TEMPORAL AND SPATIAL CHARACTERIZATION OF AN INFESTATION OF *PARATACHARDINA LOBATA LOBATA* (HEMIPTERA: KERRIIDAE), A NEW INVASIVE PEST IN FLORIDA

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ABSTRACT

The lobate lac scale, *Paratachardina lobata lobata* (Chamberlin) was first found in south Florida in 1999. Reported hosts are present in the germplasm collection located at the USDA/ARS Subtropical Horticulture Research Station in Miami, and the scale was first found there in the summer of 2002. A study was initiated to determine the spatio-temporal dynamics of a lobate lac scale infestation at SHRS from Jul 2003 to Jul 2005. Numbers and percentages of viable adults, and reproductive success as indicated by ratio of nymphs to viable adults (<2 cm diam and 30 cm long branch sample) were recorded. There were 55 plants evaluated over the ~80 hectares study site. Infestation increased from 42% of sampled plants at the start of the study to 75% at the end, and most of the plants had low or moderate levels of infestation (between 0 and 100 adults per 30 cm branch) over the course of the study. Percentage of non-viable adults dropped from ~27% at the start of the study to ~7% by the end of the study, and ratio of nymphs to viable adults dropped from ~9% to ~2%. Spatial analysis showed that initial infestations were along the eastern edge of the sampled area, with populations declining over the first half of the study but then increasing during the second half. Over the course of the study, heavy infestations (≥100 scales per 30 cm branch) were found on only seven host plants. Among plants located in areas of high infestation probabilities, individual host susceptibility appeared to be the primary factor regulating infestation level.

Key Words: Lobate lac scale, infestation level, distribution, spatial analysis

RESUMEN

La escama de laca lobulada, *Paratachardina lobata lobata* (Chamberlin), fue encontrada por primera vez en el sur del estado de Florida en 1999. Los hospederos reportados estan presentes en la colección de germplasma localizada en la Estación de Investigación de Horticultura Subtropical (EIHS) de USDA/ARS en Miami, donde se encontró la escama por primera vez en el verano del 2002. Desde julio de 2003 hasta julio de 2005 se inició un estudio para determinar la dinámica espacial-temporal de la infestación de la escama de laca lobulada en EIHS. El número y el porcentaje de los adultos viables, asi como su éxito reproductivo indicado por la razón de las ninfas con los adultos viables en las plantas (en muestras de ramas <2 cm diam y 30 cm de largo) fueron registrados. Habian 55 plantas evaluadas por las ~80 hectares en el sitio del estudio. La infestación aumentó desde 42% en las plantas muestradas en el inicio del estudio hasta 75% al final, y la mayoria de las plantas tenian un nivel de infestación bajo o moderado (entre 0 y 100 adultos por 30 cm de rama) sobre el recorrido del estudio. El porcentaje de los adultos no viables bajó de ~27% en el inicio del estudio a ~7% para el final del estudio, y la razón de las ninfas con los adultos viables bajó del ~9% al 2%. El análisis espacial mostró que las infestaciones iniciales estaban localizadas por el borde que da al este del área muestreado, con las poblaciones declinando en la primera mitad del estudio pero luego aumentando durante la segunda mitad. Sobre el recorrido del estudio, infestaciones altas (≥100 escamas por 30 cm de rama) fueron encontradas en solo siete plantas hospederas. Entre las plantas en áreas de probabilidades de infestaciones altas, los hospederos en forma individual susceptibles paracen ser el factor principal en regular el nivel de la infestación.

The lobate lac scale, *Paratachardina lobata lobata* (Chamberlin), an insect native to India and Sri Lanka, was first found in the U.S. when it was discovered in Broward County, Florida on *Hibiscus rosasinensis* L. in 1999 (Hamon 2001). It was first found in western Miami-Dade County, Florida in two locations in 2000, then in six locations in 2001 (Howard et al. 2004) and subsequently in over 30 locations throughout Miami-Dade County by 2002 (FL Dept. Agric. and Cons. Serv., personal communication). The number of reported host species increased rapidly from seven in the initial report to over 120 species in 44 families by Oct 2002 (Howard et al. 2004). The host list has since increased to include 160 plants in 49 families (Pemberton 2003a), and includes a number of species native to Florida as well as exotic species that include commercial fruit and ornamental trees. As part of the National Germplasm Repository, the USDA/ARS, Subtropical Horticulture Research Station (SHRS) located in Miami, FL, maintains U.S. clonal collections of tropical and subtropical plants including mango *Mangifera indica* L., avocado *Persea americana* Miller, sugarcane *Saccharum officinarum* L. and related grasses, ornamentals and other tropical crops. Located on the station are 254 genera and 557 species planted over an area of ~80 hectares (Anonymous 2005). Of the 45 plant families listed as lobate lac scale hosts (Howard et al. 2004), 21 are represented in SHRS germplasm. SHRS is located in eastern Miami-Dade County along Biscayne Bay. An infestation of lobate lac scale was first found at SHRS on a black olive tree, *Bucida buceras* L., during the summer of 2002 (F. Howard, personal communication).

To assess the invasive potential of this insect, Pemberton (2003b) evaluated an infestation among plants in a 0.1 hectare yard with a diverse planting of potential host plants in Broward County, Florida in Jul 2002. In that study, 37 of 67 plant species had infestations ranging from a few to many scales and the most severely infested species was wax myrtle, *Myrica cerifera* L. Essentially nothing is known about the biology and control of this pest (Howard et al. 2004), and because it was not known how long the scale had been present in the 0.1 hectare yard, it could not be determined if infestation levels observed were related to time elapsed since initial attack or to susceptibility of the host plant (Pemberton 2003b). Laboratory rearing methods and procedures were not available to address these questions; therefore a field study was initiated in the summer of 2003 to study the spatial and temporal aspects of the relatively recent infestation of the scale at SHRS. Results of this study will provide information on the population dynamics of the lobate lac scale, an essential prerequisite for implementation of a pest management program.

Materials and Methods

The plant database in the USDA/ARS Germplasm Resources Information Network (GRIN) (Anonymous 2005) was reviewed to determine the presence of host plants (Howard et al. 2004) in the collections at SHRS. An initial sampling of representative host plants was conducted from Jul to Aug 2003. Subsequent samplings were performed at ~ 6 month intervals (during Jan-Feb 2004, Jun-Jul 2004, Jan-Feb 2005, and Jun-Jul 2005) for a total of five sampling periods. All plants were assigned identification numbers, plant locations within the ~790 by ~1000 m experimental area at SHRS were obtained by GPS (GPS III Plus; Garmin International, Inc., Olathe, KS) and were recorded in coordinates of longitude and latitude. Plants were visually inspected by examining branches that were <2 cm diam (Howard et al. 2004), and presence or absence of scales was recorded. If scales were observed, then five subsamples of branches (<2 cm diam and 30 cm long) were collected. Subsamples were brought to the laboratory and examined under a stereomicroscope (10×), and number of adult scales per subsample was determined. Scales were recorded as adult if the characteristic lobes were observed (Chamberlin 1923, 1925; Howard et al. 2004). Males have not been observed in Florida (Hamon 2001; Howard et al. 2004), and all scales were assumed to be female. Adults were further classified as viable or non-viable. Viable adult scales had a shiny red appearance, while non-viable adult scales had a dull, reddish-purple color and appeared dry. When the viability of the adult was questionable, the scale was removed from the branch, and presence or absence of a live insect was confirmed by dissection. Percentage of non-viable adults was determined by dividing the number of non-viable adults by the total number of adults per subsample. For all but the first sampling period, numbers of nymphs per subsample were also recorded. The ratio of number of nymphs to number of viable adults was used as an indicator of reproductive success of the scales on the different hosts.

Infestation level on each host was based on the average number of adults per 30 cm length of branch. Infestations were rated as heavy ($x > 100$), moderate ($10 < x \leq 100$), low ($0 < x \leq 10$), or not infested ($x = 0$) (Pemberton 2003b). Two-way analysis of variance with interaction was used to determine the effects of infestation level and sampling period on percentage of adults that were not viable and on the ratio of nymphs to viable adults using a mixed model in Proc GLM (SAS Institute 1998). The Box-Cox procedure, which is a power transformation that regresses log-transformed standard deviations (y + 1) against log-transformed means (x + 1), was used to determine if transformation was necessary to stabilize the variance before analysis (Box et al. 1978).

Contour analysis was used to visualize the spatial distribution of adult scale populations within the experimental site. This was performed with Surfer 8 (Golden Software, Inc., Golden, CO), with GPS coordinates for host locations, a 100 by 65 grid, interpolation by kriging, and a linear variogram model. For this analysis, the raw insect counts (number of adult scales per sample per plant) were converted to indicator variables (Brenner 1993; Arbogast et al. 2000) to reflect the level of infestation. A variable of "1" was assigned to plants with >10 scales per sample, and a variable of "0" was assigned to plants with ≤10 scales per sample. The threshold value of 10 was chosen to differentiate the moderate and heavy infestation levels from the low and no infestation levels, according to the rating system of Pemberton (2003b). Surfer grids were generated from the indicator variables, and maps were constructed using probability contours to highlight areas with moderate to high infestations at each of the five sampling periods.

Results and Discussion

The plant species and average number of adult scales per 30 cm branch per plant for each of the five sampling periods are given in Table 1. Of the 128 plant species included in the Oct 2002 host list (Howard et al. 2004), 35 host species (37 plants with two species sampled twice) were evaluated in the initial 2003 sampling. In addition, 11 non-listed species from reported host genera were evaluated, including seven *Ficus* spp. on which SHRS personnel noted infestations. Thus, a total of 48 plants representing 46 species were examined in Jul-Aug 2003. By fall 2003, heavy scale infestations had been discovered on two *Antidesma* species (Euphorbiaceae), specifically *A. dallachyanum* Baill. and *A. bunis* (L.). Samples were sent for confirmation of identification to FDACS, DPI in Gainesville, FL. These two plants and another related but uninfested plant, *A. venosum* E. Mey, were added to the survey during the Jan-Feb 2004 sampling period, along with two infested *Ficus citrifolia* Mill. Some of the host plants could not be sampled over the full course of the study due to plant death, construction activities that limited access to plants, or tree trimming activities by maintenance personnel that removed most of the small, low branches suitable for scale infestation and for sampling.

The total number of plants evaluated over the 5 sampling periods was 55, but the number sampled during a single period ranged from 49 during Jun-Jul 2004 to 39 during Jun-Jul 2005. There were four plants sampled in the initial survey that were not able to be sampled again due to construction activities at SHRS (*Terminalia muelleri* Bentham, *Peltophorum pterocarpum* (DC.), *Ficus benjamina* L. and *Macadamia integrifolia* Maiden & Betche) and none were infested. A grapefruit, *Citrus* × *paradisi* Macfad., was sampled in the initial survey and a miniature date palm, *Phoenix roebelenii* O'Brien, was sampled in the first two surveys and found to be not infested, but were not sampled again due to plant death. Five plants were sampled throughout the study and were never infested. This included a pond apple, *Annona glabra* L., a pitch apple, *Clusia rosea* Jacquin, a gumbo limbo, *Bursera simaruba* (L.) Sarg., an avocado and a mango.

Among the plants on which scale infestation was found at some time during the study, there were few consistent patterns of population increase or decrease (Table 1). Summary statistics on lobate lac scale population parameters are given in Table 2. Many of the plants inspected were not infested during the first sampling period, but the number of infested plants increased over the course of the study. An increase in the number of plants with low infestations was observed over the first year of the study, but that number declined by the final sampling period. An increase also was observed in the number of plants with moderate infestations, but little change was noted in the number of plants that had heavy infestations. Average number of adults per infestation level remained fairly constant within the low and moderately infested hosts, but numbers increased over time in the heavily infested hosts. No interactions between effects due to infestation level or sampling period were found on the percentage of scales that were non-viable, but there was an effect due to sampling period ($F = 7.29$; $df = 4, 148$; $P < 0.001$; Table 2). The average (± SD) percentage of non-viable adults ranged from 27.1 ± 25.89 to 37.9 ± 31.04 during Jul-Aug 2003 to Jun-Jul 2004, but decreased to 6.5 ± 7.46 to 12.0 ± 18.21 during the Jan-Feb 2005 to Jun-Jul 2005.

Less information was available on the ratio of nymphs to viable adults (Table 2), but there was no single factor or interaction effect of infestation level or sampling period ($F = 0.81$; $df = 11, 117$; $P = 0.6266$). The reproductive success of adults was constant, as indicated by the ratio of nymphs to viable adults, among the three infestation levels during most of the sampling periods, but a trend was detected with decreasing ratios as infestation level increased during the third sampling period. There was also a trend in decreasing reproductive success over time, especially for the plants with low infestation levels.

Spatial aspects of the scale infestation in the experimental site are shown in Fig. 1, which shows the location of host plants sampled and the probability contour maps for moderate-heavy scale infestations during the five sampling periods. The shading in the contour maps indicates infestation probability level, with the darker shading representing higher probability that a host plant within that area will exceed the threshold of 10 adult scales per 30-cm branch. The areas with the highest probabilities of infestation during the initial Jul-Aug 2003 sampling were located on the eastern half of the site (Fig. 1B). This area included the black olive tree (#12) where lobate lac scale was first detected at SHRS in 2002. By Jan-

TABLE 1. AVERAGE NUMBER OF ADULT LOBATE LAC SCALES PER 30-CM LENGTH BRANCH (<2 CM DIAM) AS DETERMINED DURING SAMPLING CONDUCTED AT THE USDA/ARS, SUBTROPICAL HORTICULTURE RESEARCH STATION IN MIAMI, FL.

Family	Species	Common name	Jul-Aug 2003	Jan-Feb 2004	Jun-Jul 2004	Jan-Feb 2005	Jun-Jul 2005
Anacardiaceae	*Mangifera indica* L.	Mango	0.0 ± 0.00	0.2 ± 0.45	1.2 ± 1.64	0.4 ± 0.89	0.0 ± 0.00
Annonaceae	*Annona cherimola* Mill	Atemoya	0.0 ± 0.00	2.6 ± 4.22	1.6 ±1.52	0.4 ± 0.55	0.4 ± 0.55
Annonaceae	*Annona muricata* L.	soursop	0.0 ± 0.00	4.2 ± 5.12	4.6 ±3.29	7.8 ± 3.56	6.4 ± 6.54
Annonaceae	*Annona squamosa* L.	sugar apple	1.4 ± 1.14	21.8 ± 18.05	29.8 ±10.23	26.6 ± 35.81	38.4 ± 74.19
Combretaceae	*Bucida buceras* L.	black olive	129.8 ± 80.35	109.8 ± 84.97	7.2 ± 5.76	27.0 ± 28.20	21.4 ± 9.29
Combretaceae	*Conocarpus erectus* L.	buttonwood	6.0 ± 4.47	5.8 ± 5.02	5.0 ± 7.91	36.4 ± 22.85	123.0 ± 89.21
Combretaceae	*Terminalia catappa* L.	tropical almond	130.0 ± 55.31	9.6 ± 2.61	9.0 ± 8.12	3.8 ± 5.54	13.4 ± 14.57
Ebenaceae	*Diospyros digyna* Jacquin	black sapote	4.6 ± 3.05	16.8 ± 15.69	12.6 ± 11.24	64.8 ± 81.20	81.8 ± 47.96
Elaeocarpaceae	*Elaeocarpus japonicus* Turcz.**	none	11.4 ± 18.60	7.0 ± 9.59	6.2 ± 6.65	7.8 ± 9.86	ns
Euphorbiaceae	*Antidesma bunius* (L.) Spreng.	bignay	ns	197.4 ± 119.77	272.0 ± 159.25	426.6 ± 56.60	3.4 ± 7.60
Euphorbiaceae	*Antidesma dallachyanum* Baill.*	Herbert River cherry	ns	148.0 ± 104.13	114.0 ± 73.36	238.2 ± 132.23	ns
Euphorbiaceae	*Antidesma venosum* E. Mey.*	tassle berry	ns	0.0 ± 0.00	0.2 ± 0.45	0.4 ± 0.55	0.0 ± 0.00
Fabaceae	*Bauhinia* sp.**	orchid tree	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 00	0.4 ± 0.89
Fabaceae	*Inga* sp.**	none	0.0 ± 0.00	7.8 ± 3.56	38.6 ± 49.33	26.6 ± 10.76	ns
Fagaceae	*Quercus virginiana* Miller	live oak	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.2 ± 0.45	0.0 ± 0.00
Lythraceae	*Lagerstroemia* sp.**	crape myrtle hybrid	0.0 ± 0.00	0.2 ± 0.45	1.0 ± 1.00	2.0 ± 1.58	1.4 ± 1.14
Lythraceae	*Lagerstroemia speciosa* (L.) Pers.	queen's crape myrtle	0.0 ± 0.00	0.0 ± 0.00	0.4 ± 0.55	5.2 ± 5.17	ns
Moraceae	*Brosimum alicastrum* Sw.	Mayan breadnut	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.4 ± 0.55	ns
Moraceae	*Ficus altissima* Blume*	blume council tree	5.8 ± 5.54	4.4 ± 2.41	5.8 ± 5.67	10.0 ± 17.93	3.4 ± 1.67
Moraceae	*Ficus aurea* Nutt.	strangler fig	8.6 ± 8.44	0.0 ± 0.00	0.6 ± 0.89	1.8 ± 3.49	ns
Moraceae	*Ficus citrifolia* Mill.*	shortleaf fig	ns	ns	16.6 ± 10.83	10.2 ± 5.76	7.0 ± 8.51
Moraceae	*Ficus citrifolia* Mill.*	shortleaf fig	ns	ns	5.4 ± 5.22	4.0 ± 8.40	13.8 ± 12.46
Moraceae	*Ficus microcarpa var. rigo* (F.M. Bailey)	Indian laurel	6.0 ± 5.05	4.2 ± 3.42	2.2 ± 2.68	0.2 ± 0.45	3.0 ± 5.10
Moraceae	*Ficus racemosa* L.*	cluster fig ficus	12.6 ± 7.57	5.4 ± 3.65	17.4 ±1 7.04	6.4 ± 8.38	1.8 ± 1.79
Moraceae	*Ficus religiosa* L.*	bodhi tree peepul tree	0.4 ± 0.89	5.6 ± 9.32	0.2 ± 0.45	0.0 ± 0.00	0.2 ± 0.45
Moraceae	*Ficus superba var. henneana* (Miq.)*	port hacking fig superb	27.2 ± 19.88	32.0 ± 10.68	31.2 ± 40.20	31.4 ± 23.75	13.2 ± 14.39
Moraceae	*Ficus sur* Forssk*.	cape fig	6.6 ± 7.13	2.0 ± 1.87	8.8 ± 19.68	2.0 ± 2.00	2.8 ± 1.92
Moraceae	*Ficus tinctoria sub. parasitica* (Willd.)*	fig	24.6 ± 27.52	55.4 ± 32.73	68.8 ± 74.33	81.0 ± 96.44	55.2 ± 74.52
Moraceae	*Ficus virens* Aiton*	big leaved fig	6.2 ± 13.86	3.0 ± 2.12	2.50 ± 2.55	4.0 ± 6.82	6.0 ± 3.08
Myrtaceae	*Callistemon viminalis* (Sol. ex Gaertn.)	weeping bottle brush	0.0 ± 0.0	1.2 ± 0.84	4.6 ± 4.72	0.4 ± 0.55	ns
Myrtaceae	*Eugenia uniflora* L.	Suriname cherry	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.6 ± 0.55	2.0 ± 2.45
Myrtaceae	*Pimenta dioica* (L.)	allspice	0.0 ± 0.00	0.0 ± 0.00	0.6 ± 1.34	ns	ns
Myrtaceae	*Pimenta dioica* (L.)	allspice	0.0 ± 0.00	0.0 ± 0.00	0.8 ± 1.79	0.0 ± 0.00	0.0 ± 0.00

Infested plants* or genera** not listed previously as hosts for lobate lac scale (Howard et al. 2004).
ns = not sampled due to late addition or loss of plant due to plant death (allspice, rose) or tree trimming activities.

TABLE 1. (CONTINUED) AVERAGE NUMBER OF ADULT LOBATE LAC SCALES PER 30-CM LENGTH BRANCH (<2 CM DIAM) AS DETERMINED DURING SAMPLING CONDUCTED AT THE USDA/ARS, SUBTROPICAL HORTICULTURE RESEARCH STATION IN MIAMI, FL.

Family	Species	Common name	Jul-Aug 2003	Jan-Feb 2004	Jun-Jul 2004	Jan-Feb 2005	Jun-Jul 2005
Myrtaceae	*Psidium littorale* Raddi	cattley guava	152.2 ± 26.03	273.8 ± 41.45	58.0 ± 40.45	22.0 ± 26.61	72.2 ± 65.21
Myrtaceae	*Syzigium cumini* (L.)	java plum	31.4 ± 20.12	22.0 ± 18.75	1.8 ± 2.95	0.0 ± 0.00	31.0 ± 17.82
Myrtaceae	*Syzigium cumini* (L.)	java plum	21.4 ± 7.44	43.6 ± 26.38	33.8 ± 19.77	7.4 ± 5.32	ns
Myrtaceae	*Syzygium polyanthum* (Wight)*	Indonesian bay leaf	ns	0.0 ± 0.00	8.8 ± 19.12	20.2 ± 23.70	12.2 ± 16.24
Oxalidaceae	*Averrhoa carambola* L.	carambola	63.6 ± 44.46	109.2 ± 69.44	16.8 ± 23.83	189.6 ± 138.72	516.4 ± 451.37
Polygalaceae	*Polygala cowellii* (Britton)	violet tree	71.4 ± 54.51	47.6 ± 46.13	37.2 ± 39.16	36.0 ± 14.09	19.2 ± 15.63
Roseaceae	*Rosa* sp	rose	ns	5.6 ± 5.22	0.4 ± 0.89	ns	ns
Sapindaceae	*Blighia sapida* K. D. Koenig	akee	0.0 ± 0.00	0.0 ± 0.00	0.8 ± 1.30	1.0 ± 1.00	17.4 ± 14.86
Sapindaceae	*Litchi chinensis* Brewster	lychee	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.2 ± 0.45	5.4 ± 3.51
Sapotaceae	*Manilkara zapota* (L.)	sapodilla	0.0 ± 0.00	0.0 ± 0.00	2.6 ± 3.21	0.0 ± 0.00	14.0 ± 4.18

Infested plants* or genera** not listed previously as hosts for lobate lac scale (Howard et al. 2004).
ns = not sampled due to late addition or loss of plant due to plant death (allspice, rose) or tree trimming activities.

Feb 2004 (Fig. 1C), a new focus of high probability was obtained in the northwest corner of the site. The three trees sampled in this area included a custard apple, *Annona reticulata* L., a sugar apple, *Annona squamosa* L., and a black sapote, *Diospyros digyna* Jacquin (#18). Of those three trees, infestation increased from none to low in the custard apple and from low to moderate in the other two trees. Areas of 0.75 probability of at least moderate infestation levels within the eastern portion were reduced slightly by Jan-Feb 2004, and were greatly reduced by the Jun-Jul 2004 sampling period (Fig. 1D). Probability of at least moderate infestation levels then increased by the Jan-Feb 2005 (Fig. 1E) through the Jun-Jul 2005 (Fig. 1F) sampling periods. The populations detected in Jan-Feb 2004 in the northwest corner, however, remained stable during the subsequent sampling periods.

Of the 55 plant species sampled over the five sampling periods, heavy scale infestations were found on only seven plants, whose positions are shown in Figure 1A. These were bignay (#5), Herbert River cherry (#6), carambola (#8), black olive (#12), buttonwood (#17), cattley guava (#47) and tropical almond (#53). Except for the initial sampling period, most of the remaining plants sampled had either low or moderate infestations. The three plants with heavy infestations at the start of the study (black olive, cattley guava, and tropical almond) dropped to moderate or low infestations over the time period of the study. The other four plants either maintained heavy infestations for several sampling periods or increased to heavy infestations late in the study. No pesticide application or other control measures were applied but all were subject to pruning and other germplasm maintenance operations that may have either limited or increased the amount of small branches available for additional scale population growth. Spatial analysis of the adult distribution showed an increase in infestation in the northwest corner between Jul-Aug 2003 and Jan-Feb 2004 (due to moderate infestation on black sapote, #18), but level of infestation in that area remained constant over the remaining three sampling periods. In contrast, scale infestations along the eastern edge of the sampling area decreased between Jul-Aug 2003 and Jun-Jul 2004 (primarily on black olive and tropical almond) but then increased over the final two sampling periods (on other host plants). Between Jun-Jul 2004 and Jan-Feb 2005, several hurricane-related wind events impacted the plants in the sampling area. It is not known why populations rebounded, but post-hurricane regrowth of small branches may have stimulated the population increase in susceptible hosts on which infestation had dropped to low levels prior to the 2004 hurricane activity.

Over the two years of monitoring changes in lobate lac scale populations on infested plants, indi-

TABLE 2. AVERAGE (± STD. DEV.) NUMBER OF ADULT LOBATE LAC SCALES, PERCENT OF ADULTS THAT WERE NOT VIABLE, AND RATIO OF NYMPHS TO VIABLE ADULTS PER 30-CM LENGTH BRANCH (<2 CM DIAM) FOR EACH INFESTATION LEVEL AS DETERMINED DURING SAMPLING CONDUCTED AT THE USDA/ARS, SUBTROPICAL HORTICULTURE RESEARCH STATION IN MIAMI, FL.

Infestation level	*n*	Jul-Aug 2003	*n*	Jan-Feb 2004	*n*	Jun-Jul 2004	*n*	Jan-Feb 2005	*n*	Jun-Jul 2005
Number of adult scales										
none	28	0.0 ± 0.00	19	0.0 ± 0.00	11	0.0 ± 0.00	10	0.0 ± 0.00	10	0.0 ± 0.00
low	9	5.1 ± 2.59	17	4.1 ± 2.76	22	3.1 ± 2.84	22	2.7 ± 2.70	14	3.1 ± 2.30
moderate	8	33.0 ± 22.47	7	34.6 ± 15.23	14	34.6 ± 23.28	12	32.7 ± 20.86	13	31.0 ± 23.98
heavy	3	137.4 ± 12.82	5	167.6 ± 69.47	2	241.3 ± 139.65	3	284.8 ± 125.18	2	319.7 ± 278.18
Percent of adults that were dead										
low	9	31.5 ± 16.70	17	32.4 ± 31.91	22	30.3 ± 31.93	22	7.8 ± 12.96	14	5.2 ± 8.22
moderate	8	19.1 ± 14.61	7	47.2 ± 31.43	14	21.6 ± 14.01	12	20.6 ± 25.37	13	8.9 ± 6.62
heavy	3	35.7 ± 9.73	5	43.6 ± 29.53	2	30.8 ± 12.82	3	8.7 ± 3.27	2	1.2 ± 0.73
Ratio of nymphs to live adults										
low	not determined		17	8.2 ± 8.10	20	10.0 ± 31.61	22	0.8 ± 1.29	12	0.9 ± 0.96
moderate	not determined		7	10.6 ± 15.17	14	5.8 ± 10.60	12	0.8 ± 0.74	13	2.7 ± 3.55
heavy	not determined		5	7.4 ± 7.59	2	1.2 ± 0.55	3	0.8 ± 1.04	2	2.0 ± 1.98

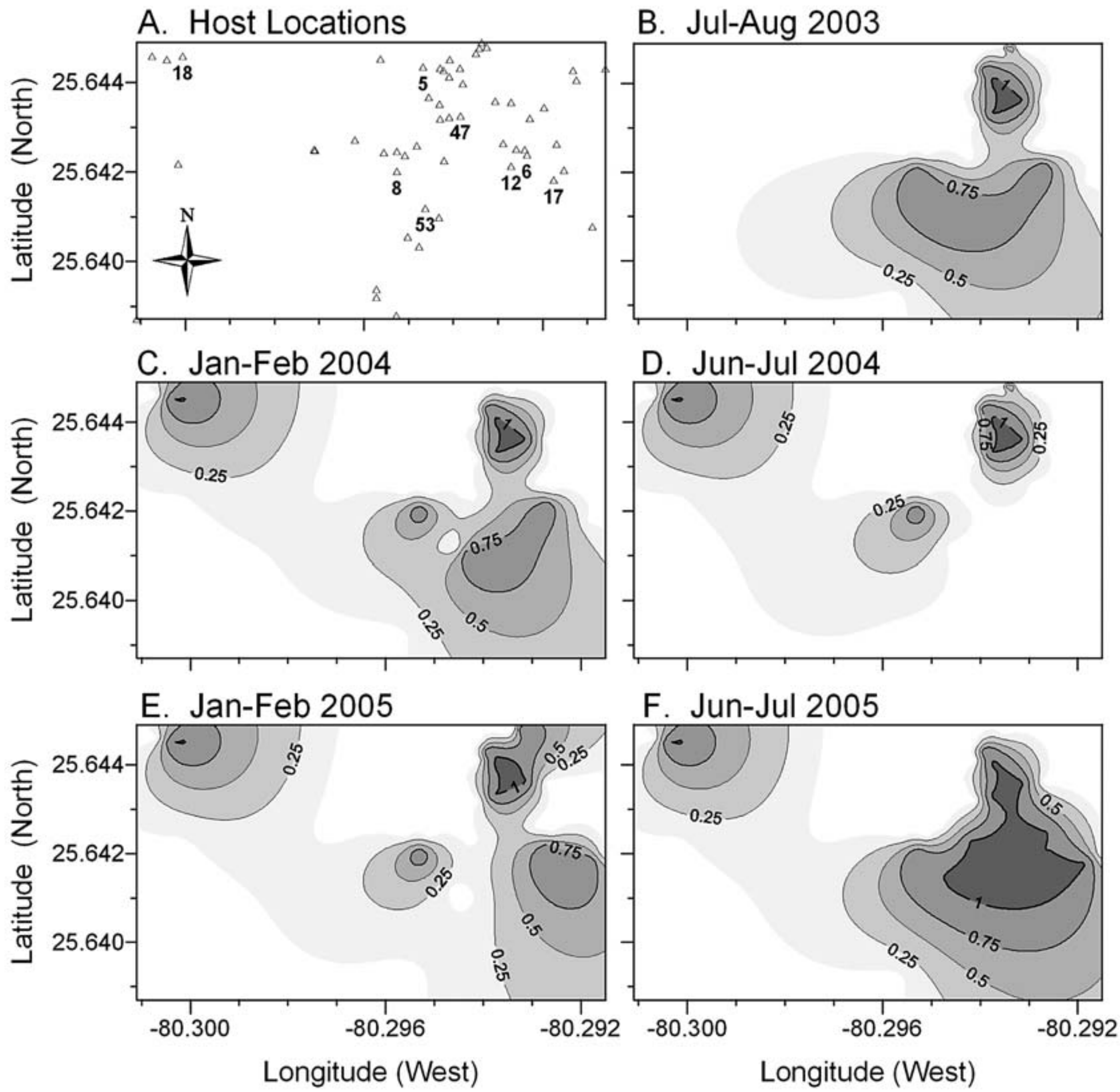

Fig. 1. Location of plants sampled for lobate lac scale over ~80 hectares of germplasm maintained at the USDA/ARS, SHRS in Miami, FL (A); and probability contour maps of moderate to heavy scale infestations detected from July-August 2003 (B), January-February 2004 (C), June-July 2004 (D), January-February 2005 (E), and June-July 2005 (F). Identification numbers on map A indicate the most heavily infested host plants. Moderate to heavy infestation is specified as more than 10 adult scales per 30 cm length branch (Pemberton 2003b).

vidual host susceptibility appeared to be the primary factor regulating population level once the infestation was initiated. Percentage viable adults and reproductive success was not affected by infestation level. Scale populations on some hosts fluctuated rapidly, with populations either building up or crashing. Other plants had only low infestation levels or remained uninfested even though they have been reported as hosts for the scale and were located near infested plants. Seven plants evaluated in our study were listed as highly susceptible to lobate lac scale (Howard et al. 2004), and we found heavy infestations on three, i.e., black olive, buttonwood, and carambola. The other four plants (mango, strangler fig, Indian laurel, and lychee) had either no or low infestations. A number of plants included in our study also were evaluated by Pemberton (2003b) and, of the highly susceptible plants that were listed by Howard et al. (2004) and that were included in both studies, there was a heavy infestation on carambola and moderate infestations on black olive, lychee, and mango. Among the remaining plants, sugar apple had a moderate infestation and atemoya, suriname cherry, and allspice had low infestations in both studies; while soursop had a lower infestation level and sapodilla had a higher infestation level in our study. Thus, there may be varietal differences among potential hosts that will further influence host susceptibility.

The recent invasion of this insect into the study site presented a unique opportunity to follow the spatio-temporal dynamics of the invasion by what was, at that time, a new pest to the area. The most dynamic changes within the experimental area throughout the study occurred in the area of the initial infestation. Comparisons over time found that the population decreased by the 2nd and 3rd samplings, but then increased by the 4th and 5th samplings. Since scales primarily infest twigs and small branches <2 cm diam (Howard et al. 2004), the hurricane activity in Aug-September 2004 may have resulted in a flush of new growth on trees that were susceptible to scale infestations resulting in an increase in feeding sites that promoted scale population growth. Additional studies are needed to determine growth parameters for lobate lac scale and to better understand the relationship between host susceptibility and population growth of this insect. Identification of host varieties that are resistant to lobate lac scale infestation would provide an important component for IPM approaches for this pest.

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