

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 (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 guadeloupe* 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. guadeloupe* 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. | <i>Ruellia simplex</i> | Acanthaceae |
| 2. | <i>Sagittaria latifolia</i> | Alismataceae |
| 3. | <i>Mangifera indica</i> | Anacardiaceae |
| 4. | <i>Schinus terebinthifolia</i> | Anacardiaceae |
| 5. | <i>Spondias mombin</i> | Anacardiaceae |
| 6. | <i>Spondias purpurea</i> | Anacardiaceae |
| 7. | <i>Spondias</i> sp. | Anacardiaceae |
| 8. | <i>Annona</i> sp. | Annonaceae |
| 9. | <i>Annona squamosa</i> | Annonaceae |
| 10. | <i>Cananga odorata</i> | Annonaceae |
| 11. | <i>Catharanthus roseus</i> | Apocynaceae |
| 12. | <i>Philodendron selloum</i> | Araceae |
| 13. | <i>Araucaria heterophylla</i> | Araucariaceae |
| 14. | <i>Adonidia merrillii</i> | Arecaceae |
| 15. | <i>Allagoptera arenaria</i> | Arecaceae |
| 16. | <i>Archontophoenix alexandrea</i> | Arecaceae |
| 17. | <i>Archontophoenix cunninghamiana</i> | Arecaceae |
| 18. | <i>Chamaedorea</i> sp. | Arecaceae |
| 19. | <i>Coccothrinax</i> sp. | Arecaceae |
| 20. | <i>Cocos nucifera</i> | Arecaceae |
| 21. | <i>Dictyosperma album</i> | Arecaceae |
| 22. | <i>Dypsis decaryi</i> | Arecaceae |
| 23. | <i>Dypsis lutescens</i> | Arecaceae |
| 24. | <i>Hyophorbe lagenicaulis</i> | Arecaceae |
| 25. | <i>Hyophorbe verschaffeltii</i> | Arecaceae |
| 26. | <i>Phoenix roebelenii</i> | Arecaceae |
| 27. | <i>Pinanga coronata</i> | Arecaceae |
| 28. | <i>Ptychosperma elegans</i> | Arecaceae |
| 29. | <i>Roystonea regia</i> | Arecaceae |
| 30. | <i>Sabal palmetto</i> | Arecaceae |
| 31. | <i>Syagrus romanzoffiana</i> | Arecaceae |
| 32. | <i>Veitchia arecina</i> | Arecaceae |
| 33. | <i>Veitchia</i> sp. | Arecaceae |
| 34. | <i>Washingtonia robusta</i> | Arecaceae |
| 35. | <i>Wodyetia bifurcata</i> | Arecaceae |
| 36. | <i>Basella alba</i> | Basellaceae |
| 37. | <i>Ceiba</i> sp. | Bombacaceae |
| 38. | <i>Brassica rapa</i> | Brassicaceae |
| 39. | <i>Bursera simaruba</i> | Burseraceae |
| 40. | <i>Canna flaccida</i> | Cannaceae |
| 41. | <i>Chrysobalanus icaco</i> | Chrysobalanaceae |
| 42. | <i>Calophyllum antillanum</i> | Clusiaceae |
| 43. | <i>Calophyllum brasiliense</i> | Clusiaceae |
| 44. | <i>Calophyllum inophyllum</i> | Clusiaceae |
| 45. | <i>Calophyllum</i> sp. | Clusiaceae |
| 46. | <i>Bucida buceras</i> | Combretaceae |
| 47. | <i>Conocarpus erectus</i> | Combretaceae |
| 48. | <i>Terminalia catappa</i> | Combretaceae |
| 49. | <i>Terminalia</i> sp. | Combretaceae |
| 50. | <i>Diospyros kaki</i> | Ebenaceae |
| 51. | <i>Acalypha wilkesiana</i> | Euphorbiaceae |
| 52. | <i>Jatropha curcas</i> | Euphorbiaceae |
| 53. | <i>Acacia auriculiformis</i> | Fabaceae |
| 54. | <i>Inga</i> sp. | Fabaceae |
| 55. | <i>Leucaena leucocephala</i> | Fabaceae |
| 56. | <i>Lysiloma latisiliquum</i> | Fabaceae |
| 57. | <i>Lysiloma sabicu</i> | Fabaceae |
| 58. | <i>Pithecellobium keyense</i> | Fabaceae |
| 59. | <i>Pongamia pinnata</i> | Fabaceae |
| 60. | <i>Quercus laurifolia</i> | Fagaceae |
| 61. | <i>Quercus virginiana</i> | Fagaceae |

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

| | Scientific name | Family |
|------|------------------------------------|----------------|
| 62. | <i>Carya floridana</i> | Juglandaceae |
| 63. | <i>Laurus nobilis</i> | Lauraceae |
| 64. | <i>Ocotea coriacea</i> | Lauraceae |
| 65. | <i>Persea americana</i> | Lauraceae |
| 66. | <i>Cordyline fruticosa</i> | Liliaceae |
| 67. | <i>Smilax auriculata</i> | Liliaceae |
| 68. | <i>Lagerstroemia speciosa</i> | Lythraceae |
| 69. | <i>Hibiscus rosa-sinensis</i> | Malvaceae |
| 70. | <i>Sterculia foetida</i> | Malvaceae |
| 71. | <i>Thespesia populnea</i> | Malvaceae |
| 72. | <i>Artocarpus heterophyllus</i> | Moraceae |
| 73. | <i>Ficus aurea</i> | Moraceae |
| 74. | <i>Ficus benjamina</i> | Moraceae |
| 75. | <i>Ficus carica</i> | Moraceae |
| 76. | <i>Ficus microcarpa</i> | Moraceae |
| 77. | <i>Ficus</i> sp. | Moraceae |
| 78. | <i>Musa</i> sp. | Musaceae |
| 79. | <i>Myrica cerifera</i> | Myricaceae |
| 80. | <i>Rapanea punctata</i> | Myrsinaceae |
| 81. | <i>Eugenia axillaris</i> | Myrtaceae |
| 82. | <i>Eugenia foetida</i> | Myrtaceae |
| 83. | <i>Eugenia</i> sp. | Myrtaceae |
| 84. | <i>Eugenia uniflora</i> | Myrtaceae |
| 85. | <i>Myrcianthes fragrans</i> | Myrtaceae |
| 86. | <i>Psidium cattleianum</i> | Myrtaceae |
| 87. | <i>Psidium guajava</i> | Myrtaceae |
| 88. | <i>Syzygium cumini</i> | Myrtaceae |
| 89. | <i>Syzygium jambos</i> | Myrtaceae |
| 90. | <i>Bougainvillea</i> sp. | Nyctaginaceae |
| 91. | <i>Zeuxine strateumatica</i> | Orchidaceae |
| 92. | <i>Piper sarmentosum</i> | Piperaceae |
| 93. | <i>Saccharum officinarum</i> | Poaceae |
| 94. | <i>Coccoloba diversifolia</i> | Polygonaceae |
| 95. | <i>Coccoloba uvifera</i> | Polygonaceae |
| 96. | <i>Rosa</i> sp. | Rosaceae |
| 97. | <i>Citrus hystrix</i> | Rutaceae |
| 98. | <i>Citrus</i> sp. | Rutaceae |
| 99. | <i>Zanthoxylum coriaceum</i> | Rutaceae |
| 100. | <i>Dimocarpus longan</i> | Sapindaceae |
| 101. | <i>Melicoccus bijugatus</i> | Sapindaceae |
| 102. | <i>Chrysophyllum oliviforme</i> | Sapotaceae |
| 103. | <i>Manilkara roxburghiana</i> | Sapotaceae |
| 104. | <i>Manilkara zapota</i> | Sapotaceae |
| 105. | <i>Sideroxylon foetidissimum</i> | Sapotaceae |
| 106. | <i>Sideroxylon salicifolium</i> | Sapotaceae |
| 107. | <i>Simarouba glauca</i> | Simaroubaceae |
| 108. | <i>Ravenala madagascariensis</i> | Strelitziaceae |
| 109. | <i>Strelitzia nicolai</i> | Strelitziaceae |
| 110. | <i>Strelitzia reginae</i> | Strelitziaceae |
| 111. | <i>Strelitzia</i> sp. | Strelitziaceae |
| 112. | <i>Cissus verticillata</i> | Vitaceae |
| 113. | <i>Leea guineensis</i> | Vitaceae |
| 114. | <i>Parthenocissus quinquefolia</i> | Vitaceae |
| 115. | <i>Vitis rotundifolia</i> | Vitaceae |
| 116. | <i>Vitis</i> sp. | Vitaceae |
| 117. | <i>Alpinia</i> sp. | Zingiberaceae |
| 118. | <i>Alpinia zerumbet</i> | Zingiberaceae |

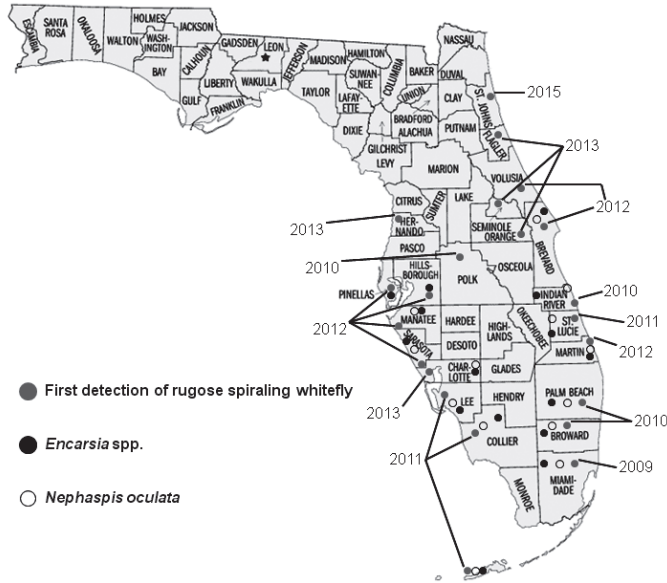


Fig. 1. County distribution of rugose spiraling whitefly and its key natural enemies (*Encarsia* spp. and *Nephaspis oculata*) in Florida.

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. guadeloupa*. Although the displacement of *E. guadeloupa* 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 orbiger* *orbiger* Mulsant, *Chilocorus cacti* (L.), *Cryptolaemus montrouzieri* Mulsant, *Delphastus pallidus* (LeConte), *Harmonia axyridis* (Pallas), *Hyperaspis bigeminata* (Randall), and *Psyllobora parvino-tata* 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 guadeloupa* 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

References Cited

Barton K. 1997. Scientists pit natural enemies against giant whitefly, <http://ucce.ucdavis.edu/files/repositoryfiles/ca5106p5-67707.pdf> (last accessed 15 Mar 2015).

Boughton AJ, Mendez MA, Francis AW, Smith TR, Osborne LS, Mannion CM. 2015. Host stage suitability and impact of *Encarsia noyesi* (Hymenoptera: Aphelinidae) on the invasive rugose spiraling whitefly, *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae), in Florida. *Biological Control* 88: 61–67.

Evans GA. 2008. The whiteflies (Hemiptera: Aleyrodidae) of the world and their host plants and natural enemies, http://keys.lucidcentral.org/keys/v3/whitefly/PDF_PwP%20ETC/world-whitefly-catalog-Evans.pdf (last accessed 15 Mar 2015).

Gordon RD. 1985. The Coccinellidae (Coleoptera) of America, north of Mexico. *Journal of the New York Entomological Society* 93: 1–912.

Hansson C, La Salle J. 2003. Revision of the Neotropical species of the tribe Euderomphalini (Hymenoptera: Eulophidae). *Journal of Natural History* 37: 697–778.

Hernández-Suárez E, Carnero A, Aguiar A, Prinsloo G, LaSalle J, Polaszek A. 2003. Parasitoids of whiteflies (Hymenoptera: Aphelinidae, Eulophidae, Platygasteridae; Hemiptera: Aleyrodidae) from the Macaronesian archipelagos of the Canary Islands, Madeira and the Azores. *Systematics and Biodiversity* 1: 55–108.

- Kumar V, McKenzie CL, Mannion C, Stocks I, Smith T, Osborne LS. 2013. Rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae). EENY578. University of Florida, IFAS Extension, http://entnemdept.ufl.edu/creatures/orn/Aleurodicus_rugioperculatus.htm (last accessed 15 Mar 2015).
- Kumashiro BR, Lai PY, Funasaki GY, Teramoto KK. 1983. Efficacy of *Nephaspis amnicola* and *Encarsia haitiensis* in controlling *Aleurodicus dispersus* in Hawaii. Proceedings of the Hawaiian Entomological Society 24: 261–269.
- Martin JH. 2004. The whiteflies of Belize (Hemiptera: Aleyrodidae) Part 1—introduction and account of the subfamily Aleurodicinae Quaintance & Baker. Zootaxa 681: 1–119.
- Mayer H, McLaughlin J, Hunsberger A, Vasquez L, Olczyk T, Mannion C. 2010. Common questions about the gumbo limbo spiraling whitefly (*Aleurodicus rugioperculatus*). The Miami-Dade Cooperative Extension, <http://monroe.ifas.ufl.edu/pdf/Hort/GumboLimboSpiralingWhiteflyQuestions.pdf> (last accessed 15 Mar 2015).
- Nguyen R, Hamon AB. 2002. Biological control of giant whitefly, *Aleurodicus dugesii* Cockerell, in Florida. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, http://www.nhm.ac.uk/resources/research-curation/projects/chalcidoids/pdf_X/NguyenHa2002.pdf (last accessed 15 Mar 2015).
- Stocks I. 2012. Rugose spiraling whitefly host plants. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, http://monroe.ifas.ufl.edu/pdf/Hort/RSW_Host_Plants_May_2012.pdf (last accessed 15 Mar 2015).
- Stocks IC, Hodges G. 2012. The rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin, a new exotic whitefly in south Florida (Hemiptera: Aleyrodidae). Florida Department of Agriculture and Consumer Services, Division of Plant Industry, <http://freshfromflorida.s3.amazonaws.com/aleurodicus-rugioperculatus-pest-alert.pdf> (last accessed 15 Mar 2015).
- Taravati S, Mannion C, Glenn H, Osborne L. 2013. Natural enemies of rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Insecta: Hemiptera: Aleyrodidae) in the south Florida landscape. ENY-870. University of Florida, IFAS Extension, <http://edis.ifas.ufl.edu/pdf/IN/IN100400.pdf> (last accessed 15 Mar 2015).
- Turnbow Jr RH, Thomas MC. 2008. An annotated checklist of the Coleoptera (Insecta) of the Bahamas. Insecta Mundi 34: 1–64.