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NATURAL ENEMIES MANAGING THE INVASION OF THE FIG WHITEFLY, *SINGHIELLA SIMPLEX* (HEMIPTERA: ALEYRODIDAE), INFESTING A *FICUS BENJAMINA* HEDGE

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The fig whitefly, *Singhiella simplex* (Singh), a recent adventive species native of Burma, China and India (Singh 1931) has become a major pest in Florida (Hodges 2007) feeding on and defoliating *Ficus* shrubs and trees. This pest, first discovered in Miami-Dade County in 2007, is spreading throughout Florida; and recently it was found in Saint Lucie County, FL (personal observation, Avery 2009). Literature on the biology of the fig whitefly is sparse and most references are extension documents (Mannion et al. 2008; Caldwell 2009; Mannion 2010). The life cycle may be similar to that of the other *Singhiella* species that are present in Florida, (*Singhiella citrifolii* (Morgan), with at least three generations per year (Hodges 2007). Leaves of *Ficus* that turn yellow prior to defoliation are one of the most obvious symptoms of a fig whitefly infestation. The fig whitefly is most commonly found infesting weeping fig (*Ficus benjamina*), but may eventually damage other species of *Ficus* as well (Mannion et al. 2008).

In the landscape, several natural enemies have been observed attacking this whitefly, which may play an important role in long term control. Awareness of these natural enemies is very important in making pesticide application decisions so as not to adversely affect them. Commonly observed natural enemies include ladybird beetle predators, *Harmonia axyridis* (Pallas), *Olla-v-nigrum* (Mulsant), *Exochomus children* Mulsant, *Chilocorus nigritis* (F.), *Curinus coeruleus* (Mulsant); parasitoids, *Encarsia protransvena* Viggiani, *Amitus bennetti* Viggiani & Evans; and lacewings, *Chrysopa* spp. (Mannion 2010). Moreover, enzootic entomopathogenic fungi may also play a role in managing this pest (Elliot et al. 2000; Torres-Barragán et al. 2004). However, no entomopathogenic fungus isolated from the fig whitefly in Florida has been reported to date.

During the fall of 2009, a fig whitefly invasion occurred on a *F. benjamina* hedge at a residence in Ft. Pierce, Florida. We used this opportunity to: 1) identify and inventory the natural enemies present, and 2) determine their effectiveness for managing the fig whitefly over the Sep to Nov time period.

The layout for the study was a complete block design with four plots in a linear design. Each plot measured ~5 m of a *F. benjamina* hedge (~10-15 plants), which ran along a concrete block wall (~1.2 m tall) located at a residence in Ft. Pierce, Florida. Each hedge segment (northern 27'22"50.94 N × 80'22"00.22 W and southern 27'22"48.96 N × 80'22"00.25 W) was divided by a concrete driveway; and the northern side was more severely affected by leaf drop than the southern. Randomly chosen leaf samples (10 per plot) were detached from the hedge on a weekly basis for 7 wk. Each sample was placed into individual re-sealable plastic bags and brought back to the lab for examination under a binocular microscope (40X) to count the number of live, dead, or parasitized whitefly nymphs. Parasitism was recognized either by observing the development of the parasitoid inside the translucent nymphal case, or by observing a blackened (melanized) nymphal case with or without an exit hole. A total of 40 disks were punched with a #5 cork borer (50.3 mm^2 diam) near the center of each leaf on one side of the midrib. The abaxial and adaxial sides of 1 disk per leaf were used for observation and counting the number of nymphs of each category mentioned above. The total weekly mean (±SEM) number of nymphs, number parasitized, and percent parasitism on the leaf disks were determined for 49 d. Based on photos of the parasitized nymphs (Mannion et al. 2008; Mannion 2010), the parasitoids appear to be *E. protransvena*; however, *Encarsia* species identification was not confirmed.

Disks were then placed on moist filter paper in a Petri dish, covered, sealed with Parafilm™, and incubated at 25°C for 14 d to allow for the development of mycosis, and to determine percent mortality due to fungal pathogens. After incubation, 5 mycosed nymphs/disk randomly chosen were removed from the leaf disk using a pin and placed on water agar (20 per plate) for isolation and identification of the fungal pathogen. Percent nymphs infected with a fungal species were determined for 0, 14, and 49 d post initial observation. Agar plates were sealed with Parafilm™, and incubated at 25°C under a 16 h photophase for at least 1 week. The fungi were re-isolated from the mycosed nymphs and grown on PDA plates for identification. Voucher fungal *in vitro* culture isolates were sent to Svetlana Gouli at the University of Vermont, Dr. Richard Humber at the USDA, Ithaca, New York and to Dr. Rob Samson's research team at the CBS-KNAW Fungal Diversity Centre in The Netherlands for identification and deposition.

The insect pests observed included the fig whitefly, *S. simplex*, another whitefly, *Tetraleurodes fici* Quaintance & Baker (one parasitized with an exit hole) and the weeping ficus thrips, *Gynaikothrips uzeli* Zimmerman (Table 1). The parasitoids, *Encarsia* species (all appeared to be *E. protransvena*) were observed after parasitization, and within the melanized nymphal case with or without an exit hole. Adult ladybird beetles, *C. coeruleus*, *H. axyridis* and eggs and larvae of the green lacewing, *Chrysopa* species were observed on the leaves. The natural enzootic pathogenic fungi isolated were *Isaria fumosorosea* Wize, *Paecilomyces lilacinus* Thom (Samson), and *Lecanicillium*, *Fusarium*, and *Aspergillus* species.

The total percent nymphal mortality per leaf disk due to pathogenic fungi varied overtime. *I. fumosorosea* and *Lecanicillium*, *Aspergillus* and *Fusarium* species were isolated from 5, 5, 48 and 50% of the dead nymphs at d 0, respectively. After 14 d, 85 and 15% of the nymphs were infected with *Aspergillus* sp. and *P. lilacinus*, respectively. At d 49, *Aspergillus* and *Fusarium* species were isolated 65% and 35% of the time, respectively. The fungal species isolated from the mycosed nymphs were assumed to have caused the mortality of the insect; however, Koch's postulate was not confirmed.

The total weekly mean (±SEM) number of nymphs, number parasitized, and percent parasitism observed on both sides of the leaf disks over 49 d were 57.7 ± 9.91, 5.9 ± 3.72, and 7.3 ± 3.62, respectively. The proportion of nymphal mortality on a weekly basis due to parasitism was ~10% up to 35 d post initial observation; after that, no parasitized nymphs (second- fourth instars) were observed on leaf disks.

Gerling et al. (2001) indicated that all *Encarsia* species parasitize and emerge from the fourth instar of their whitefly host, but attack mainly the second - fourth instar hosts. Therefore, the low number of older (third - fourth instars) nymphs available to be parasitized after 35 d, may have resulted from leaf drop. Throughout this field pilot study based on leaf disk samples, only ~10% mortality was attributed to parasitization by *Encarsia* species, ~90% was due to other natural causes; i.e. enzootic entomopathogenic fungi, predation, etc. This finding warrants confirmation through in-depth research.

This is the first record of Hypocreales fungi; *I. fumosorosea*, *P. lilacinus*, and *Aspergillus*, *Lecanicillium*, and *Fusarium* species being isolated

TABLE 1. INSECT PESTS AND NATURAL ENEMIES OBSERVED ON A RESIDENTIAL *FICUS BENJAMINA* HEDGE IN FT. PIERCE, FLORIDA BETWEEN SEP-NOV 2009.

Category	Order	Family	Scientific name	Common Name	Observations
Insect pests					
	Hemiptera	Aleyrodidae	*Singhiella simplex*	fig whitefly	feeding on leaves
	Hemiptera	Aleyrodidae	*Tetraleurodes fici*	whitefly	feeding on leaves
	Thysanoptera	Phlaeothripidae	*Gynaikothrips uzeli*	weeping ficus thrip	in leaf fold galls
Natural Enemies					
	Hymenoptera	Aphelinidae	*Encarsia* sp.*	parasitoid	parasitized fig whitefly nymphs
	Coleoptera	Coccinellidae	*Harmonia axyridis*	Multicolored Asian lady beetle	adults roaming on leaves
	Coleoptera	Coccinellidae	*Curinus coeruleus*	Metallic blue lady beetle	adults roaming on leaves
	Neuroptera	Chrysopidae	*Chrysopid* sp.	green lacewing	eggs and larvae on a leaves
	Hypocreales	Cordycipitaceae	*Isaria fumosorosea*	entomopathogenic fungi	leaf surface and on fig whitefly
	Hypocreales	Clavicipitaceae	*Paecilomyces lilacinus*	entomopathogenic fungi	leaf surface and on fig whitefly
	Hypocreales	Cordycipitaceae	*Lecanicillium* sp.	entomopathogenic fungi	leaf surface and on fig whitefly
	Hypocreales	Nectriaceae	*Fusarium* sp.	filamentous fungi	leaf surface and on fig whitefly
	Eurotiales	Trichocomaceae	*Aspergillus* sp.	green mold	leaf surface and on fig whitefly

*All appeared to be *E. protransvena*.

from dead fig whitefly nymphs on *F. benjamina*. *Aspergillus* and *Fusarium* species, not commonly known as entomopathogenic, are now being tested as potential biocontrol agents for controlling whitefly species (Panyasiri et al. 2007). The other fungal species, *I. fumosorosea*, *P. lilacinus* and *Lecanicillium* species are commonly used as biopesticides (de Faria & Wraight 2007) for controlling whitefly (Avery et al. 2008; Cabanillas & Jones 2009; Shinde et al. 2010), except *P. lilacinus* which is nematophagous. However, recently *P. lilacinus* has demonstrated potential for controlling whitefly species (Gökçe & Er 2005; Fiedler & Sosnowska 2007).

Based on this study, it would be recommended that the endemic population of parasitoids and enzootic entomopathogenic fungi be considered as part of a multi-trophic ecosystem, which may be adversely impacted by the application of any pesticide. Therefore, it is important to assess the long term ecological impact that a pesticide application against the fig whitefly may have on the natural enemies in the landscape ecosystem.

Summary

Based on leaf disk samples taken in this field pilot study, only ~10% of the fig whitefly mortality was attributed to parasitization by *Encarsia* species, ~90% was due to other natural causes; i.e. enzootic entomopathogenic fungi, predation, etc. This is the first record of the Hypocreales fungi, *I. fumosorosea*, *P. lilacinus*, and *Aspergillus*, *Lecanicillium*, and *Fusarium* species being isolated from dead *S. simplex* nymphs on *F. benjamina*. It is important to assess the long term impacts pesticide applications made for managing the fig whitefly may have on the ecosystem, and especially the ecological impact on the natural enemies which include enzootic entomopathogenic fungi.

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