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**PARATACHARDINA PSEUDOLOBATA
(COCCOIDEA: KERRIIDAE): BIONOMICS IN FLORIDA**

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ABSTRACT

The lobate lac scale, *Paratachardina pseudolobata* Kondo & Gullan, attacks large numbers of plants in Florida. The scales primarily infest the branches and main stems <2 cm in diameter; rarely were they found on stems that were larger than 4 cm in diameter or on leaves and never on roots. They produce honeydew, but ants did not tend the scales nor did ants appear attracted to the honeydew, which is ejected from the scale instead of being present in collectable droplets. Males have not been found in Florida populations of the lobate lac scale and females are parthenogenetic and ovoviviparous. The scales developed into adult females in 15-19 weeks. Crawlers of second generation were present 21 weeks after young crawlers of the previous generation were placed on a host plant. The pre-imaginal stadia were: first instar 8-11 weeks; second instar 7-8 weeks. The numbers of crawlers counted per month on host plants were notably uniform throughout the year, but there was evidence of a slight increase in crawler production during the warmer months. Lobate lac scales subjected to a simulated frost of -3°C had a low survival rate. In a test of survival without a host, one of 22 crawlers survived 14 d, and 3 of 32 survived 18 d. Based on the numbers of exit holes in mature female tests, the parasitism rate since this pest was found in Florida is not greater than 1%.

Key Words: lobate lac scale, bionomics, Florida, parasitism

RESUMEN

La escama lobulada de la laca, *Paratachardina pseudolobata* Kondo & Gullan, ataca un gran número de plantas en la Florida. Las escamas principalmente infestan las ramas y tallos principales de <3 cm en diámetro; raramente se encuentran en tallos mayores de 4 cm de diámetro o sobre las hojas y nunca en las raíces. Estas producen gotas de miel, pero no son atendidas por las hormigas y las hormigas tampoco están atraídas por las gotas de miel, que la escama eyecta en vez de ser producida en gotas recolectables. No se ha encontrado machos de la escama lobulada de la laca en las poblaciones de la Florida y las hembras son partenogenéticas y ovovíparas. Las escamas se desarrollan en las hembras adultas en un periodo de 15 a 19 semanas. Las larvas (1 estadio) del segundo generación estuvieron presentes 21 semanas después de que las larvas juvenes de la generación anterior fueron puestas sobre la planta hospedera. Los estadios pre-imaginales fueron como los siguiente: primer estadio 8-11 semanas; segundo estadio 7-8 semanas. El número de larvas contadas por mes sobre las plantas hospederas fue notablemente uniforme por todo el año, pero hubo evidencia de un aumento ligero en la producción de larvas durante los meses mas cálidos. Las escamas lobuladas de la laca que fueron sujetas a una escarcha simulada de -3°C tuvieron una tasa de sobrevivimiento baja. En una prueba de sobrevivimiento sin hospedero, una de las 22 larvas sobrevivió por 14 días, y 3 de las 32 sobrevivieron por 18 días. Basado en el número de hoyos de salida de los "test" (capa cerosa) de la hembra adulta, la tasa de parasitismo no fue mas de >1% desde que esta plaga fue encontrada en la Florida.

Paratachardina pseudolobata (Kondo & Gullan) (Coccoidea: Kerriidae) was found for the first time in Florida in 1999 (Hamon 2001). The first

specimens were found in Broward County on a single infested hibiscus shrub, *Hibiscus rosa-sinensis* L., in a residential area by Rita J. Carpen-

ter, District Plant Inspector with the Florida Department of Agriculture and Consumer Services, Division of Plant Industry (DPI). It was initially identified by Avas Hamon (DPI Bureau of Entomology) as *Paratachardina lobata* (Chamberlin); the identification was confirmed by D. R. Miller (Systematic Entomology Laboratory, U.S. Department of Agriculture, Beltsville, MD). The infested plant was destroyed, but additional infestations were found in Miami-Dade and Broward Counties in 2000 and on 17 sites in Palm Beach, Broward, and Miami-Dade counties in 2001. Within the next few years, it became widely disseminated in southeastern Florida and was recognized as a severe pest of many species of woody plants in both urban landscapes and natural areas. As of Jun 2009, the species was distributed in all Florida counties south of Lake Okeechobee, with scattered records in coastal areas north to St. Lucy and Indian River counties.

Avas Hamon received specimens of this same species from New Providence, Bahamas, in 1992 (personal communications). In 2005, this species was found in the central region of Cuba (Novoa et al. 2007) and has been known for an undetermined number of years on Christmas Island (Australia) in the Indian Ocean (Abbott & Green 2007; Kondo & Gullan 2007). It is obviously an adventive in these localities. The scale was identified as *P. lobata*, native to southern India and Sri Lanka.

The species became known in Florida by the vernacular name lobate lac scale in reference to its taxonomic position in the lac scale family, and to the presence in the female test with 4 prominent lobes, a conspicuous character that is found in some other species of *Paratachardina*, but distinguishes this species from other scale insects commonly encountered in Florida.

The lobate lac scale has been referred to as *P. lobata* in previous publications on identification of 307 plant species as hosts in Florida (Pemberton 2003b; Howard et al. 2006) and 5 additional host plant species in Cuba (Novoa et al. 2007); temporal and spatial characterization of an infestation (Epsky et al. 2006), chemical control methods (Howard & Steinberg 2005), progress in developing classical biological control (Pemberton 2003a; Pemberton et al. 2006; Schroer & Pemberton 2007; Schroer et al. 2008a) and the reporting of 2 parasitoid species, *Metaphycus* sp. and *Ammonoencyrtus caroliniensis* N. Comb. (Hymenoptera: Eulophidae), that attack the lobate lac scale in Florida (Howard & Pemberton 2003; Schauff 2005).

In a recent revision of the genus *Paratachardina*, Kondo & Gullan (2007) recognized *P. lobata* as the junior synonym of *P. silvestri* (Mahdihasan) and determined that the adventive species previously identified as *P. lobata* in Florida, Christmas Island, and the Bahamas is a new species that they described as *P. pseudolobata*. Mo-

lecular analysis of the lobate lac scales from Florida, Christmas Island, Cuba, and the Bahamas found them to be identical (Schroer et al. 2008b). The species is likely to be native to Asia or Oceania, since the other 8 described species of *Paratachardina* are reported from various localities there (Kondo & Gullan 2007). Lobate lac scale continues to be widely recognized as the vernacular name of this species.

In this paper, we report some observations on lobate lac scale that may be useful to researchers studying this pest with the ultimate objective of developing methods for management.

MATERIALS AND METHODS

Host Plant Relationships

Observations of lobate lac scale were conducted on plants in the field in natural and urban landscaped areas and plants grown in containers at the Fort Lauderdale Research & Education Center (FLREC). The plants included 3 each of 6 species growing in containers at Fort Lauderdale Research & Education Center (FLREC): cocoplum, *Chrysobalanus icaco* L.; yaupon holly, *Ilex vomitoria* Aiton; wild coffee, *Psychotria nervosa* Swartz; Bahama wild coffee, *P. ligustrifolia* (Northrop) Milspaugh; guamá, *Inga edulis* Martius; and white indigo-berry, *Randia aculeate* L. Containerized plants were grown in a potting mix consisting of about equal portions of muck, sand, bark chips, and perlite. The containers were black plastic with a volume of 9.5-38 L depending on the size of the plant. The plants were lightly fertilized at 6-month intervals with Osmocote 14-14-14 (N-P-K) (Scotts Co., Marysville, OH) at rates adjusted to the size of each plant to a maximum of 90 g/plant. Plants were grown in full sun or under partial shade and irrigated by overhead sprinklers usually twice a week, with irrigation suspended during rainy periods.

Some scale insect species are eurymorous (i.e., they infest different parts of the same plant), while other species prefer or are even restricted to distinct plant parts, such as the leaves. Observations were made to determine which parts of the host plants were most frequently attacked by the lobate lac scale. Scales were observed to determine the presence of collectable droplets of honey dew and tending ants.

Since some species of Coccoidea, notably in the families Pseudococcidae, Margarodidae, Eriococcidae, and rarely Diaspididae, infest the roots of their host plants (Howard et al. 1999), we attempted to determine whether the lobate lac scale infests roots. We estimated the numbers of tests of mature lobate lac scales on the above-ground parts of plants, then lifted each from its container and washed the roots of soil by immersion and gentle agitation in a large bucket of water.

Life History

Observations were conducted to determine the time of development of the lobate lac scale from early first instar to mature female and to the advent of the crawlers of the subsequent generation. Lobate lac scales were identified to instar based on gross morphological characters (Kondo & Gullan 2007) and measurements. Examinations were conducted with a 10X-hand lens, and measurements with a steel measuring scale calibrated to 0.1 mm (Ted Pella, Redding, CA).

On 10 Oct 2003, 50 crawlers were obtained by dissecting mature female scales infesting a wax-myrtle plant (*Myrica cerifera* L.). They were transferred with a human hair to 2 guamá plants (*Inga edulis*), which had been propagated by cuttings and grown in potting mix in plastic cones (5 cm diameter upper rim \times 25 cm length). The infested guamá plants, 25-30 cm tall when infested with the crawlers, were placed in a Percival™ environmental chamber set at 27°C with 12 h light and 12 h dark. The scale insects were identified to stage and counted weekly.

Seasonal Abundance of Crawlers

Scale detection and counts were conducted on 3 plant species (wax myrtle, wild coffee, and red-berry stopper) that are highly susceptible to lobate lac scale (Howard et al. 2006) to reveal the relative numbers of crawlers during a 12-month period. The host plants were in different habitats, growing conditions, and locations as follows:

(1) Wax myrtles, 1.0 ± 0.4 m tall, in 38-liter black plastic containers with growing medium and fertilizer applications as described above in full sun at the FLREC (25°5'N, 80°14'W).

(2) Wild coffee, 1.7 ± 0.3 m tall, growing as a hedge in full sun on the campus of Broward College, which is adjacent to the FLREC (25°5'N, 80°14'W).

(3) Wild coffee, 1.9 ± 0.3 m tall, occurring naturally as an understory plant in a hardwood hammock at Fern Forest Nature Center (Broward County Division of Parks and Recreation) (26°13'N, 80°11'W).

(4) Redberry stopper (*Eugenia confusa* De Candolle), 1.8 ± 0.6 m tall, as understory in a hardwood hammock at Simpson Park (Miami Division of Parks and Recreation) (25°46'N, 80°12'W).

Three plants were randomly selected from infested plants in each of the 4 sites. The initial heights of the plants were measured from ground level to the highest point on the shrub. On 3 branches, single segments (5 cm long), where the lobate lac scale populations occurred at maximum densities, were delimited and marked on each

plant. These segments will be referred to as "sample stem segments". Observations were initiated at Sites 2 and 4 in Dec 2005, and at Sites 1 and 3 in Jan 2006. At the commencement of observations in each host plant/habitat situation, the numbers of mature female lobate lac scales and of crawlers were counted on the entire surface of each sample stem segment. This procedure was repeated monthly. Data were not collected on environmental factors at any of the sites. During the period of observations, 3 sample stem segments that were lost due to breakage or die-back of branches were replaced with 5 cm segments of similar diameters and population levels. Observations were not made in Jun 2006 on wax myrtle at Site 1 (FLREC). The diameter at midpoint of the sample stem segments was measured to 0.1 cm every third month with a Vernier caliper and the circumference and surface area of each 5-cm segment calculated to enable comparisons of crawlers per 1 cm² of stem surface per month. Numbers per stem sample segment were pooled per plant species-habitat situation. The number of crawlers per sample by date were analyzed by the Tukey honest significant difference (HSD) test of ANOVA (SPSS 10.0, SPSS Inc., Chicago, IL) at 5% level.

Survival of a Simulated Frost

An experiment was performed to test the survivorship of second instar and mature female lobate lac scales exposed to a simulated frost that decreased from an above-freezing temperature to a minimum temperature of -3°C. The experiment was initiated on 23 Dec 2003. Two wax myrtle plants infested with lobate lac scale were selected for simulated frost treatment and one as a control. All adult females and second instars on 1 branch of each plant were determined as live or dead by examination, with probing of apparently dead insects for verification. Two test plants were placed in a Sanyo™ temperature cabinet set at -3°C. The chamber door was briefly opened and a digital thermometer observed to determine the temperature inside the cabinet at 15, 25, 40, and 80 min after the plants were placed in it, since it was expected that heat of the container and plant would raise the cabinet temperature temporarily. After 80 min, the cold-treated plants were removed from the cold chamber and placed outdoors in the nursery at the FLREC. The minimum daily outdoor temperature at the FLREC during 15 d post-treatment was +12°C, recorded by the Florida Automatic Weather Network (FAWN) on Dec 27, 2003. Fifteen days after the cold treatment the branch examined prior to treatment was removed from each wax myrtle plant and the scale insects examined for survivorship by examination and probing under a stereoscopic microscope.

Survival of the First Instar Without a Host

Long distance spread of scale insects is thought to be almost exclusively via movement of their host plants. To obtain evidence of whether lobate lac scales could be spread for a long distance without host plants (for example, on the clothing of an international airline passenger), we conducted observations to determine how long crawlers deprived of host plants survived. Young crawlers were obtained by dissecting female lobate lac scales that infested wax myrtles. The crawlers were placed in a polystyrene tube (14 mL, 17 × 100 mm) lined with moist filter paper, and the tube was capped. The tube was kept in a laboratory at about 23°C. After a predetermined number of days, the survival of the crawlers was assessed by microscopic examination. Two sets of observations were made: (1) 22 crawlers transferred to the tube on 20 Nov 2003 and examined 14 d later, and (2) 32 crawlers transferred on 9 Jan 2004 and examined 18 d later.

Status of Natural Enemies in Florida

The 2 parasitoid species reported from lobate lac scale hosts in Florida (Howard & Pemberton 2003; Schauff 2005) were identified from only a few specimens reared from a total of about 3000 lobate lac scale-infested twig samples that were collected from various field sites in southeastern Florida during 2002-2003. Monitoring was continued for the presence of natural enemies to obtain data indicating any changes in the frequency of parasitism of lobate lac scale in the field. Sections of infested branches 15 cm long were collected on a total of 37 sites in Broward County, Florida, during 2003-2009. The branch sections were examined in the laboratory under a stereoscopic microscope and the numbers of mature females with and without parasitoid exit holes determined.

RESULTS

Host Plant Relationships

After examining thousands of lobate lac scale infestations on many plant species distributed on multiple sites in southern Florida, we found that this scale infested primarily the branches and main stems of <2 cm in diameter. Rarely were they on stems larger than 4 cm in diameter. They did not infest leaf tissue, except for rare cases, e.g., when a few lobate lac scales were on the relatively fibrous petioles of guamá.

Although the surfaces of lobate lac scale-infested plants were sticky with honeydew and coated with crusts of sooty mold, and ants were often present near and on plants, we did not see ants tending lobate lac scales or feeding on their

honeydew. The honeydew is ejected from the scale and not present as collectible droplets. In southern Asia, ants were not associated with the honeydew of a closely related species, *Paratachardina silvestri* (as *Tachardina lobata* Green) (Hassan 1979). This is intriguing, because the association between ants and honeydew-producing insects, with the latter providing honeydew to attract the ants, protects the honeydew producers, and is a familiar example of mutualism. It is unlikely that lobate lac scale honeydew is repellent to ants. In the plants of 6 species that were examined for above-ground and root infestations, there was a mean of 408.4 (SD = 954.5) mature female scales estimated per plant on the above-ground stems and branches. However, no live scale insects of any stages or remains of dead scales were found on the roots of any of the plants. Thus, it appears that in lobate lac scales there are no root-infesting populations to serve as a source of infestation of above-ground parts, as is the case in cycad aulacaspis scale, *Aulacaspis yasumatsui* Takagi (Howard et al. 1999).

Life History

We observed that lobate lac scales do not oviposit on plant surfaces, as is true of most of the Coccoidea. They apparently oviposit within the test where the eggs quickly hatch, a form of ovoviviparity found in other species of the subfamily Tachardininae (Kapur 1962). The crawlers exit the mother's test through the dorsal anal opening, as reported in the true lac scale.

When 50 first instar crawlers were transferred to a guamá plant, 23 crawlers had settled on the plant when examined 1 week later. The remaining 27 crawlers apparently had moved from the plant. Seven of the 23 settled first instars developed to adult females, reaching the mature female stage 15-19 weeks after being placed on the plant. Twenty-one weeks after placement of young larvae on the plant, >100 crawlers of the second generation were observed on the plant. The stadia of pre-imaginal instars were first instar 8-11 weeks and second instar 7-8 weeks. Thus, the development time in lobate lac scales from crawler to adult, about 4-5 months, is of relatively long duration, since a development time of 1 month is probably more typical of scale insects in general. For example, development from young crawler to adult is about 1 month in both the cycad aulacaspis scale (Diaspididae) (Howard et al. 1999) and in *Dactylopius coccus* Costa (Dactylopiidae) (Guerra & Kosztarab 1992). The longer development time of lobate lac scale is similar to that of some other Kerriidae. For example, depending on conditions, 1 strain of the true lac scale develops from egg to adult in about 8-9 months (Kapur 1962).

Of the thousands of lobate lac scale examined, there was no male stage. In field studies of lobate lac scale over a 3-year period on Christmas Island, there was no evidence of a male stage (Dr. Kirsti Abbott, School of Biological Sciences, Victoria University of Wellington, New Zealand, Personal Communications). Kondo & Gullan 2007 reported that a male stage was unknown in lobate lac scale, and suggested that this species may be parthenogenetic.

Seasonal Abundance of Crawlers

The numbers of crawlers observed throughout the year were lower than expected (Table 1). The sampling from surfaces with high density of female scales may have biased the data towards fewer crawlers. Because scale crawlers tend to settle near where they hatched or were oviposited, stem segments of high mature female scale density would be expected to have high numbers of crawlers. However, a higher density of both the mature and immature scales at these stem segments may have stimulated crawlers to disperse to surfaces of lower scale density on the same or other plants.

Nevertheless, the data were sufficient to reveal that crawlers were present on plants each month throughout the year in all 4 host plant species/habitats (except for Mar 2006). The numbers of crawlers were notably uniform throughout the year, but there were some indications of a slight increase in crawler numbers during the warmer season: Crawlers were present on 18 of the stem sample segments examined during Apr-Sep compared to eight of the stem sample segments exam-

ined during Oct-Mar. Also, there were small statistically significant (Tukey HSD test at $P < 0.05$) increases in numbers of crawlers from the previous month in 6 monthly counts during Apr-Sep compared to 2 such increases during Oct-Mar (Table 1). This reveals a seasonal pattern of year-round reproduction with a slight increase in the warmer and rainier months, which is typical of insects adapted to a humid tropical climate.

Survival of Simulated Frosts

In the experiment on the effect of a simulated frost on lobate lac scale, the temperatures recorded inside the cabinet after placing the plants in it were 0° -1°, -2°, and -3°C, at 15, 25, 40, and 80 min, respectively. The cabinet temperature had been initially set at -3°C, and the temporary increase to 0° fifteen min after the plants were placed in it was probably largely due to convection heat from the soil, plants, and container. During the 15-day post-treatment period when the plants were in the nursery, the minimum daily outdoor temperature at FLREC was 12.0° on Dec 27, 2003 (FAIRS). At the end of the post-treatment period, 9 of 71 second instars and 3 of 74 mature female scales on Plant #1 had survived the simulated frost. None of the scales on Plant #2, including 48 second instars and 1 mature female, survived. On the control plant, 77% of 36 second instars and 71.6% of 88 mature females survived. The cause of mortality of scales in the controls is unknown.

Chong (et al. 2008) evaluated the lobate lac scale's ability to survive at various cold temperatures of longer duration. They concluded that the insect scale may have a higher potential to invade

TABLE 1. MEAN NUMBERS OF LOBATE LAC SCALE CRAWLERS PER CM² OBSERVED IN MONTHLY EXAMINATIONS OF SAMPLE AREAS ON BRANCHES IN 4 DIFFERENT HOST PLANT-HABITAT COMBINATIONS, DEC 2005-NOV 2006.

Month observed	<i>Myrica cerifera</i> in containers (FLREC)	<i>Psychotria nervosa</i> in urban landscape Broward College	<i>Psychotria nervosa</i> in natural hammock Fern Forest	<i>Eugenia confusa</i> in natural hammock Simpson Park
Dec 2005	—	0.01 ab	—	0.02 a
Jan 2006	0.02 a	0.00 a	0.01 a	0.06 a
Feb	0.00 a	0.02 ab	0.00 a	0.00 a
Mar	0.00 a	0.00 a	0.00 a	0.00 a
Apr	0.11 ab	0.00 a	0.02 a	0.02 a
May	0.13 ab	0.00 a	0.02 a	0.46 b
Jun	—	0.11 ab	0.03 a	0.02 a
Jul	0.69 b	0.01 a	0.74 b	0.11 a
Aug	0.00 a	0.19 b	0.01 a	0.05 a
Sep	0.07 a	0.00 a	0.01 a	0.14 a
Oct	0.00 a	0.00 a	0.01 a	0.02 a
Nov	0.00 a	0.03 ab	0.09 a	0.00 a

—= data not recorded; FLREC = Fort Lauderdale Research & Education Center, Means ($n = 9$) followed by the same letter within a column do not differ significantly, as determined by Tukey HSD test at $P < 0.05$.

areas where the average winter temperatures do not drop below freezing for an extended duration (3 or more consecutive d), such as southern Florida, Rio Grande Valley in Texas, and Colorado river Delta between California and Arizona.

From these observations, it appears that a light frost would greatly reduce field populations of lobate lac scale but not eliminate them, so that in time their populations would recover. However, it seems possible that in some cases mature females that survive a frost may not be reproductive. Subfreezing temperatures could also have an impact on lobate lac scale by killing their host plants. The host range of lobate lac scale includes over 300 plant species in Florida, including tropical and temperate zone species. The frost-tolerance among different species is undoubtedly highly variable.

Survival of the First Instar Without a Host

In 2 sets of observations to determine survivorship of crawlers without a host plant, initiated 20 Nov 2003 and 9 Jan 2004, respectively, one of 22 crawlers survived 14 d without a host, and 3 of 32 survived 18 d without a host.

The survival of crawlers for relatively long periods without a host was unexpected, and although the survival rate was low, a single individual of a parthenogenetic species such as lobate lac scale can initiate an infestation. A remaining question, which has important implications for preventing international spread of scale insects, is whether crawlers deprived of a host for long periods are capable of settling, developing, and reproducing.

Status of Natural Enemies in Florida

A total of 22,828 mature female lobate lac scales were examined on branch samples collected on 36 field visits in Broward County during the period Mar 2003-Jun 2009. Samples were obtained from 21 host plant species. A mean of 0.4% (SD = 0.4) of the mature female scale insects per site had parasitoid exit holes. Scales in about half of the samples (20/39) and on 10/18 sampled plant species had exit holes. While parasitism is low, it is often present in lobate lac scale populations. We conclude that although at least 2 species of hymenopterous parasitoids attack lobate lac scale in Florida, their impact on this scale insect is negligible. Thus, classical biological control remains the most promising option for long term management of this pest.

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