

Rapid Communication

Cycad *Aulacaspis* Scale (*Aulacaspis yasumatsui* Takagi, 1977) in Mexico and Guatemala: a threat to native cycads

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Abstract

Cycad *Aulacaspis* Scale (Hemiptera: Diaspididae: *Aulacaspis yasumatsui* Takagi, 1977), which is native to Southeast Asia, is a devastating pest of some species of cycads in areas where it is invasive. In September 2016, it was reported to be present in Chiapas in southern Mexico, a country with 60 native cycad species, most of which are endemic and endangered. Here we report the presence of the pest in 6 additional Mexican states and in Guatemala. Surveys of natural populations and quasi-natural sustainable nurseries in 4 states, including Chiapas, find no evidence that the pest has yet spread to natural populations. At present, it appears to be confined to cultivated cycads, presenting a window of opportunity for effective control.

Key words: armored scale insects, botanical gardens, Coccoidea, endangered species, ethnobotany, Hemiptera, ornamental plants

Introduction

Cycads (Cycadophyta: Cycadales) are one of five extant divisions of seed plants, comprising 348 extant species, of which almost all are threatened or endangered (Donaldson 2003; Calonje et al. 2017). Cycad *Aulacaspis* Scale (*Aulacaspis yasumatsui* Takagi, 1977) is an armored scale insect (Hemiptera: Diaspididae) that exclusively attacks cycads and

may kill its host (Marler and Lawrence 2012). Cycad *Aulacaspis* Scale is native to Southeast Asia and has been inadvertently introduced in many regions around the world, probably due to international trade in cultivated cycads. The most worrisome of these introductions from a conservation perspective are those in areas with native cycads, such as tropical Pacific islands (Marler and Lawrence 2012), South Africa (Nesamari et al. 2015), and the New World

Table 1. Surveys of natural populations. Latitude and longitude are given as low-resolution figures as a security measure given the prevalence of poaching. All localities are in Mexico. The results were uniformly negative: no potential Cycad Aulacaspis Scale (that is, no armored scale insects with white scale covers and marginal exuviae) were found in any of these populations.

Date	State	Locality	Latitude	Longitude	Cycad species	Individuals searched
13-Sep-2016	Chiapas	Jiquipilas	16.62	-93.58	<i>Dioon merolae</i> De Luca, Sabato & Vázquez-Torres, 1981	11
14-Sep-16	Chiapas	Arriaga	16.40	-93.98	<i>Ceratozamia alvarezii</i> Pérez-Farr., Vovides & Iglesias, 1999	27
15-Sep-2016	Chiapas	Cristobal Obregón	16.37	-93.61	<i>Ceratozamia mirandae</i> Pérez-Farr., Vovides & Iglesias, 2001	20
17-Sep-2016	Chiapas	Ocozocouatlá	16.93	-93.45	<i>Zamia splendens</i> Schutzman, 1984	10
19-Sep-2016	Chiapas	San Fernando	16.94	-93.23	<i>Zamia splendens</i> Schutzman, 1984	6
19-Sep-2016	Chiapas	San Fernando	16.94	-93.23	<i>Ceratozamia robusta</i> Miq., 1847	3
19-Sep-2016	Chiapas	San Fernando	16.95	-93.25	<i>Ceratozamia robusta</i> Miq., 1847	2
19-Sep-2016	Chiapas	San Fernando	16.96	-93.27	<i>Ceratozamia robusta</i> Miq., 1847	8
19-Sep-2016	Chiapas	San Fernando	16.96	-93.27	<i>Zamia splendens</i> Schutzman, 1984	5
5-Oct-2016	Hidalgo	Malila	20.73	-98.73	<i>Ceratozamia fuscoviridis</i> W. Bull., 1879	11
6-Oct-2016	Hidalgo	Tlanchinol	20.97	-98.67	<i>Ceratozamia fuscoviridis</i> W. Bull., 1879	10
6-Oct-2016	Hidalgo	Tlanchinol	21.04	-98.64	<i>Ceratozamia fuscoviridis</i> W. Bull., 1879	11
7-Oct-2016	Hidalgo	San Bartolo Tutotepec	20.41	-98.21	<i>Ceratozamia fuscoviridis</i> W. Bull., 1879	9
18-Oct-2016	Querétaro	Valle Verde	21.48	-99.21	<i>Dioon edule</i> Lindl., 1843	14
19-Oct-2016	Querétaro	Valle Verde	21.62	-99.18	<i>Dioon edule</i> Lindl., 1843	19
6-Dec-2016	Veracruz	Monte Obscuro	19.39	-96.78	<i>Dioon edule</i> Lindl., 1843	10
6-Dec-2016	Veracruz	Monte Obscuro	19.39	-96.78	<i>Zamia furfuracea</i> L.f., 1789	2
6-Dec-2016	Veracruz	Monte Obscuro	19.39	-96.79	<i>Zamia loddigesii</i> Miq., 1843	7
6-Dec-2016	Veracruz	Monte Obscuro	19.39	-96.79	<i>Dioon edule</i> Lindl., 1843	2

(González-Gómez et al. 2016). By far the most devastating effects of Cycad Aulacaspis Scale have been seen in forests of native *Cycas* L., 1753, on tropical Pacific islands, especially *C. micronesica* K.D. Hill, 1994, in Guam. Marler and Lawrence (2012) reported that Cycad Aulacaspis Scale killed every *C. micronesica* seedling in a population, preventing successful reproduction by the plants. Cycad Aulacaspis Scale also attacks native cycad species in South Africa and the New World (Howard et al. 1999; Nesamari et al. 2015), albeit thus far with less severe effects on host fitness than those reported from Guam, and with infestations reported primarily from gardens rather than from natural populations.

In the New World, Cycad Aulacaspis Scale has been reported from the Southeastern USA (Texas to Florida and South Carolina) and the Caribbean (Bahamas, Puerto Rico, Cayman Islands, US Virgin Islands, Martinique, St. Kitts, Guadeloupe, and Barbados) (García Morales et al. 2016). Most recently, this pest was also reported as present in Chiapas, Mexico (González-Gómez et al. 2016). Although that report was entitled “First report of *Aulacaspis yasumatsui* ... in Mexico”, we have found an earlier published record of its presence in another Mexican state (Sinaloa), in a specialized publication for Mexican botanical gardens (Sosa Ramos and Pagaza Calderón

2015). The presence of Cycad Aulacaspis Scale in Mexico is particularly troubling from a conservation perspective, because Mexico is a center of cycad diversity, with 60 native species of which 90% are endemic (Nicolalde-Morejón et al. 2014; Calonje et al. 2017). A decline of native cycad species in Mexico could threaten subsistence livelihoods, as cycad seeds are traditionally used as food during times of scarcity (often mixed with maize to make tortillas and atoles) (Vite et al. 2010). It could also pose a threat to traditional ritual and ornamental use of cycad foliage (Pérez-Farrera and Vovides 2006). Here we report infestations of Cycad Aulacaspis Scale on cultivated cycads in several Mexican states and in Guatemala, showing that it is much more widely distributed in the New World tropics than previously reported. We also report surveys of natural populations of cycads in several Mexican states.

Material and methods

Field survey of natural populations

In September–December 2016, we conducted field surveys of several natural populations of native cycads in Chiapas, Hidalgo, and Querétaro, as well as quasi-natural sustainable nurseries in Veracruz (Table 1, Figure 1). For each individual cycad, we conducted a 5-minute or 10-minute search of its foliage,

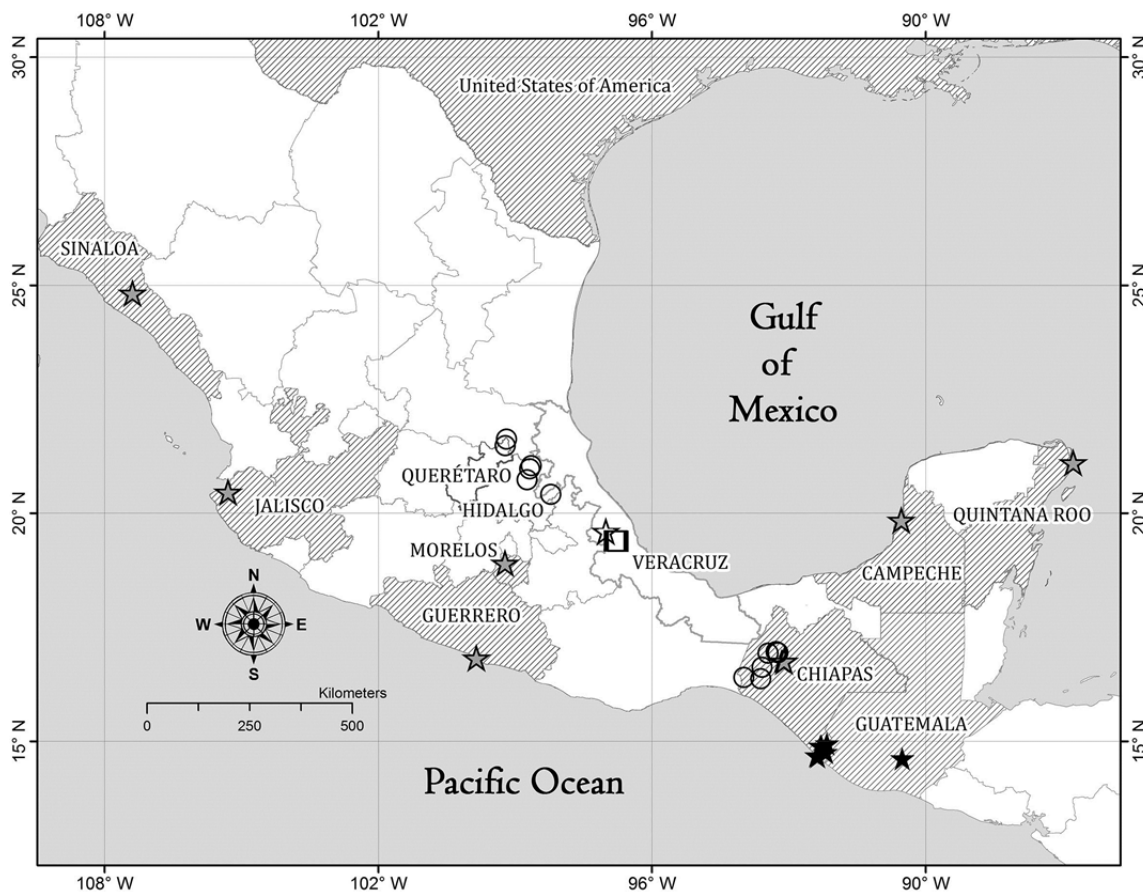


Figure 1. Map showing the localities of surveyed populations and reported infestations. Circles = natural populations surveyed. Squares = quasi-natural sustainable nurseries surveyed. Stars = botanical gardens and other cultivated cycads. Open symbols = surveyed sites in which no *Cycad Aulacaspis Scale* was detected. Filled black symbols = sites where presence of *Cycad Aulacaspis Scale* has been corroborated by microscopic examination. Filled gray symbols = sites where there is credible photographic evidence of *Cycad Aulacaspis Scale* infestation but not yet any microscopic corroboration. Countries or states with evidence of *Cycad Aulacaspis Scale* infestations are shaded using diagonal hatch-marks; those with no reports of infestations are colored white.

looking for scale insects or other sternorrhynchan insects (whiteflies, aphids, or jumping plant lice). We aimed to search 10 or more individuals per population. Leaflets appearing to have live sternorrhynchan insects were removed, placed in labeled Ziploc bags, and stored in a refrigerator. Within a week of collection, each leaflet was examined under a dissecting microscope. Any live sternorrhynchan insects were transferred to ethanol; any armored scale insects (family Diaspididae) were identified as precisely as possible based on characters of the scale cover, looking in particular for characters consistent with *Cycad Aulacaspis Scale*.

Survey of National Cycad Collection

Using the same protocol as that for natural populations, we surveyed 149 individuals, comprising

59 cycad species, in the outdoor collections of the National Cycad Collection, Jardín Botánico Francisco Javier Clavijero, Instituto de Ecología (INECOL), Xalapa, Veracruz. We also sampled scale-insect-infested leaflets from 27 individuals in the National Cycad Collection's greenhouses, comprising 18 cycad species.

Assessing presence of Cycad Aulacaspis Scale based on characters of the scale cover

The scale cover of an adult female armored scale insect typically consists of the exuviae (cast cuticles) of the 1st and 2nd instars, together with a secreted waxy scale cover. The arrangement, shape, and color of the elements of the scale cover provide strong clues to species identity, though definitive identification is usually based on microscopic characters of



Figure 2. A close-up of 2 Cycad Aulacaspis Scale females and 1 male. The female scales are on either side, showing the broad white scale cover and the exuviae (shed cuticles of the immature instars) on the left margin of each scale cover. The smaller male is between them. Photo by Catharine Mannion, University of Florida Institute of Food and Agriculture.

the cleared and stained cuticle of the adult female herself. Cycad Aulacaspis Scale adult females have a broad white scale cover with orange-tan exuviae at one margin (Miller and Davidson 2005) (Figure 2). The scale cover of a male armored scale insect typically consists of the exuviae of the 1st instar, together with a secreted waxy scale cover. Cycad Aulacaspis Scale males have an elongate white scale cover with 3 conspicuous ridges, and orange-tan exuviae at one end (Figure 2). Dense infestations of Cycad Aulacaspis Scale typically include many males intermixed with females. Many species share the basic scale characters of Cycad Aulacaspis Scale, though few of these have been reported from Mexico. Of these, only Cycad Aulacaspis Scale is known to form dense aggregations on cycads. We regarded any individual with a white scale cover and marginal exuviae to be a potential specimen of Cycad Aulacaspis Scale. We regarded dense aggregations (visible as a white crust from a distance of >1m) on cycads of scale insects with these field characters to represent Cycad Aulacaspis Scale. In some cases, cuticles of adult females were permanently mounted on microscope slides, following the method of Williams and Granara de Willink (1992), to check positive identifications of Cycad Aulacaspis Scale, using published keys (Suh and Ji 2009; Takagi and De Faveri 2009; Nesamari et al. 2015). These mounted specimens were deposited in the Colección Entomológica de la Dirección de Sanidad Vegetal (ColEnt-DGSV), Tecamác, Estado de México (accession number 83631/15P0030844), and the Colección de Insectos de El Colegio de la Frontera Sur (ECO-TAP-E), Tapachula, Chiapas (accession

numbers 0015L-0017L). Additional ethanol-preserved material will be deposited in the University of Massachusetts Insect Collection (catalog numbers D7876-D7880).

Compilation of observations of conspicuous infestations of cultivated cycads

Severe infestations of cultivated cycads by Cycad Aulacaspis Scale result in a white crust on the leaves that is highly conspicuous. In November 2016, we sent an e-mail to members of the Mexican Association of Botanical Gardens, asking if anyone had seen scale-encrusted cycads. We have also received additional reports of infestations from various sources and have ourselves come across several infestations. We were careful never to visit native cycad populations after encountering an infested plant (see *Minimizing the risk to native cycads*, below.)

Results

Field survey of natural populations and Survey of National Cycad Collection

We found many armored scale insects, but none that had the combination of white scale covers and marginal exuviae that would mark them as potential Cycad Aulacaspis Scale.

Observations of conspicuous infestations of cultivated cycads

We have found and documented cultivated cycads infested with Cycad Aulacaspis Scale in Chiapas

Table 2. Infestations of cultivated cycads.

date	country	state	locality	latitude	Longitude	cycad species	ID corroborated
14-Oct-2016	Guatemala	Guatemala	Guatemala City	14.6147	-90.5129	<i>Cycas revoluta</i> Thunb., 1782	no
3-Jan-2017	Mexico	Campeche	Campeche	19.8461	-90.5364	<i>Cycas revoluta</i> Thunb., 1782	no
1-Jan-2017	Mexico	Chiapas	F. I. Madero	14.7520	-92.1910	<i>Cycas revoluta</i> Thunb., 1782	yes
1-Jan-2017	Mexico	Chiapas	Playa Linda	14.6813	-92.3887	<i>Cycas revoluta</i> Thunb., 1782	yes
1-Jan-2017	Mexico	Chiapas	Playa Linda	14.6637	-92.3664	<i>Cycas revoluta</i> Thunb., 1782	yes
20-Aug-2015	Mexico	Chiapas	Tapachula	14.8872	-92.2865	<i>Cycas revoluta</i> Thunb., 1782	yes
20-Aug-2015	Mexico	Chiapas	Tapachula	14.8890	-92.2825	<i>Cycas revoluta</i> Thunb., 1782	yes
20-Aug-2015	Mexico	Chiapas	Tapachula	14.8773	-92.2870	<i>Cycas circinalis</i> L., 1763	yes
20-Aug-2015	Mexico	Chiapas	Tapachula	14.8721	-92.2882	<i>Cycas revoluta</i> Thunb., 1782	yes
20-Aug-2015	Mexico	Chiapas	Tapachula	14.8817	-92.3046	<i>Cycas revoluta</i> Thunb., 1782	yes
1-Jan-2017	Mexico	Chiapas	Tuxtla Chico	14.9387	-92.1603	<i>Cycas circinalis</i> L., 1763	yes
20-Sep-2016	Mexico	Chiapas	Tuxtla Gutiérrez	16.7411	-93.0844	<i>Cycas revoluta</i> Thunb., 1782	no
20-Sep-2016	Mexico	Chiapas	Tuxtla Gutiérrez	16.7547	-93.1372	<i>Cycas revoluta</i> Thunb., 1782	no
20-Sep-2016	Mexico	Chiapas	Tuxtla Gutiérrez	16.755	-93.1439	<i>Cycas revoluta</i> Thunb., 1782	no
20-Sep-2016	Mexico	Chiapas	Tuxtla Gutiérrez	16.7561	-93.1547	<i>Cycas revoluta</i> Thunb., 1782	no
24-Nov-2016	Mexico	Chiapas	Tuxtla Gutiérrez	16.7579	-93.1075	<i>Dioon merolae</i> De Luca, Sabato & Vázq. Torres, 1981	no
9-Nov-2016	Mexico	Guerrero	Acapulco	16.8229	-99.8460	<i>Cycas revoluta</i> Thunb., 1782, <i>C. circinalis</i> L., 1763	no
20-Jun-2015	Mexico	Jalisco	Puerto Vallarta	20.4628	-105.2928	<i>Cycas</i> sp.	no
June 2014	Mexico	Morelos	Cuernavaca	18.9087	-99.2238	<i>Cycas revoluta</i> Thunb., 1782	no
3-Sep-2016	Mexico	Quintana Roo	Cancún	21.1096	-86.7646	<i>Cycas revoluta</i> Thunb., 1782	no



Figure 3. A typical dense infestation of Cycad Aulacaspis Scale on *Cycas revoluta* Thunb., 1782, showing a conspicuous white incrustation of scale covers. Photo by A. García & F. Riverón.

Campeche, and Guatemala City, and we have received photographically documented reports of infestations in Jalisco, Morelos, Guerrero, and Quintana Roo. Details of all the documented infestations are given in Table 2 and locations are shown by the filled black and gray stars on Figure 1. Most of the hosts are introduced species of *Cycas*, but at one locality a native Mexican species, *Dioon merolae* De Luca, Sabato & Vázq. Torres, 1981, is also infested. All of

the infestations listed in Table 2 are heavy. On *Cycas*, at least some foliage has a conspicuous whitish crust formed by the massed scale covers of the pest (Figure 3). On *Dioon* Lindl., 1843, the infestation is slightly less heavy, with spaces between scales rather than a continuous crust (Figure 4). Every apparent Cycad Aulacaspis Scale infestation checked using microscopic characters was corroborated as Cycad Aulacaspis Scale (Table 2).

Figure 4. Cycad Aulacaspis Scale infestation on *Dioon merolae* in the Tuxtla Gutiérrez Botanical Garden, Chiapas, Mexico. *D. merolae* is endemic to the states of Chiapas and Oaxaca. Natural populations of *D. merolae* within 70 km of this botanical garden are still free of Cycad Aulacaspis Scale. Photo by M. A. Escobar-Castellanos.



Discussion

We have found that Cycad Aulacaspis Scale is present on cultivated cycads in at least 7 Mexican states and in Guatemala City, but we have not found any evidence that the pest has spread to natural populations. Although the most commonly reported hosts of Cycad Aulacaspis Scale are species of *Cycas*, which are not native to Mexico, 7 Mexican species have also been reported as hosts, in botanical gardens outside their native range (García Morales et al. 2016). At least one of these, *Zamia loddigesii* Miq., 1843, was reported as suffering from a heavy infestation (Muniappan et al. 2012). Here we report heavy infestation of a second Mexican species, *Dioon merolae*. But in this case, the site of the infested individual is less than 70 km from a natural population of *D. merolae* that we found to be completely free of Cycad Aulacaspis Scale. That natural population's prospects for remaining free of this invasive pest must now be regarded as precarious.

Assessing the risk to native cycads

Some Mexican cycads grow at high altitudes, in climate regimes that may not be suitable for Cycad Aulacaspis Scale. A niche-modeling study of Cycad Aulacaspis Scale may be useful to map the areas, populations, and species at lowest vs. highest risk of infection. Also, not all cycad species are equally susceptible to the pest. Species of *Cycas*, which are not native to Mexico, seem to be most susceptible. Some highly susceptible *Cycas* species are native to Southeast Asia, and their native range appears to overlap with that of Cycad Aulacaspis Scale. Nonetheless, at least two native Mexican species, in

different genera, have been reported to have suffered extremely heavy infestations of Cycad Aulacaspis Scale in botanical gardens: *Zamia loddigesii* Miq., 1843 (Muniappan et al. 2012) and *Dioon merolae* (Table 2, Figure 4). Less heavy infestations have been reported for 5 other species of *Dioon* and one other species of *Zamia* L., 1763, all in botanical gardens outside their native range (Howard et al. 1999; Malumphy and Marquart 2012; García Morales et al. 2016). One previous study has asserted that the other Mexican cycad genus, *Ceratozamia* Brongn., 1846, is a recorded host of Cycad Aulacaspis Scale (Muniappan et al. 2012), but the reference given for this record is ScaleNet, which in its present form does not report any records of *Ceratozamia* as a host (García Morales et al. 2016). Thus there do not appear to be any solid records of Cycad Aulacaspis Scale infesting *Ceratozamia* species, and it is possible that they are relatively resistant to the pest.

Minimizing the risk to native cycads

The best course for native cycad conservation would include an intensive program of control of Cycad Aulacaspis Scale by affected botanical gardens, using oil treatments and systemic insecticides (Hodges et al. 2003). It would also include improved monitoring to prevent importation and sale of infested cycads, as well as research into potential host-specific agents of classical biological control. In cultivated *Cycas* species in southern Mexico, we have observed *Chilocorus cacti* L. (Coleoptera: Coccinellidae) feeding on Cycad Aulacaspis Scale. This beetle species has also been recorded as a predator of Cycad Aulacaspis Scale in Florida (Cave 2006). Further studies of the effects of this native predator in Mexico are warranted. In the

meantime, careful quarantine protocols should be followed to protect native cycad populations from infection by Cycad *Aulacaspis* Scale, and high-risk native cycad populations should be identified and monitored. In the life history of scale insects, the dispersal phase is the first-instar nymph, or “crawler”. Scale insect crawlers are a fraction of a millimeter in length and are often windborne, though they can also apparently be vectored by other insects or by birds (Gwiazdowski et al. 2006; Magsig-Castillo et al. 2010). In the case of Cycad *Aulacaspis* Scale, perhaps the vectors at highest risk of transmitting the scales to natural populations are people. Cycads are of great interest to people, and people who deal with both cultivated and wild cycads could easily serve as vectors of infection. This category includes unscrupulous cycad-rustlers who illegally dig up natural cycads for sale (which is why we present only low-resolution locality information in Table 1). But it also includes researchers and ethical cycad enthusiasts—you, the readers of this article—who could easily transmit the scales inadvertently if you visit sites where cycads grow. If you have been in close proximity to an infested cycad, you should assume that your clothing, hair, and skin are contaminated with Cycad *Aulacaspis* Scale crawlers for the next 72 hours or so, and you should avoid any natural cycad populations until your clothing and person have been washed with hot water. According to Mexico’s Federal Law of Plant Health (<http://www.diputados.gob.mx/LeyesBiblio/pdf/117.pdf>), Cycad *Aulacaspis* Scale qualifies an exotic pest, and responsibility for its management falls to SEMARNAT (Secretary of Environment and Natural resources).

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