Honeydew-Producing Hemipterans in Florida Associated with Nylanderia fulva (Hymenoptera: Formicidae), an Invasive Crazy Ant

Authors: Sharma, Shweta, Oi, David H., and Buss, Eileen A.

Source: Florida Entomologist, 96(2) : 538-547

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.096.0219
HONEYDEW-PRODUCING HEMIPTERANS IN FLORIDA ASSOCIATED WITH NYLANDERIA FULVA (HYMENOPTERA: FORMICIDAE), AN INVASIVE CRAZY ANT

SHWETA SHARMA1, DAVID H. OI2 AND EILEEN A. BUSS1,*
1Department of Entomology and Nematology, University of Florida, Gainesville, FL 32611-0620, USA
2USDA, ARS, Center for Medical, Agricultural, and Veterinary Entomology (CMAVE), 1600 S.W. 23rd Drive, Gainesville, FL 32608, USA
*Corresponding author: E-mail: eabuss@ufl.edu

ABSTRACT

Nylanderia fulva (Mayr) (Formicidae) is an invasive pest ant that has been reported in Florida, Texas, Louisiana and Mississippi. Workers tend various honeydew producing hemipterans in Florida landscapes and natural areas. We sought to understand the seasonal foraging activities of N. fulva and its relationship with honeydew producing hemipterans. Twenty-two hemipteran species were collected from 15 different plant hosts sampled in Florida from Jul 2010 to Jul 2012. The relative density of hemipterans on 4 plant species [live oak (Quercus virginiana Mill.; Fagales: Fagaceae), holly (Ilex cornuta Lindl.; Aquifoliales: Aquifoliaceae), magnolia (Magnolia grandiflora L.; Magnoliales: Magnoliaceae), and sugarberry (Celtis laevigata Willd.; Urticales: Ulmaceae)] was compared to the relative density of N. fulva at the base or stem of the selected plants. The number of N. fulva and hemipterans on each plant species was positively correlated from spring through fall. Both N. fulva and hemipteran populations increased from May to Sep and decreased from Oct to Apr. In addition, Cinara juniperivora (Wilson) (Hemiptera: Aphididae) on southern red cedar and Toumeyella liriodendri (Gmelin) (Hemiptera: Coccidae) on magnolia were covered with carton shelters presumably constructed by N. fulva, suggesting that this ant potentially protects certain hemipterans species.

Key Words: Paratrechina pubens, tawny crazy ant, Caribbean crazy ant, Rasberry crazy ant, Hemiptera, invasive ants, carton shelter

RESUMEN

Se ha reportado la presencia de Nylanderia fulva (Mayr), una hormiga plaga invasora en la Florida, Texas, Louisiana y Mississippi. Los trabajadores atienden varios hemípteros que producen rocio de miel en los campos y áreas naturales de la Florida. Tratamos a comprender las actividades estacionales de alimentación de N. fulva y su relación con los hemípteros que producen rocio de miel. Veinte y dos especies de hemípteros fueron recolectadas sobre 15 plantas hospederas diferentes muestreadas en Florida desde el julio de 2010 hasta el julio de 2012. Se comparó la densidad relativa de los hemípteros sobre 4 especies de plantas [roble vivo (Quercus virginiana Mill.; Fagales: Fagaceae), el acebo (Ilex cornuta Lindl.; Aquifoliales: Aquifoliaceae), magnolia (Magnolia grandiflora L.; Magnoliales: Magnoliaceae), y el almez de Mississippi (Celtis laevigata Willd.; Urticales: Ulmaceae)] con la densidad relativa de N. fulva en la base o tallo de las plantas seleccionadas. Se correlacionó positivamente el número de N. fulva y hemípteros en cada especie de planta desde la primavera hasta el otoño. La población de N. fulva y los hemípteros incrementó desde mayo hasta septiembre y decreció de octubre a abril. Además, los Cinara juniperivora (Wilson) (Hemiptera: Aphididae) sobre el cedro rojo del sur y los Toumeyella liriodendri (Gmelin) (Hemiptera: Coccidae) sobre la magnolia fueron cubiertos con refugios de cartón supuestamente construidos por N. fulva, lo que sugiere que esta hormiga potencialmente protege ciertas especies de hemípteros. Este es el primer informe de la construcción de refugios por N. fulva.

Palabras Clave: Paratrechina pubens, hormiga loca del Caribe, hormiga loca de frambuesa, Hemiptera, hormigas invasoras, refugio de cartón

Nylanderia fulva (Mayr) (Formicidae) is an invasive pest ant from South America that heavily infests buildings and landscapes in Florida, Louisiana, Mississippi and Texas (MacGown & Layton 2010; Warner & Scheffrahn 2010; Aguillard et al. 2011). The ants in Florida were originally identi-
**TABLE 1. HEMIPTERANS TENDED BY *NYLANDERIA FULVA* IN GAINESVILLE, FLORIDA, FROM JUL 2010 TO OCT 2010.**

| Insect Species         | Common name             | Host plant          |
|------------------------|-------------------------|---------------------|
| **Family**             | **Scientific Name**     | **Common Name**     | **Host Plant**     |
| Aleyrodida             | *Dialeurodes citri* (Ashmead)* | Citrus whitefly     | Ligustrum          |
| Aphidida               | *Aphis craccivora* Koch* | Cowpea aphid        | Hemp sesbania      |
| Aphidida               | *Aphis vernoniae* Thomas |                     |                    |
|                       | *Chaitophorus vimincola* Hille Ris Lambers | Willow aphid | Black willow      |
|                       | *Cinara juniperwora* (Wilson) | Juniper aphid     | Southern red cedar |
|                       | *Sanbornia juniperi* Pergande |             | Southern red cedar |
|                       | *Shivaphis celti* Das* | Asian wooly hackberry aphid | Sugarberry       |
| Coccida                | *Ceroplastes floridensis* Comstock* | Florida wax scale | Burford holly     |
|                       | *Neopulvinaria innumerabilis* (Rathvon) | Cottony maple scale | Virginia creeper  |
| Kermesida              | *Allokermes* sp.        | Kermes scale        | Live oak          |
| Pseudococcida          | *Antonina graminis* (Maskell)* | Rhodes grass mealybug | St. Augustine grass |
|                       | *Antonina pretiosa* Ferris* | Noxious bamboo mealybug | Switch cane      |
|                       | *Dysmicoccus brevipes* (Cockerell)* | Pineapple mealybug | Live oak          |
|                       | *Phenacoccus parvus* Morrison* | Lantana mealybug  | Live oak          |
|                       | *Palmiculter lumparensis* (Takahashi)* | Bamboo mealybug  | Switch cane       |
| Psyllidae              | *Pachysylla venusta* (Osten-Sacken) | Hackberry petiole gall psyllid | Sugarberry       |
| Tingidae               | *Corythucha floridana* Heidemann | Florida oak lace bug | Live oak          |

*Indicates introduced hemipteran insects to U.S.
fied as *N. pubens* (Forel) and have been called the brown crazy ant, the Caribbean crazy ant, and the hairy crazy ant (Wetterer & Keularts 2008; Warner & Scheffrahn 2010; Calibeo & Oi 2011). The ants from Texas and Mississippi were called the Rasberry crazy ant, and were designated as *Nylanderia* sp. near *pubens* (Meyers & Gold 2008; MacGown & Layton 2010). However, Zhao et al. (2012) determined that all the specimens of *Nylanderia* species in both Texas and Florida are identical and Gotzek et al. (2012) confirmed that the pestiferous ants identified as *N. pubens* populations were actually *N. fulva*. *Nylanderia fulva* has caused electrical short circuits in Texas (Meyers 2008), destroyed and occupied bee hives in Texas (Harmon 2009), bitten people, and has displaced some native ant species in Colombia and Texas (Meyers 2008). *Nylanderia fulva* also has caused problems in parts of South America (Zenner-Polania 1990) and the Caribbean Islands because of their abundance and mutualism with hemipteran populations that damage crops, such as coconut (Wetterer & Keularts 2008).

Mutualisms between ants and honeydew-producing hemipterans (e.g., aphids, scales, mealybugs, leafhoppers) are well-documented. Ants benefit from their association with hemipterans because their honeydew is an important source of carbohydrates (Stout 1979; Anderson & McShea 2001; Moya-Raygoza & Larsen 2008; Vanek & Potter 2010). Furthermore, hemipterans can serve as a protein resource if they are directly consumed by ants (Rosengren & Sundström 1991; Sakata 1994; Gullan 1997).

Conversely, hemipterans that produce honeydew benefit when they are tended by ants. Ants protect hemipterans from natural enemies and they sometimes provide them shelter (Sheppard et al. 1979; Stout 1979; Anderson & McShea 2001; Moya-Raygoza & Larsen 2008; Vanek & Potter 2010), thus allowing more hemipterans to survive and reproduce (Fritz 1982; Bristow 1983; Fowler & MacGarvin 1985; Buckley 1987). In addition, hemipterans that live inside ant nests (e.g., root feeding aphids and soft scales) are protected from climatic extremes (Buckley...
Some ants have been reported to assume parental care of hemipteran nymphs, enabling adult female hemipterans to produce more offspring (Bristow 1983). The removal of honeydew by ants may improve the hemipteran’s environment by reducing the accumulation of sooty mold that grows on honeydew (Fokkema et al. 1983; Haines & Haines 1978). Sooty mold can suffocate hemipteran eggs (Moya-Raygoza & Nault 2000), affect crawler settling (Bess 1958), and cause adult mortality (Way 1954; Das 1959).

In this study, we identified hemipteran species that were associated with *N. fulva* and documented *N. fulva* foraging activity with seasonal hemipteran abundance.

**Materials and Methods**

**Hemipterans Associated with *Nylanderia fulva***

From Jul to Oct 2010, colonies of *N. fulva* were observed in parks, natural areas and neighborhoods in Gainesville (Alachua Co.), Florida, for any tending behavior towards natural infestations of hemipterans on trees, shrubs and other plants. *Nylanderia fulva* trails on plants were visually followed until ants were seen tending individual hemipterans. Leaves or stems with the hemipterans were collected and insects and plants were identified by specialists at the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (FDACS/DPI).

**Seasonal Sampling**

*Nylanderia fulva* populations and honeydew-producing hemipterans were monitored monthly from Feb 2011 to Jul 2012 at 3 sites in Gainesville, Florida. Four plant species [live oak (*Quercus virginiana* Mill.; Fagales: Fagaceae), holly (*Ilex cornuta* Lindl.; Aquifoliales: Aquifoliaceae), magnolia (*Magnolia grandiflora* L.; Magnoliiales: Magnoliaceae) and sugarberry (*Celtis laevigata* Willd.; Urticales: Ulmaceae)] that were infested with at least 1 honeydew-producing hemipteran species, and had trails of *N. fulva* going up the stem were selected for monitoring. Four plants of each species were sampled except for magnolia, for which only one plant was sampled in 2011 and 3 more plants were added in 2012. The selected plant species were all located in managed landscapes, usually along driveways. Six to 10 terminal shoots per plant with at least 6 to 10 leaves were arbitrarily chosen, cut with a pole pruner and transported in plastic bags to the laboratory on ice. The total number of honeydew-producing insects on terminal shoots was counted within 24 h of collection.

*Nylanderia fulva* activity was estimated in 3 ways for each plant. First, a slice of sausage (0.5 × 2.5 cm Armour Original Vienna Sausage, Cherry Hill, New Jersey) was placed on the center of an index card (7.6 × 12.7 cm) that was positioned about 25 cm from the base of the plant on the northern and southern sides. After 15 min, each card with ants was individually bagged, frozen and the number of ants per sausage was determined. Second, the number of *N. fulva* foraging trails going up one major trunk per plant from the ground was counted. Finally, the number of workers walking past a specific point (~30.5 cm above the ground) on the most active foraging trail was counted for 20 s. All sampling occurred between 0900-1500 h when the air temperature was > 21 °C.

Pearson’s correlation was used to examine the association between the total number of hemip-
### Table 2. List of Trees, Sampling Locations, Insects and Number of Leaves That Were Sampled.

| Tree                      | Site | Mean tree ht (m) | Honeydew producers                                                                                     | No. of leaves/branch |
|---------------------------|------|------------------|--------------------------------------------------------------------------------------------------------|----------------------|
| Burford holly (Ilex cornuta Lindl.) | Site 1 | 0.76             | Florida wax scale (*Ceroplastes floridensis* Comstock) Mealybug (*Dysmicoccus texensis* (Tinsley))        | 6                    |
| Live oak (Quercus virginiana Mill.) | Site 1 | 4.27             | Lace bug (*Corythucha floridana* Heidemann) Aphids (*Myzocallis puncata* (Monell)) Kermes scale (*Allokermes* sp. (Cockerell)) Bullet gall (*Disholcaspis quercusvirens* (Ashm.)) Pineapple mealybug (*Dysmicoccus brevipes* (Cockerell)) | 10                   |
| Magnolia (Magnolia grandiflora L.) | Site 2 | 2.29             | Tuliptree scale (*Toumeyella liriodendri* (Gmelin))                                                   | 3                    |
| Sugarberry (Celtis laevigata Willd.) | Site 2 | 6.4              | Asian wooly hackberry aphid (*Shivaphis celi* Das) Flatid plant hopper Psyllid gall (*Pachypsylla* sp.) | 10                   |

![Graph a](https://bioone.org/journals/Florida-Entomologist on 06 Apr 2020)

**Fig. 3.** a) Mean number of hemipterans collected from the shoots every month from holly in Gainesville from Feb 2011 to Jun 2012. b) Correlation between number of hemipterans and number of ants (trailing intensity) on holly (r = 57). c) Mean number of ants collected on sausage samples every month at the base of holly in Gainesville from Feb 2011 to Jun 2012. d) Mean trailing intensity (i.e. ants crossing a specific point in 20 s × number of trails) on holly from Feb 2011 to Jun 2012.
terans on a shoot and the 20 s ant count. Due to the increased number of trails per trunk in the summer, the 20 s count was multiplied by the number of trails to provide an index of trailing intensity. Analysis of variance (ANOVA) was conducted to determine differences in 20 s ant counts from the most active ant trail among plant species and Tukey’s HSD test was used to conduct a mean separation among plant species (R Development Core Team 2012).

RESULTS AND DISCUSSION

Hemipterans Associated with Nylanderia fulva

A total of 17 species from 7 families of honeydew-producing hemipterans were tended by N. fulva on 10 plant species (Table 1). We did not observe Nylanderia fulva exhibiting any obvious preference for any particular hemipteran species. Aphids and mealybugs were the most prevalent and had the greatest diversity of species, with 6 species of aphids and 5 species of mealybugs. Similar observations of greater species diversity for these 2 families have also been reported in previous studies. Zenner-Polania (1990) reported N. fulva tending whiteflies and scale insects in orange trees and mealybugs in rangeland grass, sugarcane and coffee berries. They also observed that the ants transported the hemipterans from infested to uninfested plants and protected the hemipterans from the predators by constructing protective shelters over the mealybugs.

We observed carton shelters on magnolia branches, where N. fulva had covered tuliptree scales using soil and plant debris (Fig. 1). Shelters were also observed on the trunk and near the base of the trunk where there were pruning injuries. Nylanderia fulva also built carton shelters around Juniper aphids (Cinara juniperivora (Wilson); Aphididae) along a split on the trunk on Southern red cedar (Juniperus silicicola (Small); Pinales: Cupressaceae) (Fig. 2). The structures were built in such a way that ants had access to enter and exit those shelters. When the carton was broken apart, many N. fulva workers scrambled out of the shelters and the juniper aphids or tuliptree scales (Toumeylla liriodendri (Gmelin); Coccidae) that were previously covered were vis-
ible. Many ants, like *Acropyga*, *Formica*, *Lasius*, *Odontomachus* and *Oecophylla*, build protective shelters of soil and plant debris, or carton, over honeydew producing hemipterans (Wheeler 1910; Way 1963; Evans & Leston 1971). These shelters are thought to protect the hemipterans from adverse environments (Way 1963; Helms & Vinson 2002), thereby increasing hemipteran populations and the availability of honeydew for the ant colony (Dejean et al. 1997).

**Seasonal Sampling**

The hemipterans collected from plants that were sampled monthly from Feb 2011 to Jun 2012 are listed in Table 2. The predominant hemipteran species on each host plant were Florida wax scale, *Ceroplastes floridensis* Comstock (Coccidae), on holly; the aphid, *Myzocallis punctata* (Monell), on live oak; the tuliptree scale, *Toumeyella liriodendri* (Gmelin), on magnolia; and the Asian wooly hackberry aphid, *Shivaphis celti* Das, on sugarberry. *Nylanderia fulva* were observed tending 5 hemipteran species on live oak and 3 species on sugarberry. Two hemipterans were sampled from holly, and only one was on magnolia. Among the sampled tree species, live oak and sugarberry were large, mature trees while holly and magnolia were smaller and younger landscape plantings that were pruned (Table 2). Thus, the difference in plant age and architecture could have affected the diversity of herbivorous hemipterans.

Hemipteran populations were higher during the warmer months (May to Sep) and decreased as ambient temperatures dropped at the end of Oct (Figs. 3a-6a). Similar temporal patterns of hemipteran distribution have been reported by Barlow (1962) for *Myzus persicae* (Sulzer) (Aphididae) on potatoes, *Macrosiphum euphorbiae* (Thomas) (Aphidae) on tobacco, and by Dixon (1977) in walnut aphid, lime aphid, cereal aphids and black bean aphid. Stevens et al. (1998) found that the population of several ant species that were tending the honeydew producing hemipterans decreased in cooler months when hemipteran numbers declined and increased in warmer months when hemipterans returned.

Similarly, *N. fulva* activity was greater during the warmer months (e.g., May to Aug) on all 4 plant species (holly, love oak, magnolia and...
sugarberry). Figure 3c-6c shows the number of ants foraging on the sausage provided during the samplings. The average number of ants crossing a specific point in 20 s during the 16 mo period in 2011-2012 is presented in Figures 3d-6d. As the daily average temperature decreased in Oct and Nov (< 21 °C), ant numbers declined slightly. When the temperatures cooled further in Dec and Jan (< 19 °C), ant foraging decreased dramatically, suggesting that the *N. fulva* activity is largely dictated by temperature. Ants are poikilothermic, thus their foraging activity depends on different abiotic factors like relative humidity and soil temperature (Traniello 1989; Valenzuela-González et al. 1995). Porter & Tschinkel (1987) reported that *Solenopsis invicta* foraging activity was limited due to low temperatures in several locations of southeastern United States. *Nylanderia fulva*’s activity appeared to be less in 2012 than in 2011 during similar months (Figs. 3a,c,d-6a,c,d). This was possibly due to the lower average RH (< 30%) in 2012 than in 2011. In addition, the average precipitation for Dec to Apr was also lower in 2012 (3.6 cm) than in 2011 (7 cm). Hölldobler & Wilson (1990) suggested that warmer temperatures may not be enough for high ant activity. A relatively humid environment may be needed to avoid desiccation and to resume their activities in the open. Therefore, lower humidity and rainfall might have contributed to reduced *N. fulva* abundance in 2012 as compared to similar time periods in 2011. Hemipteran population size (Figs. 3a-6a) was also lower in 2012 than in 2011. It was not clear from our sampling alone that hemipteran numbers were lower because of decreased ant abundance or vice versa. More research will be required to evaluate this relationship.

Significant positive correlations were found between the total number of ants (trailing intensity) and the number of hemipterans in holly (*r* = 0.57, *P* < 0.0001), magnolia (*r* = 0.63, *P* < 0.0001), live oak (*r* = 0.80, *P* < 0.0001) and sugarberry (*r* = 0.44, *P* < 0.0001) (Figs. 3b-6b). Trees with higher hemipteran populations had higher *N. fulva* trailing intensity (i.e., the number of trailing ants crossing a specific point in 20 s × number of trails). Trailing intensity over time differed significantly among the 4 plant species (Fig. 7). Magnolia had an average trailing intensity of 136 ants throughout the sampling period which was significantly
higher than the 43 ants on live oak. The trailing intensity on sugarberry and holly were similar at 8 and 7 ants, respectively (Fig. 7). Greater N. fulva trailing on magnolia and live oak could be attributed to greater hemipteran diversity and abundance. Tuliptree scale in magnolia is present in all stages of development during the winter in southern states (Donley & Burns 1971) and even though most insect species found in live oak were present in warmer months, lace bugs were present throughout the year in areas with mild winters like Florida (Dreistadt & Perry 2006) providing a continuous supply of honeydew to N. fulva. In contrast, on holly and sugarberry hemipterans were found only during the warmer months (Jul to Oct), and as a deciduous tree, sugarberry was defoliated from Oct to Feb. Brightwell & Silverman (2011) determined that there were fewer Linepithema humile (Mayr) (Formicidae) nests around deciduous trees in fall, but were present around evergreen species Pinus taeda L. (Pinales: Pinaceae) throughout winter and successfully foraged in these trees even when ambient temperatures were below the minimum foraging threshold. This pattern of behavior may be similar for the deciduous trees in our study where N. fulva moved their nests away from sugarberry in the winter, thus reflecting the reduced number ants in sugarberry after Oct 2011 (Figs. 6a,c,d).

In this study, the activity periods of honeydew producing hemipterans and N. fulva were positively associated, which reflected the seasonal changes in temperatures. During the warmer months (May to Oct), the presence and abundance of hemipterans increased, which was associated with greater ant foraging. Our paper also documents that some species of honeydew producing hemipterans that were tended by N. fulva were apparently protected by shelters created by N. fulva. Thus, there is evidence of mutualism between N. fulva and honeydew-producing hemipterans. Understanding the seasonal phenology between honeydew-producing hemipteran species tended by N. fulva could be important in developing control strategies for this invasive ant. Controlling hemipteran species would remove a food resource of N. fulva and thus could help decrease the density of ants in the landscape.

ACKNOWLEDGMENTS

We would like to thank the owners and managers of our study sites in Gainesville for their cooperation and patience. Drs. S. Halbert and I. Stocks (FDACS/DPI) kindly provided species identifications. We appreciate the technical assistance provided by P. Ruppert, M. Poudel, T. Garrick, D. Sekora and S. Rachel during field sampling. Dr. G. Hodges (FDACS/DPI) reviewed an earlier draft of this manuscript. This research was funded by the Tropical and Subtropical Agricultural Research (TSTAR) grant (2010-34135-21096).

REFERENCES CITED

AGUILLARD, D., STRECKER, R. M., AND HOOPER-BùI, L. M. 2011. Extraction of super colonies of crazy ants from soil and wood. Midsouth Entomol. 4: 53-56.

ANDERSON, C., AND MCGHEE, D. W. 2001. Intermediate-level parts in insect societies: adaptive structures that ants build away from the nest. Insectes Sociaux 48: 291-301.

BARLOW, C. A. 1962. The influence of the growth on the growth of experimental populations of Myzus persicae (Sulzer) and Macrosiphum euphorbiae (Thomas) (Homoptera). Canadian J. Zool. 40: 145-156.

BESS, H. A. 1958. The green scale, Coccus viridis (Green) (Homoptera: Coccidae), and ants. Proc. Hawaiian Entomol. Soc. 16: 349-355.

BRIGHTWELL, R. J., AND SILVERMAN, J. 2011. The Argentine ant persists through unfavorable winters via a mutualism facilitated by a native tree. Environ. Entomol. 40: 1019-1026.

BRISTOW, C. M. 1983. Treehoppers transfer parental care to ants: a new benefit of mutualism. Science 220: 532-533.

BUCKLEY, R. 1987. Ant-plant-hemipteran interactions. Adv. Ecol. Res. 16: 53-85. Academic Press. [Online] http://www.sciencedirect.com/science/article/pii/0065250408600872. Last Accessed 9 Feb 2011.

CALIBE, D., AND OR, F. 2011. Integrated pest management (IPM) of the Caribbean crazy ant, Nylanderia (=Paratrechina) pubens (Forel). ENY-2006 (IN889). University of Florida, Gainesville, FL.

DAS, G. M. 1959. Observations on the association of ants with coccids of tea. Bull. Entomol. Res. 50: 437-448.

DEJAN, A., NGNÈGUÈU, P. R., DURAND, J. L., AND BOURGOIN, T. 1997. The influence of ants (Hymenoptera: Formicidae), particularly tramp species, on the proliferation of a maize pest. Sociobiology 30: 85-93.

DIXON, A. F. G. 1977. Aphid ecology: life cycles, polymorphism, and population regulation. Ann. Rev. Ecol. and System 8: 329-353.
Sharma et al.: Ant Interaction with Honeydew Producers 547

Porter, S. D., and Tschinkel W. R. 1987. Foraging in Solenopsis invicta (Hymenoptera: Formicidae): effects of weather and season. Environ. Entomol. 16: 802-808.

Core Team. 2012. R: A language and environment for statistical computing. R Foundation For Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org/.

Rosenberg, R., and Sundstrom, L. 1991. The interaction between red wood ants, Cinara aphids and pines: a ghost of mutualism past?, pp. 80-91 In C. R. Huxley and D. F. Cutler [eds.], Ant-plant interactions. Oxford University Press, New York.

Sakata, H. 1994. How an ant decides to prey on or to attend aphids? Res. Popul. Ecol. 36: 45-51.

Sheppard, C., Martin, P. B., and Mead, F. W. 1979. A planthopper (Homoptera: Cixiidae) associated with red imported fire ant (Hymenoptera: Formicidae) mounds. J. Georgia Entomol. Soc. 14: 140-144.

Stevens, M. M., James, D. G., O’Malley, K. J., and Coombes, N. E. 1998. Seasonal variations in foraging by ants (Hymenoptera: Formicidae) in two New South Wales citrus orchards. Australian J. of Exp. Agric. 38: 889-896.

Stout, J. 1979. An association of an ant, a mealybug, and an understory tree from a Costa Rican rain forest. Biotropica 11: 309-311.

Traniello, J. F. A. 1989. Foraging strategies of ants. Annu. Rev. Entomol. 34: 191-210.

Valenzuela-González, J., López-Méndez, A., and Lachaud, J. P. 1995. Activity patterns and foraging activity in nests of Ectatomma tuberculatum (Hymenoptera: Formicidae) in cacao plantations. Southwestern Entomol. 20: 507-515.

Vaneck, S. J., and Potter, D. A. 2010. An interesting case of ant-created enemy-free space for magnolia scale (Hemiptera: Cocidae). J. Insect Behav. 23: 389-395.

Warner, J., and Scheffrahn, R. H. 2010. Caribbean crazy ant (proposed common name, N. fulvus = Paratrechina) pubens (Forel) (Insecta: Hymenoptera: Formicidae: Formicinae). [Online] http://edis.ifas.ufl.edu/in560. Last accessed 3 Nov 2012.

Way, M. J. 1954. Studies on the association of the ant Oecophylla longinoda (Latr.) (Formicidae) with the scale insect Saissetia zanibarensis Williams (Coccidae). Bull. Entomol. Res. 45:113-134.

Way, M. J. 1963. Mutualism between ants and honeydew-producing Homoptera. Annu. Rev. Entomol. 8: 307-344.

Wetterer, J. K., and Keularts, J. L. W. 2008. Population explosion of the hairy crazy ant, Paratrechina pubens (Hymenoptera: Formicidae), on St. Croix, US Virgin Islands. Florida Entomol. 91: 423-427.

Wheeler, W. M. 1910. Ants: Their structure, development, and behavior. Columbia University Press, New York, USA.

Zener-Polanía, I. 1990. Biological aspects of the “Hormiga Loca”, Paratrechina (Nylanderia) fulva (Mayr), in Colombia. pp. 290-297 In R. K. Vander Meer, K. Jaffe and A. Cedeno [eds.], Applied Myrmecology, A World Perspective. Westview Press, Boulder, Colorado.

Zhao, L., Chen, J., Jones, W. A., Oi, D. H., and Deere, B. M. 2012. Molecular comparisons suggest Caribbean crazy ant from Florida and Raspberry crazy ant from Texas (Hymenoptera: Formicidae: Nylanderia) are the same species. Environ. Entomol. 41: 1008-1018.