each planter was fertilized with ca. 40 g of 15-9-12 NPK plus micronutrients timed-release fertilizer (Osmocote, The Scotts Company, Maryville, Ohio, USA) and then watered as needed. *Euphorbia heterophylla* was grown in 32 planters and monitored for the presence of coccinellids from 1 Jun to 15 Oct 2016. Since *E. heterophylla* grows minimally in the cooler months of the year in south Florida, coccinellid monitoring was conducted on *C. fasciculata* from 28 Sep 2016 to 21 Feb 2017 in 8 planters. Sampling was terminated when the nectary plants began to senesce.

Coccinellid species diversity and abundance were determined from captures of adults made on (13.5 cm W × 20 cm H) yellow sticky card traps (Alpha Scents, West Linn, Oregon, USA). The sticky card traps were attached to bamboo stakes (100–120 cm) with twist ties and positioned so that they were level with the top of the nectary plant canopy. The bamboo stakes were inserted into the potting soil for stability. Four traps were placed at equidistant intervals across the length of the planter arrays. The traps were replaced weekly and returned to the lab for examination.

Thirteen coccinellid species consisting of a total of 663 specimens were collected over the course of the 8-mo sampling period (Table 1). A total of 464 specimens comprising 12 species were collected from *E. heterophylla*. Three species comprised the majority of species collected: *Coelophora inequalis* (F.) (38.6% of total specimens), *Cryptolaemus montrouzieri* (Mulsant), (30.2% of total specimens), and *Harmonia axyridis* (Pallas) (24.1% of total specimens) (all Coleoptera: Coccinellidae). A total of 199 specimens comprising 6 species were collected from *C. fasciculata*. Nearly 80% of the specimens collected from *C. fasciculata* were *C. montrouzieri*, *Harmonia axyridis*, *Azya orbigera* (Mulsant) (Coleoptera: Coccinellidae), and *C. inaequlis* comprised 12% of the specimens collected. Since sampling on this plant occurred only during the cooler periods of the yr, further studies are needed to determine the abundance and species composition of coccinellids that might be associated with *C. fasciculata* during the warmer months.

Eleven of the 13 species collected, comprising 97.5% of all specimens captured, are known to feed on *D. citri* (Table 1). These results indicate that *E. heterophylla* and *C. fasciculata* can be used to provide nourishment for coccinellids that prey upon *D. citri* in residential and urban areas and that insectary plants can perform in this capacity across seasons. Interestingly, the nectaries of *E. heterophylla* were observed to continue to secrete nectar during fruit maturation, perhaps taking on the function of an extra-floral nectary to nourish natural enemies of fruit and seed herbivores. Fruit maturation was sequential within *E. heterophylla*, so the nectaries in a single inflorescence-infructescence remained active for a period lasting many weeks. *Chamaecrista fasciculata* grew vigorously during most of the sampling period. Because polistine wasps were frequently observed foraging on the extra-floral nectaries over the course of the trapping period, it is assumed that the extra-floral nectaries remained active during the duration of the study period.

A number of other insectary plant species will be monitored in anticipated studies to determine their utility with respect to attracting coccinellids and other natural enemies of *D. citri*, such as lacewings and

Table 1. Occurrence of coccinellid species on inflorescences of *Euphorbia heterophylla* and *Chamaecrista fasciculata* grown in a residential area in south Florida.

	Euphorbia heterophylla[1]		*Chamaecrista fasiculata*[2]		
Coccinellid Species	No. Trapped	% of Total	No. Trapped	% of Total	Preys on *D. citri**
Coelophora inaequalis (Fabricius)	179	38.6	7	3.5	2, 5
Cryptolaemus montrouzieri Mulsant	140	30.2	159	79.9	5
Harmonia axyridis (Pallas)	112	24.1	9	4.5	1-4, 6, 7
Azya orbigera Mulsant	10	2.2	8	4.0	6, 8
Brachiacantha dentipes (Fabricius)	9	1.9	0	0	3
Cycloneda sanguinea (L.)	5	1.1	0	0	2-9
Exochomus childerni Mulsant	3	0.6	0	0	2, 3, 4
Olla v-nigrum Mulsant	2	0.4	0	0	1-4, 6, 8, 9
Chilocorus stigma (Say)	1	0.2	0	0	7
Coleomegilla maculata Mulsant	1	0.2	1	0.5	2, 3
Rodolia cardinalis Mulsant	1	0.2	0	0	4
Chilocorus circumdatus (Gyllenhal in Schönherr)	1	0.2	0	0	No record
Psyllobora vigintimaculata (Say)	0	0	15	7.5	No record
TOTAL NO. TRAPPED	464		199		

[1]Collection period 1 Jun to 15 Oct 2016
[2]Collection period 28 Sep 2016 to 21 Feb 2017
*References: 1 Michaud 2001; 2 Michaud 2002; 3 Michaud 2004; 4 Michaud & Olsen 2004; 5 Pluke et al. 2005; 6 Qureshi & Stansly 2009; 7 Chong et al. 2011; 8 Lozano Contreras & Jasso Argumedo 2012; 9 Kondo et al. 2015

hoverflies, in urban and other kinds of unmanaged landscapes. These include crown-of-thorns (*Euphorbia milii*) (des Moulins) [Euphorbiaceae]), flowering buckwheat (*Fagopyrum esculentum* (Moench) [Polygonaceae]), and alyssum (*Lobularia maritima* ([L.] Desvaux) [Brassicaceae]). Natural enemies have been observed foraging on and benefitting from the flowers on these plants (Baggen & Gurr 1998; Chaney 1998; Wäckers & van Rijn 2012; Brennan 2013; Foti et al. 2017; Patt & Rohrig 2017). Since the establishment of *T. radiata* has both been erratic and unpredictable (Hall & Rohrig 2015; Kistner et al. 2016), it would be useful to know whether the inclusion of nectary plants in the target landscape would benefit this parasitoid. Ultimately we will need to determine whether insectary plant inclusion will result in an increase in natural enemy abundance and diversity and a concomitant reduction in *D. citri* populations in nearby host plants.

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Summary

Adding plant-based nutritional resources to a landscape may help to recruit and retain predaceous and parasitic arthropods. As a first step in determining whether the addition of nectary plants can increase the abundance and diversity of biocontrol agents of *Diaphorina citri* and psyllid suppression in urban and unmanaged landscapes in southern Florida, the occurrence of coccinellids was recorded on a native poinsettia, *Euphorbia heterophylla* (L.) and partridge pea, *Chamaecrista fasciculata* (Michx.) Greene, a native legume. Thirteen coccinellid species consisting of a total of 663 specimens were collected over the course of the 8-mo long sampling period. A total of 464 specimens comprising 12 species were collected from *E. heterophylla* from Jun to Oct, with 3 species, *Coelophora inequalis*, *Cryptolaemus montrouzieri*, *Harmonia axyridis*, comprising the majority of species collected. A total of 199 specimens comprising 6 species were collected from *C. fasciculata* from Sep to Feb. Nearly 80% of the specimens collected from *C. fasciculata* were *C. montrouzieri*.

Key Words: Conservation biological control, Coccinellidae, nectar, extra-floral nectary, floral resources

Sumário

La adición de recursos nutricionales a base de plantas a un paisaje puede ayudar a reclutar y retener a los artrópodos predadores y parasitarios. Como primer paso para determinar si la adición de plantas nectarias puede aumentar la abundancia y diversidad de agentes de control biológico de *Diaphorina citri* y la supresión de psílidos en paisajes urbanos y no manejados en el sur de la Florida, se registró la presencia de coccinélidos en una natividad nativa, *Euphorbia heterophylla* L.) y perdiz, *Chamaecrista fasciculata* (Michx.) Greene, una leguminosa nativa. Trece especies de coccinelidos consistentes en un total de 663 especímenes fueron recolectadas durante el período de muestreo de 8 meses. Un total de 464 especímenes que comprenden 12 especies fueron recolectadas de E. heterophylla de jun a oct, con 3 especies, *Coelophora inequalis*, *Cryptolaemus montrouzieri*, *Harmonia axyridis*, que comprende la mayoría de las especies recogidas. Un total de 199 especímenes que comprenden 6 especies se recogieron de *C. fasciculata* de sep a feb. Casi el 80% de los especímenes recolectados de *C. fasciculata* fueron *C. montrouzieri*.

Palabras Claves: Control biológical de la conservación, Coccinellidae, néctar, nectario extra floral, recursos florales

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