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Host plants and natural enemies of rugose spiraling whitefly (Hemiptera: Aleyrodidae) in Florida

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Rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), was first described from Belize (Martin 2004). It was reported for the first time from Miami-Dade County, Florida, in Mar 2009, and in Florida is associated with numerous plant species (Stocks & Hodges 2012). Kumar et al. (2013) reported that this pest caused a great deal of concern in southern coastal counties in previous years. Rugose spiraling whitefly is a phloem feeder and excretes large quantities of honeydew, which covers anything under the infested plant. Thick layers of sooty mold rapidly develop, which is unsightly, disrupts normal leaf physiology, and exacerbates the nuisance condition. The type and level of damage vary by plant species and plant condition, and although this whitefly does not kill large or healthy trees, smaller or unhealthy plants might succumb to very high infestation levels (Mayer et al. 2010). Clean-up and chemical control costs can be substantial for affected homeowners and businesses (Kumar et al. 2013). The best long-term solution for rugose spiraling whitefly is biological control, which has already yielded success in affected areas. The objective of this study was to report the current distribution and host range of this whitefly and the composition of the natural enemy complex that attacks it.

Based on Florida Department of Agriculture and Consumer Services (FDACS), Division of Plant Industry (DPI) records from 2009 to 2015, rugose spiraling whitefly has been identified on at least 118 plant species from >500 whitefly samples. These hosts included edible plants, ornamentals, palms, and weeds of both native and non-native species (Stocks 2012). Susceptible hosts were found in 43 families, but 27 families were each represented by a single host species (Table 1). Many of the reported plant species are likely to be incidental hosts that cannot maintain long-term rugose spiraling whitefly populations and therefore require minimal or no management practices. DPI host record frequency data from 2009 to 2012 showed that 22% of rugose spiraling whitefly–affected hosts were palm species (Arecales: Arecaceae), 16% were gumbo limbo (*Bursera simaruba* (L.) Sarg.; Sapindales: Burseraceae), 10% were *Calophyllum* spp. (Malpighiales: Clusiaceae), 9% were avocado (*Persea americana* Mill.; Laurales: Lauraceae), 4% were black olive (*Bucida buceras* L.; Myrtales: Combretaceae), and 3% were mango varieties (*Mangifera indica* L.; Sapindales: Anacardiaceae). Within the family Arecaceae (palms), 44% of samples were coconut (*Cocos nucifera* L.) and the remainder comprised diverse species. Based on host frequencies, these species are primary or preferred hosts that may require additional management. White bird of paradise (*Strelitzia nicolai* Regel & Körn.; Zingiberales: Strelitziaceae) and *Musa* species (Zingiberales: Musaceae) were not included in the compiled data, but these popular south Florida landscape plants and other Musaceae are also considered preferred hosts.

Survey activities began in Dec 2012 and continued to May 2014, with over 300 locations visited. Examination of primary host plants for natural enemies was emphasized. Due to the diverse and variable nature of these locations, sampling times and locations were relatively unstructured. On large residential properties, for example, 4 to 8 plants of a preferred species were examined using a 5 to 10× folding pocket magnifier. At roadside areas with lower numbers of infested hosts, 1 to 3 plants were examined. If rugose spiraling whitefly was found with evidence of associated natural enemies (parasitoid exit holes and adult parasitoids, or adult and/or immature predators), 1 to 3 infested leaves or 3 to 6 terminal ends (20 cm long) per plant were clipped, stored in labeled plastic bags, and maintained in coolers until returned to the laboratory. In the laboratory, adult predators were collected from field material and placed in labeled vials with 70% alcohol. A predator was determined by having been observed feeding on the whiteflies. Adult parasitoids were reared from parasitized nymphs, along with immature to adult predators kept for some time on leaf material stored in vented containers. Natural enemies were collected, placed in vials of alcohol, and sent to DPI in Gainesville, Florida, for identification.

Rugose spiraling whitefly populations were found in 22 counties based on DPI detection records (Fig. 1), indicative of its rapid spread from 2009 to 2015. Following the last major outbreaks in 2013 (Fig. 1), there were no new reports until Aug 2015 in St. Johns County. Flagler, Hernando, Polk, Seminole, and Volusia Counties had single host records, and infestations in these areas caused no noticeable levels of aesthetic damage and did not elicit the public concern that was observed in southern Florida. Consequently, counties such as Miami-Dade (40%), Broward (14%), and Palm Beach (18%) accounted for 72% of plant samples submitted for identification during the first 2 yr of the rugose spiraling whitefly outbreak.

Although a diverse assemblage of rugose spiraling whitefly–associated natural enemies was collected during the survey, the most commonly found parasitoid species were *Encarsia guadeloupae* Viggiani and *Encarsia noyesi* (Hayat) (Hymenoptera: Aphelinidae). Both species were recorded from 15 counties (Fig. 1). A change in the parasitoid species composition was noted in St. Lucie and Martin Counties. At 12 sampling points within an area overlapping both counties in Jul 2013, of 464 dead parasitoids collected from whitefly samples, *E. guadeloupae* was the dominant species, comprising 76%, and the remaining

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Table 1. Host plants associated with rugose spiraling whitefly from 43 botanical families in Florida.

	Scientific name	Family
1.	*Ruellia simplex*	Acanthaceae
2.	*Sagittaria latifolia*	Alismataceae
3.	*Mangifera indica*	Anacardiaceae
4.	*Schinus terebinthifolia*	Anacardiaceae
5.	*Spondias mombin*	Anacardiaceae
6.	*Spondias purpurea*	Anacardiaceae
7.	*Spondias* sp.	Anacardiaceae
8.	*Annona* sp.	Annonaceae
9.	*Annona squamosa*	Annonaceae
10.	*Cananga odorata*	Annonaceae
11.	*Catharanthus roseus*	Apocynaceae
12.	*Philodendron selloum*	Araceae
13.	*Araucaria heterophylla*	Araucariaceae
14.	*Adonidia merrillii*	Arecaceae
15.	*Allagoptera arenaria*	Arecaceae
16.	*Archontophoenix alexandrae*	Arecaceae
17.	*Archontophoenix cunninghamiana*	Arecaceae
18.	*Chamaedorea* sp.	Arecaceae
19.	*Coccothrinax* sp.	Arecaceae
20.	*Cocos nucifera*	Arecaceae
21.	*Dictyosperma album*	Arecaceae
22.	*Dypsis decaryi*	Arecaceae
23.	*Dypsis lutescens*	Arecaceae
24.	*Hyophorbe lagenicaulis*	Arecaceae
25.	*Hyophorbe verschaffeltii*	Arecaceae
26.	*Phoenix roebelenii*	Arecaceae
27.	*Pinanga coronata*	Arecaceae
28.	*Ptychosperma elegans*	Arecaceae
29.	*Roystonea regia*	Arecaceae
30.	*Sabal palmetto*	Arecaceae
31.	*Syagrus romanzoffiana*	Arecaceae
32.	*Veitchia arecina*	Arecaceae
33.	*Veitchia* sp.	Arecaceae
34.	*Washingtonia robusta*	Arecaceae
35.	*Wodyetia bifurcata*	Arecaceae
36.	*Basella alba*	Basellaceae
37.	*Ceiba* sp.	Bombacaceae
38.	*Brassica rapa*	Brassicaceae
39.	*Bursera simaruba*	Burseraceae
40.	*Canna flaccida*	Cannaceae
41.	*Chrysobalanus icaco*	Chrysobalanaceae
42.	*Calophyllum antillanum*	Clusiaceae
43.	*Calophyllum brasiliense*	Clusiaceae
44.	*Callophyllum inophyllum*	Clusiaceae
45.	*Calophyllum* sp.	Clusiaceae
46.	*Bucida buceras*	Combretaceae
47.	*Conocarpus erectus*	Combretaceae
48.	*Terminalia catappa*	Combretaceae
49.	*Terminalia* sp.	Combretaceae
50.	*Diospyros kaki*	Ebenaceae
51.	*Acalypha wilkesiana*	Euphorbiaceae
52.	*Jatropha curcas*	Euphorbiaceae
53.	*Acacia auriculiformis*	Fabaceae
54.	*Inga* sp.	Fabaceae
55.	*Leucaena leucocephala*	Fabaceae
56.	*Lysiloma latisiliquum*	Fabaceae
57.	*Lysiloma sabicu*	Fabaceae
58.	*Pithecellobium keyense*	Fabaceae
59.	*Pongamia pinnata*	Fabaceae
60.	*Quercus laurifolia*	Fagaceae
61.	*Quercus virginiana*	Fagaceae
62.	*Carya floridana*	Juglandaceae
63.	*Laurus nobilis*	Lauraceae
64.	*Ocotea coriacea*	Lauraceae
65.	*Persea americana*	Lauraceae
66.	*Cordyline fruticosa*	Liliaceae
67.	*Smilax auriculata*	Liliaceae
68.	*Lagerstroemia speciosa*	Lythraceae
69.	*Hibiscus rosa-sinensis*	Malvaceae
70.	*Sterculia foetida*	Malvaceae
71.	*Thespesia populnea*	Malvaceae
72.	*Artocarpus heterophyllus*	Moraceae
73.	*Ficus aurea*	Moraceae
74.	*Ficus benjamina*	Moraceae
75.	*Ficus carica*	Moraceae
76.	*Ficus microcarpa*	Moraceae
77.	*Ficus* sp.	Moraceae
78.	*Musa* sp.	Musaceae
79.	*Myrica cerifera*	Myricaceae
80.	*Rapanea punctata*	Myrsinaceae
81.	*Eugenia axillaris*	Myrtaceae
82.	*Eugenia foetida*	Myrtaceae
83.	*Eugenia* sp.	Myrtaceae
84.	*Eugenia uniflora*	Myrtaceae
85.	*Myrcianthes fragrans*	Myrtaceae
86.	*Psidium cattleianum*	Myrtaceae
87.	*Psidium guajava*	Myrtaceae
88.	*Syzygium cumini*	Myrtaceae
89.	*Syzygium jambos*	Myrtaceae
90.	*Bougainvillea* sp.	Nyctaginaceae
91.	*Zeuxine strateumatica*	Orchidaceae
92.	*Piper sarmentosum*	Piperaceae
93.	*Saccharum officinarum*	Poaceae
94.	*Coccoloba diversifolia*	Polygonaceae
95.	*Coccoloba uvifera*	Polygonaceae
96.	*Rosa* sp.	Rosaceae
97.	*Citrus hystrix*	Rutaceae
98.	*Citrus* sp.	Rutaceae
99.	*Zanthoxylum coriaceum*	Rutaceae
100.	*Dimocarpus longan*	Sapindaceae
101.	*Melicoccus bijugatus*	Sapindaceae
102.	*Chrysophyllum oliviforme*	Sapotaceae
103.	*Manilkara roxburghiana*	Sapotaceae
104.	*Manilkara zapota*	Sapotaceae
105.	*Sideroxylon foetidissimum*	Sapotaceae
106.	*Sideroxylon salicifolium*	Sapotaceae
107.	*Simarouba glauca*	Simaroubaceae
108.	*Ravenala madagascariensis*	Strelitziaceae
109.	*Strelitzia nicolai*	Strelitziaceae
110.	*Strelitzia reginae*	Strelitziaceae
111.	*Strelitzia* sp.	Strelitziaceae
112.	*Cissus verticillata*	Vitaceae
113.	*Leea guineensis*	Vitaceae
114.	*Parthenocissus quinquefolia*	Vitaceae
115.	*Vitis rotundifolia*	Vitaceae
116.	*Vitis* sp.	Vitaceae
117.	*Alpinia* sp.	Zingiberaceae
118.	*Alpinia zerumbet*	Zingiberaceae

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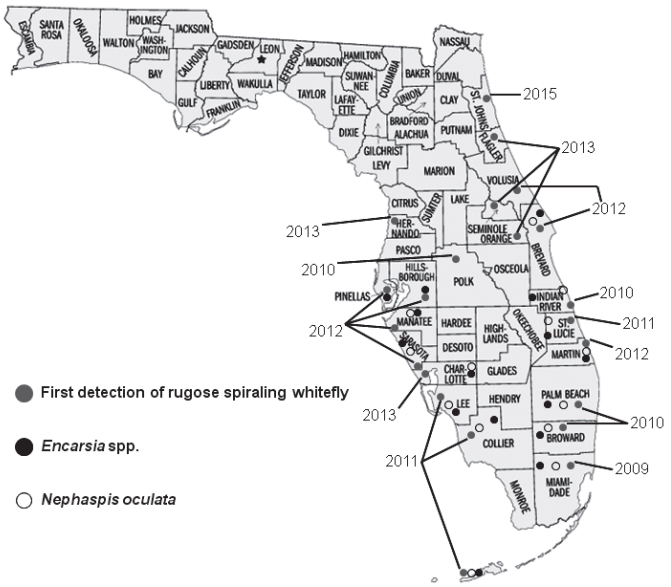

Fig. 1. County distribution of rugose spiraling whitefly and its key natural enemies (*Encarsia* spp. and *Nephaspis oculata*) in Florida.

24% were *E. noyesi*. Twelve months later, the total number of dead parasitoids collected was 212, with *E. noyesi* comprising 89%, whereas the remaining 11% were *E. guadeloupae*. Although the displacement of *E. guadeloupae* by *E. noyesi* was not extensively studied, this occurrence supports the findings by Boughton et al. (2015) that *E. noyesi* was a very promising candidate for biological control of rugose spiraling whitefly populations. Two members of another parasitoid genus, *Aleuroctonus vittatus* (Dozier) and *Aleuroctonus* sp. near *marki* Hansson & LaSalle (Hymenoptera: Eulophidae), were found by University of Florida scientists from a few rugose spiraling whitefly locations in Miami-Dade County. These eulophids have been reported from *Aleurodicus* species elsewhere (Hansson & La Salle 2003; Evans 2008).

The most frequently encountered predator was *Nephaspis oculata* (Blatchley) (Coleoptera: Coccinellidae). It is recorded from 13 counties (Fig. 1), but is probably more widely distributed than the survey suggests. Due to their generalist nature, other beneficial coccinellids, such as *Azya orbigera orbigera* Mulsant, *Chilocorus cacti* (L.), *Cryptolaemus montrouzieri* Mulsant, *Delphastus pallidus* (LeConte), *Harmonia axyridis* (Pallas), *Hyperaspis bigeminata* (Randall), and *Psyllobora parvinotata* Casey, as well as *Cybocephalus* sp. (Coleoptera: Cybocephalidae), *Chrysoperla* spp., and *Ceraeochrysa* spp. (Neuroptera: Chrysopidae) play a lesser, albeit important, role in rugose spiraling whitefly suppression.

The 3 key species identified during the surveys have a well-documented history as control agents of *Aleurodicus* species (Evans 2008). *Encarsia noyesi* was introduced from Mexico into California and subsequently into Florida to control *Aleurodicus dugesii* Cockerell (Barton 1997; Nguyen & Hamon 2002). *Encarsia guadeloupae* has a more cosmopolitan distribution (Hernández-Suárez et al. 2003). The coccinellid predator *N. oculata* is found along the U.S. Gulf Coast from Florida to Texas (Taravati et al. 2013) and specializes on whiteflies (Gordon 1985; Turnbow & Thomas 2008). It was also imported into Hawaii in 1979 for the control of *Aleurodicus dispersus* Russell (Kumashiro et al. 1983).

Presently, the leading edge of rugose spiraling whitefly infestation appears to be St. Johns County on the Atlantic coast and Hernando County on the Gulf Coast. Undoubtedly, climate and host availability play significant roles in determining the northern limits of rugose spiraling whitefly, but accidental dispersal will be a contributing factor in new outbreaks. Problems with this whitefly continue to decline as a result of passive dispersal and inoculative releases of natural enemies identified in the early stages of whitefly establishment. Resident beneficial species found during the survey have been established in Florida for some time, and it is not surprising that they exploited rugose spiraling whitefly as a host and progressively achieved substantial control of this pest. Continued monitoring of rugose spiraling whitefly will continue to quantify population decline and evaluate the long-term persistence of natural enemies.

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Summary

The rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), is a polyphagous pest that has caused significant damage in the Florida landscape. Various plants have been identified as primary hosts in affected areas. Rugose spiraling whitefly was confirmed in 22 counties, and surveys for biological control agents have found several important natural enemies and other species that collectively provide appreciable control of this whitefly pest.

Key Words: *Aleurodicus rugioperculatus*; survey; biological control; predator; parasitoid; susceptible host

Sumario

La mosca blanca espiral rugosa, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), es una plaga polífaga que ha causado un daño significativo en los campos de la Florida. Varias plantas han sido identificadas como hospederas primarias en las zonas afectadas. Se confirmó la mosca blanca espiral rugosa en 22 condados, y los sondeos de agentes de control biológico han encontrado varios enemigos naturales importantes y otras especies que proveen colectivamente un control considerable de esta plaga de mosca blanca.

Palabras Clave: *Aleurodicus rugioperculatus*; sondeo; control biológico; depredador; parasitoide; hospedero susceptible

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