Research Note

THE CYCAD SCALE, AULACASPIS YASUMATSUI *TAKAGI (HOMOPTERA: DIASPIDIDAE): A NEW INVASIVE PEST TO PUERTO RICO*[1,2]

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At least six species of scale insects occur on cycads in Puerto Rico (Martorell, 1976; Colón-Ferrer and Medina-Gaud, 1998). The most damaging is the newly introduced cycad aulacaspis scale (CAS) (*Aulacaspis yasumatsui* Takagi) (Figure 1A). This scale, native to Thailand, is currently found in China, Singapore, Hong Kong, Guam, Cayman Islands, Puerto Rico and Vieques islands, U.S. Virgin Islands, Hawaiian islands (Hawaii and Oahu) and Florida (Ben-Dov, 2003). In addition to the known distribution, CAS has also been intercepted in France (Germain, 2002). The invasive *Aulacaspis yasumatsui* was first found in Dorado, Puerto Rico, in 1999 on cycads (Dr. Rosa A. Franqui, Univ. of Puerto Rico, Agricultural Experiment Station, pers. comm.), and it has become widely distributed throughout the island of Puerto Rico (Aixa Ramírez, Department of Agriculture of Puerto Rico, pers. comm.).

For the past 40 years, cycads have become important landscaping plants in Puerto Rico. Now, subsequent to the scale's accidental introduction, plants of the genus *Cycas* are threatened island-wide. It is typical of this scale's populations to quickly reach high densities on their hosts, causing necrosis of fronds and eventually plant death (Howard et al., 1999; Hodges et al., 2004). Most infestations have been detected on *Cycas* spp., especially *C. revoluta*, which is the most widely planted cycad in Puerto Rico. Experts estimate that up to 30% of cycads in Puerto Rico have been killed by CAS in the past five years, and that up to 75% of the remaining plants suffer from some level of infestation (Aixa Ramírez, Department of Agriculture of Puerto Rico, pers. comm.).

Authors and pest control practitioners agree that CAS is unusually hard to control (Weissling et al., 1999). According to these authors, it is present on the roots; thus the inability of most pesticide applications to reach this zone makes CAS difficult to control by using conventional pesticide treatments. Initially, damage appears as chlorotic spots, but most of the fronds eventually become brown and desiccated (Figure 1B). *Aulacaspis yasumatsui* scales are consistently more numerous on the lower than on the upper surfaces of leaflets, but in heavy infestations CAS may occupy both leaf surfaces. Both males and females are found, but male scales, which are half as large as females, are nearly always more numerous in late infestations (A. Segarra, unpublished). Commonly, individuals are encrusted in several layers, where up to 500 scales per cm^2 have been observed. Highly infested cycads are almost completely coated with a white crust that includes the

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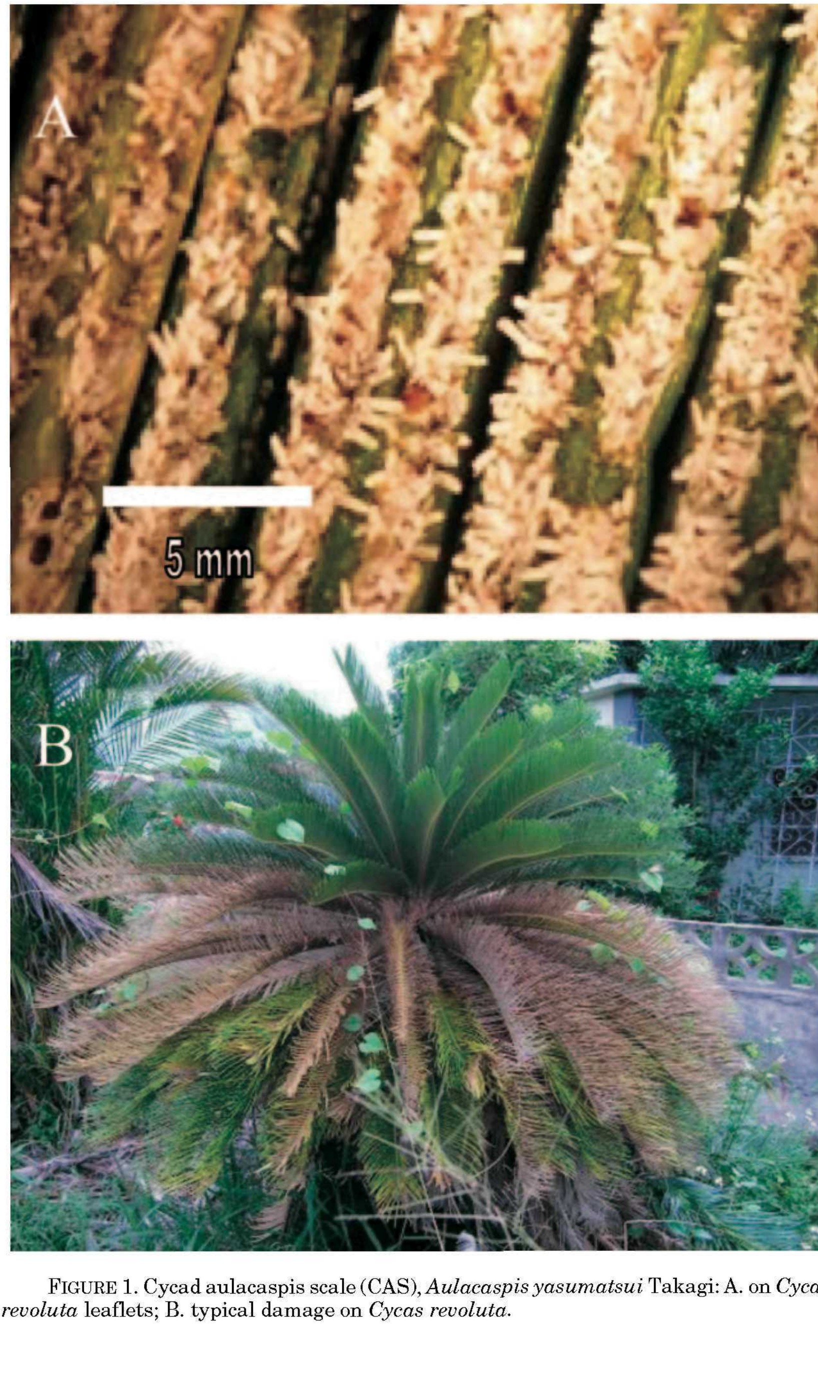

FIGURE 1. Cycad aulacaspis scale (CAS), *Aulacaspis yasumatsui* Takagi: A. on *Cycas revoluta* leaflets; B. typical damage on *Cycas revoluta*.

bodies of dead scale insects on top, and live scales buried below them (Weissling et al., 1999). This behavior is known as "burrowing".

Little is known about native or introduced natural enemies attacking CAS throughout most of its expanding range, including Puerto Rico. In Florida, two natural enemies of CAS were released in 1997 and 1998. These were a predaceous nitidulid beetle, *Cybocephalus binotatus* Grouvelle, and a parasitic wasp, *Coccobius fulvus* (Compere and Annecke). These natural enemies seem to control CAS effectively during certain periods, but for reasons yet unknown the scale insect seems to undergo population outbreaks that outstrip the natural reproductive capacity of its enemies; some of these outbreaks are more severe at some sites than at others (Hodges et al., 2004).

Given the importance of this scale and the need to identify existing natural control agents, we set forth the following goals in the present study: (1) to systematically search and record cycad scale infestations in western Puerto Rico; (2) to estimate plant morbidity and cycad scale infestation rates in the same area; (3) to identify natural enemies of CAS and quantify their load.

Survey. Since cycads are landscape ornamentals, most survey samples were collected from urban settings. A total of 27 housing developments were visited in the towns of Añasco (n = 5), Mayagüez (n = 12), Hormigueros (n = 3) and Cabo Rojo (n = 7) between May and September 2005. Two surveys were conducted in this study. One survey took place between May and early June 2005. A second survey of the same area was undertaken during August and September 2005. The same sites were visited in order to determine any progression in CAS infestation and to resample scales for parasitism. Approximately 4,200 dwellings were surveyed for presence of cycad trees; each development contained between 120 and 250 dwellings. Every cycad encountered was examined for CAS. If CAS was present, each plant was evaluated for attack severity. One of three arbitrary categories was assigned to each site: [1] lightly infested (less than 10% leaves infested or less than five scales per cm^2); [2] medium (between 10% and 50% infested or between five and 10 scales per cm^2); and [3] heavily infested (more the 50% leaves infested or more than 10 scales per cm^2). Cycad species, location, and infestation level were recorded. Finally, eggs were counted under the microscope on fifteen newly gravid females to obtain an estimate of fecundity. Hatched eggs under the scale were also counted, but no attempts were made to count eggs still in their ovaries.

Leaf Samples. Four leaves, typically from the upper mid-crown section and still green, were sampled from each infested plant, following cardinal directions (i.e., north, east, south, and west). Upper leaflet sections (apical on rachides, and containing at least 10 leaflet pairs) were collected from individual leaves. Leaflet sections were placed in plastic bags and brought to the laboratory for examination.

Natural Enemies. All sites were inspected for the presence of natural enemies. Plants were visually checked for common predators. Predator samples were collected with an aspirator and were brought to the laboratory for identification. Some 150 to 200 females were examined at each site. The presence of CAS parasitoids was determined by examining each CAS female under a dissection microscope. Males were never observed parasitized. The presence of exit holes, parasitoid eggs, larvae, or pupae was taken as signs of parasitism and so recorded. Parasitized CAS females were individually transferred to gelatin capsules. Capsules were placed inside a petri dish and observed daily until parasitoid emergence. Emerging parasitoids were transferred to 70% ethanol and sent for identification to USDA's Systematic Entomology Laboratory in Beltsville, Maryland.

Statistical Analyses. Means and standard error (SE) are reported throughout the paper. Differences in percentage parasitism among sites of different CAS population density and in parasitism levels between sampling sessions were determined by using one-way ANOVA. Means were separated by using Student-Newman-Keuls multiple comparison tests at $\alpha \leq 0.05$. Fisher's exact test for independence was used to determine the relationship between pre-gravid (no eggs) and gravid (with eggs) parasitized CAS and parasitoid sex ratio.

Infestation Levels. One hundred percent of all *Cycas* spp. individuals sampled were infested. The most common cycad found in landscapes was *Cycas revoluta* Thunberg, followed distantly by *C. rumphii* Miquel. Another common cycad sampled was *Zamia furfuracea* Aiton, but this species was never found attacked by CAS. Likewise, one specimen of *Dioon* sp., found in Añasco, was not infested, even when in close proximity to heavily infested *C. revoluta* plants. Six specimens of the endemic *Zamia portoricensis* Urban growing on the Mayagüez Campus of the University of Puerto Rico were also found unaffected by the scale.

Of the 37 sites visited, 18 (48.7%) were heavily infested, 13 had medium infestations (35.1%), and six had light infestations (16.2%). A larger number of sites were sampled in Mayagüez (18), followed by Cabo Rojo (nine), Añasco (six) and Hormigueros (four). Most of the high density sites were found in Mayagüez and Cabo Rojo (Figure 2). The latter result could be due to the greater number of sites sampled in Mayagüez.

One of the more striking findings of this investigation was the rapid extinction rate of sampled cycads, especially of the more susceptible *Cycas* spp. Of a total of 34 *C. revoluta* plants examined during the first sampling, only 17 (50%) were found alive two months later. All had been cut down by owners who had obviously found them unsightly.

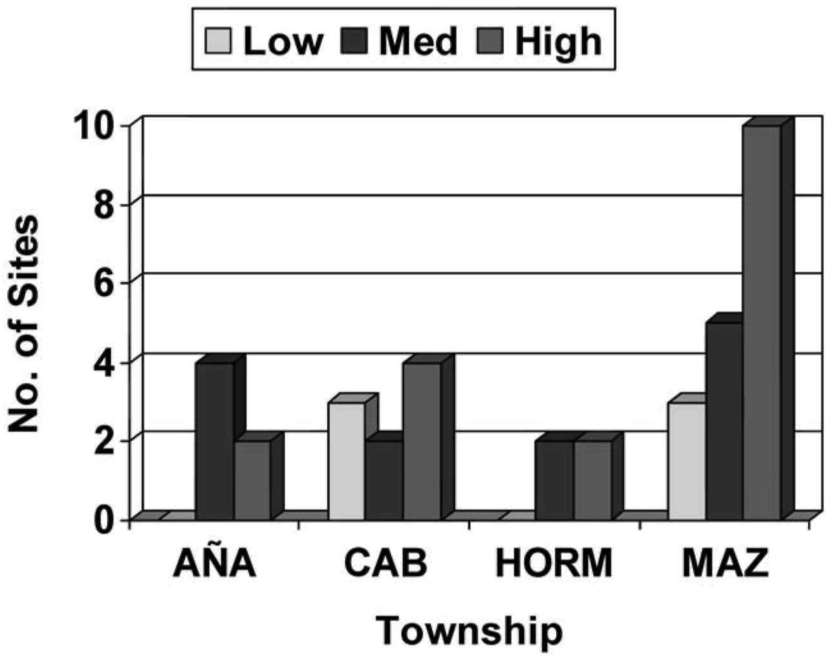

FIGURE 2. Cycad aulacaspis scale, *Aulacaspis yasumatsui*, density in surveyed sites (AÑA = Añasco; CAB = Cabo Rojo; HOR = Hormigueros; and MAZ = Mayagüez).

Predation and Parasitism. We observed very few instances of predators feeding on the cycad scale. In only one case, we found two larvae of the common mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae), feeding on CAS scales. In another instance, we found a single adult of *Chilocorus cacti* L. (Coleoptera: Coccinellidae) feeding on CAS. In both instances other scales, such as *Saissetia coffeae* (Walker), *Aonidiella orientalis* (Newstead), and *Coccus accutissimus* (Green) were also present growing on the same fronds as CAS. Presumably, these predators could have also been feeding on some of these commonly found scales.

Parasitoid sampling was conducted at 37 sites. A total of 7,491 females were examined. We isolated two hymenopterous parasitoid species: the encyrtid *Coccobius fulvus* (Compere & Annecke) and *Ablerus* sp., an aphelinid wasp. The latter is known for its habits as a hyperparasitoid of scale parasitoids. Scale parasitism averaged 24.4 ± 2.9% among sites (mean ± s.e), with a median of 21.5%; values ranged between 1.3% and 72.4%.

We did not find strong evidence of density responses by *Coccobius fulvus* to their host. We found no significant differences between parasitism levels at high CAS density sites, medium density, and low scale density sites ($F = 2.22$; $p = 0.10$). However, some form of inverse density-dependent parasitism may be at work, since high and medium density sites tended to have lower parasitism than low density sites (Table 1).

Similar reports are available for other scales attacked by *Coccobius fulvus.* Matsumoto et al. (2003) found that the host settling behavior of the arrowhead scale (*Unaspis yanonensis* Kawana) may protect it against parasitoids. At high population densities, arrowhead scale crawlers burrowed under settled scales as a defense mechanism against parasitoids. Burrowed scales were less likely to be parasitized than scales settling singly or those under which scales are burrowed. A similar defense mechanism against its parasitoids may be at work by the cycad scale as burrowing is also observed at high population densities of this species. It is likely that crawler burrowing could serve as a mechanism protecting scales from contact pesticide applications at high densities as well.

A sample of 50 parasitized female scales from 10 high-density sites showed that 27.3 ± 7.0% were gravid. The mean number of eggs in these parasitized scale females was 9.3 ± 1.5 ($n = 15$), as compared to unparasitized gravid females with 62.8 ± 4.7 eggs ($n = 15$). We found that the sex ratio of *Coccobius fulvus* was 3♀:1♂. We also explored the possibility that the sex ratio of *Coccobius fulvus* could be affected by the choice of gravid or non-gravid scale females as hosts. We found no dependence effect between scale reproductive state and parasitoid sex ratio (Fisher's exact test, $n = 36$, $p = 0.51$, N.S.).

Finally, in order to detect temporal changes in parasitism level, we visited 12 sites during both sampling periods. These sites represent those plants still extant from all municipalities, since the norm was for owners to cut down heavily infested cycads. Parasitism seemed higher in the May to June sampling (33.3 ± 5.8%) than in the August to September survey (26.0 ± 4.9%). However, we found no significant differences in parasitism levels between sampling periods ($F = 0.91$; $p = 0.35$).

TABLE 1.—*Cycad aulacaspis scale (CAS) population density and percentage parasitism by Coccobius fulvus.*[1]

CAS density	No. of sites	Mean % parasitism	SNK group
High	18	27.4 ± 4.2	ab
Medium	13	17.2 ± 3.0	a
Low	6	40.4 ± 9.8	b

[1]Means followed by the same letter are not significantly different at $p < 0.05$.

The cycad aulacaspis scale is a specialist in cycads. Thus, *Aulacaspis yasumatsui* was likely introduced into Puerto Rico through the importation of cycad plants from infested countries. It is understood that *A. yasumatsui* has a high potential for spreading to new areas via plant movements, because one or a few hidden gravid females can easily escape detection. Interestingly, we found *C. fulvus* parasitizing almost a quarter of all sampled scales. There is no indication how this parasitoid got into Puerto Rico, but we suspect that it was introduced with its host. There is no previous record of this species on the island. One possible hypothesis is that they were simultaneously introduced. Interestingly, by 1999, when the cycad scale was first reported in Puerto Rico, only Florida had already introduced *Coccobius fulvus* from Thailand for CAS control.

Another conclusion leads us to explore briefly the impact of this introduction to native and introduced cycads in Puerto Rico. We have found that the impact of this scale's introduction has been severe. Presently, homeowners and nurserymen in Puerto Rico struggle to control CAS, but its habit of attacking all parts of the plant, and its rapid rate of reproduction make its management economically demanding and technically challenging. Already, the introduction of *A. yasumatsui* has led local commercial growers to cease *Cycas* spp. propagation and sale. A comprehensive survey of Puerto Rican nurserymen shows that most have abandoned cultivation and sale of *Cycas revoluta* (Luis R. Santiago, Univ. of Puerto Rico, Agricultural Experiment Station, pers. comm.). Similarly, homeowners accustomed to these stately and low-maintenance ornamentals are generally taking down and eliminating infested and dying cycads. Cycads are valuable ornamental plants and many homeowners have lost their investment. Current trends indicate a severe threat to future cycad trade and an end to their use as landscape centerpieces in Puerto Rico.

Lastly, *C. revoluta*, the sago palm, is endemic to the Japanese islands of Kyushu and Ryukyu (Whitelock, 2002). Prized for its ornamental appearance, hardiness and adaptability, *C. revoluta* quickly gained favor of explorers and importers in the 20th century (Jones, 2002). Thanks to human action, it is without a doubt the most widely distributed member of the genus, having found a home on every continent except Antarctica. Now another human action threatens the species in its new range with the introduction of *A. yasumatsui*. It will no doubt be fascinating to observe, as this introduced species becomes more threatened, how the process of its local extinction proceeds.

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